Zoï Kapoula · Marine Vernet *Editors*

Aesthetics and Neuroscience

Scientific and Artistic Perspectives

Springer

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Preface

The interweaving of art and science, specifically aesthetics and neuroscience, is an emerging field of research. This phenomenon has sparked interest and expanded across various countries, basing itself on the existing cultural, scientific and artistic environments. In France, we benefit from an existing pluridisciplinary research institution: *Centre National de la Research Scientifique* (CNRS, National Center for Scientific Research). Groups of research in this institution aim to bring together researchers from different fields to create networks of common interest. The Aesthetic, Art and Science group, “ESARS”, was founded in 2014 by the Institute of Biological Science of the CNRS. ESARS gathers several research teams from many laboratories and universities across France. In addition to their own field of research, whether it is mathematics, physiology, neuroscience, philosophy, psychology, these teams develop a research line related to creation, creativity and aesthetics.

This without-wall laboratory is a very rich, beehive-like structure. Several meetings have brought together artistic and scientific creations. Not only does ESARS develop pluridisciplinarity, but also transdiciplinarity to create new fields at the frontier of existing ones. Taking methods from one field and adapting it to another allows for hybridization, mutation, and transformation. New paradigms are constantly invented.

In 2013, we organized a meeting in Paris in anticipation for the creation of ESARS. This meeting incorporated formal presentations, art exhibitions, interactive installations and live performances. It covered many areas of neuroscience and aesthetics: mathematical structure of pop music, neurophysiology of creation and art perception, philosophy of art, epistemological questions related to architecture, theater performance, dance, etc. This book includes a selection from these presenters and performers as well as contributions from artists and scientists who joined ESARS afterwards.

Part I of this volume guides us through the complex process of creativity. Alain Londero, Didier Bouccara and Hervé Bozec invite us to explore how visual art impacts the vestibular system of the observer. They also have us question how an artist’s vertigo or tinnitus may have contributed to their creative process. Vincent

Mignerot offers an original hypothesis, stating that creative minds may benefit from "*heueaesthesia*", a fruitful sensory facilitation of knowledge and skills. Zoï Kapoula presents a study where dyslexic children, who have overall normal intelligence but suffer from reading troubles, might be highly creative when following an adapted educational approach.

Part II of this volume investigates the neurophysiological effect of art on observers. Yannick Bressan studies the neural substrate of "*emergentist adhesion*" in theater. This allows the spectator to perceive a character when she sees an actor, in order to believe in the functional reality in addition to the proximal reality. Amel Achour Benallegue, Jérôme Pelletier and Gwenaël Kaminski, through a cognitive, anthropological, philosophical and experimental approach, illustrate how intrinsic properties of anthropomorphic representations of faces modulate their aesthetical impact. Marine Vernet provides a brief tour on what neuroscience and art can learn from each other and how artwork can intellectually, emotionally and physically move us.

Part III of this volume exemplifies how neuroscience can help us to better understand and enhance our aesthetic experience. Coline Joufflineau and Asaf Bachrach present *Labodanse*. This ambitious project shows how first and third person experimental approaches converge in front of Myriam Gourfink's choreographic work, which is based on Energy yoga techniques. This perfectly illustrates how unique scientific questions arise from unique artworks. Solène Kalénine evaluates how perception and perhaps sensitivity towards a show by The Baltazars, can be modified after an observer has the opportunity to manipulate the visual effects of the show. Laurent Sparrow demonstrates how physiological measures and eye tracking measures can help to evaluate the well-being and interest of autistic and non-autistic children, who visit a museum with a game device to help increase their engagement.

Part IV of this volume illustrates how better training and learning could be achieved by relying on the potentiation of the art–neuroscience relationship. Daria Lippi, Corinne Jola, Victor Jacono and Gabriele Sofia present a pioneer, collective experience realized during a workshop organized by the *Fabrique Autonome des Acteurs*. They created a challenging training that merged the concepts of attention, mirror neurons and body schema, to help actors improve their ongoing and deliberate practice. Claude Bruter explains that because art and mathematics have the same fundamental aim, representation, art might constitute a great educational tool to understand mathematics. Eglantine Bigot-Doll describes how interacting with various inspirational sources and expressing the results of these interactions through language and adequate software could potentially help students to elicit original architectural creations.

Part V of this volume reveals the creative processes of artists who are inspired by or relate their work to neuroscience. Sophie Lavaud-Forest describes how her project *Matrice Active*, which transforms a painting by Wassily Kandinsky into a three-dimensional interactive dynamic system, can offer new aesthetic experiences as well as novel interdisciplinary artistic-scientific research experiments. Olga Kisseleva and Claire Leroux guide us into the different meanings of time at the physical, biological/physiological and political/economic levels. Based on these concepts, Olga Kisselva's bio-art installations plays with individual physiology, allowing visitors to accelerate or on the contrary slow down art-clocks' time. Pascale Weber and Jean Delsaux describe their own performing art experience as an experimental configuration allowing them to address multiple questions of embodied neuroscience, including space perception and body movement sensation.

Finally, Part VI of this volume uses mathematical tools, evolutionary-based theories and philosophical considerations to understand and formalize aesthetics. Moreno Andreatta and Gilles Baroin show how mathematical models applied to pop music can reveal the geometry of musical scores and contribute to new musical creations. Julien Renoult guides us through several evolutionary models of aesthetics and explains how one of them, based on the exploitation of efficient information processing, can simultaneously explain the universality of aesthetic experiences and the diversity of beautiful stimuli. Bruno Trentini closes our volume by inviting researchers in neuroaesthetics to join a philosophical tradition and to focus on the exploration of the neural substrate of the "sublime" rather than the neural substrate of the "beautiful". The former would be closely related to the experience of aesthetics.

We hope that this book will reveal the diversity of our neuroscience and art community, which build bridges between multiple disciplines such as cognitive neuroscience, psychology, physiology, evolutionary biology, mathematics, philosophy, anthropology, rely on theoretical and experimental approaches, consider third- and first-person points of view, go back and forth the unique and the ubiquitous and lastly, invent new paradigms for this novel adventure through neuroscience and art.

Paris, France — Zoï Kapoula
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About the Editors

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Part I
Neuroscience of Creativity

The Vestibular System and Artistic Painting: A Theoretical Framework for the Study of Multi-modal Interactions in Aesthetic Experience of Painting and Painting Viewing

Alain Londero, Didier Bouccara and Hervé Bozec

Abstract Neuroaesthetics is an emerging neuroscientific field aimed at explaining the cognitive processes and the neurobiological correlates actually involved in both artistic practices and aesthetic experiences. Indeed the essential role of vision has already been extensively studied, but recent data suggest that aesthetic interactions may rely upon a broader multi-sensory integration including auditory or somatic inputs. In such a context, the implication of the vestibular system, which is activated for both the control of head/body movements and the sense of balance, may be considered as a crucial issue. Taking artistic painting as an example, the main purpose of this paper is to propose a schematic comprehensive theoretical framework that might be useful to pave the way for future research in this multi-sensory, multimodal and innovative neuroaesthetic field.

Keywords Multi-sensory integration · Posture · Balance · Neuroaesthetics · Arts

> Tes derniers tableaux m'ont donné beaucoup à penser sur l'état de ton esprit quand tu les a faits. …tu t'es risqué jusqu'à l'extrême point où le vertige est inévitable.
>
> Your latest paintings have given me a great deal to think about as regards your state of mind when you made them. …you endangered yourself to the extreme point where vertigo is inevitable.
>
> Quotation from a letter (16th June 1889) by Theo Van Gogh to his brother Vincent during his stay in the hospital of Arles.
>
> Amsterdam, Van Gogh Museum, inv. no. b737 V/1962.
>
> http://vangoghletters.org/vg/letters/let781/print.html.

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Introduction

Neuroaesthetics is an emerging field within the larger framework of neuroscience (Chatterjee 2011). The main goal of such a neuroscientific insight applied to the field of arts is to better understand and explain what actually happens in our sensory organs, brains and bodies when either, as an artist, one is involved in the process of art creation or when, as a spectator, one is confronted to any kind of piece of art (painting, sculpture, dance, video, literature…). Deciphering the biological and neural correlates underpinning this puzzling indirect interaction between the artist (considered as the intentional and active producer of the artwork) and the viewer (which is not only a passive bystander) via the medium (the piece of art that actively stimulates sensory organs and elicits subcortical and cortical brain activities) is indeed the very core of such a neuroscientific questioning (Nadal 2011). Even if there is still an on-going debate about the actual relevance of this kind of neuroscientific approach of arts, there is undeniably a steady increase both in the momentum of interest driven by this topic and in the amount of literature annually published in the field.

Probably due to the importance of vision in our most common aesthetic interactions, and to the huge knowledge gained in the neuroscience and psychology of vision, most of the neuro-aesthetic literature actually concentrates on the visual modality. Indeed, recent studies and reviews on neuroaesthetics focus predominantly on aesthetic experiences induced by visual forms like faces (Osaka 2012), constructions (Vartanian 2013) or different kinds of objects (Cela-Conde 2011; Chatterjee and Vartanian 2014) and by paintings (Melcher 2013). Certainly this is also why, at the end of the 20th century, even the term neuroaesthetics has been originally proposed by a vision researcher (Zeki 1999).

But aesthetic experience, even for a mere visual form of art like painting, definitely needs to be considered as a multilevel process that goes far beyond a purely visual analysis of the artwork (Nadal 2013). Undoubtedly artistic perception essentially relies upon a multi-sensory (visual, auditory, somatic…) input (Shams 2010) and a multi-modal (viscero-somatomotor, attentional, emotional…) resonance in the beholder (Cinza 2009).

The relevance of non-visual input and non-visual central pathways has been obviously studied for art production for which other sensory modalities or cognitive functions are involved (i.e. audition for the perception of music or poetry (Brattico 2013), motor system for dance performing (Calvo-Merino 2008)). But even for painting, recent research stresses the possible implication of non-visual cognitive processing and non-visual behavioral responses during the aesthetic experience induced in the beholder by paintings. For example some recent EEG data clearly demonstrate the involvement of the motor cortical areas in the viewing of static abstract artworks of Lucio Fontana in which the canvases have apparently been cut with a knife or cutter (Umiltà 2012). Other results suggest that abstract Op Art paintings providing a sense of motion in depth alike Bridget Riley's "Movements in Squares" (1961) (https://en.wikipedia.org/wiki/Bridget_Riley) and Akiyoshi Kitaoka's "Rollers" (2004) (https://en.wikipedia.org/wiki/Akiyoshi_Kitaoka) induce an increased motion illusion and a larger antero-posterior body sway both in terms of speed and displacement when compared to a control condition (Kapoula 2015).

Rather counterintuitively, it seems then even possible to suggest that painting, this very motionless and two-dimensional framed kind of visual art, is definitely an aesthetic practice that involves, even if mostly at a subconscious level, cognitive functions that are fundamentally dedicated to motion in a three-dimensional world: the control of head and body movements and the sense of balance. Both these functions depend on the activation of the vestibular system (semicircular canals, otolith organs, and cortico-subcortical vestibular pathways), which has evolved to constantly and automatically measure head motion and head position (St George 2011). Even if it does not elicit an immediate conscious perception arising from the vestibular receptors this very complex and demanding task, which may be considered as our "sixth sense" or "the sense of movement", is achieved by the means of a remarkable multimodal integration (Chen 2011). Indeed for our brains being permanently up-dated on our own head/body position is a critical prerequisite for accurate motor coordination and adequate spatial navigation. This is not only important for everyday actions, but also for artists when they create and for spectators during their aesthetic experiences. It seems then pertinent to question the possible implicit implication of the vestibular system, both from the painter's and the beholder's perspective, in this specific artistic activity (Marin 2015).

The main goal of this article is to propose a schematic comprehensive theoretical framework that might be useful for future research in this multi-sensory, multimodal and innovative neuroaesthetic field.

Vestibular Physiology: A Brief Overview

According to the Darwinian rules of species evolution, for millennia human beings have been evolving towards bipedalism. Hence, upon the two small surfaces of the soles of our feet, we need to constantly maintain our balance either in resting positions or during dynamic actions in order to immediately and automatically adapt our posture and movements in a perpetually changing environment. Maintaining a stable stance whatever the circumstances is indeed a rather challenging task. So, when discussing the notions of balance, posture, movement and gait we refer to an outstanding, and not yet fully understood, ability to stabilize our gaze, head and body whatever the environmental circumstances in which we are bound to stay or move. This system devoted to equilibrium and control of movement relies upon three different kinds of peripheral sensory inputs: the vision (eye), the proprioception (muscles, ligaments, interoception) and last, but not least, the vestibular system (inner ear or labyrinth). This multi-modal afferent information is then integrated and hierarchized, in the same multimodal way, in the vestibular nuclei that are located in the brainstem. At this level, cerebellar inputs and top-down cortical influences contribute to adapt and modulate the activation of various efferent vestibular systems originating from the vestibular nuclei among which the key vestibulo-ocular and vestibulo-spinal pathways (Brandt 2013). The physiologic maturation of this system progressively develops during childhood, one very important milestone being the progressive acquisition of walking skills (Lacour 2000). The subsequent evolution of equilibrium function with aging is also a complex phenomenon that depends eventually on multiple other sensory parameters, on different general factors such as rheumatologic, neurologic, cardiovascular associated conditions and on individual subjects' psychological profile. For example, in the elderly both the risk and the fear of falling highly contribute to the behavioral and emotional changes related to the perception of balance in these subjects (Jahn 2015). Another property of this system is its striking adaptability that relies upon rapid and efficient neuroplastic mechanisms. In many pathological conditions, such as in case of sudden or progressive vestibular deafferentation (trauma, tumors…), natural neuroplastic compensatory mechanisms will be activated leading in most of the case to a reduction of the postural consequences of vestibular disorders (Lacour 2006; Han 2011), thus permitting to remain stable if the vestibular system fails even in an extremely changing and hazardous natural environment. Concerning the subjective feelings evoked by artworks in beholders, as well as the process of creation of art pieces in artists, this peripheral vestibular sensory information integrated in wider range of sensory inputs might also constitute an essential sensory substrate underpinning higher level cognitive processing involved in aesthetic experiences.

From a phylogenetic point of view the vestibular system is the most ancient part of the inner ear, a similar system being already present in fishes and dinosaurs fossils. Along with the auditory system with which it shares strong structural analogies, the vestibular system has evolved in humans for the coding of information arising from head motion, especially angular accelerations (three angular receptors aligned along the three directions of space: anterior, posterior and lateral semicircular canals) but also linear accelerations crucially involved in speed and gravity perception (otolithic receptors: utricular and saccular maculae). Anatomically the vestibular receptors are situated at the posterior part of the cochleo-vestibular organ (membranous labyrinth) in the temporal bone at the lateral part of the head. The vestibular sensory epithelium is essentially constituted by the vestibular sensory hair cells (type I and type II) topped with stereocilia. The sensory cells are located within the endolymphatic compartment of the inner ear. The architecture of the inner ear coupled to the mechanotransduction properties of the hair cells explain the ability of the vestibular system to convert a mechanical stimulus (endolymphatic liquid displacement or otolith displacement) into an electrochemical activity transmitted to the vestibular nerve, then to the vestibular nuclei. The vestibular information follows then multiple anatomical and physiological subcortical and cortical pathways (i.e. vestibulo-ocular, vestibulo-spinal, vestibulo-cerebellar, vestibulo-vegetative, vestibule-thalamic, vestibulo-cortical pathways) explaining the wide variety of clinical consequences induced by a vestibular impairment on eye movements, posture, vegetative reflexes, cognition and emotions. Physiologically, information coming from the otolithic receptors will essentially contribute to maintaining head position during horizontal (utricule) and vertical (saccule) accelerations and, less importantly, help at the retinal image stabilization during movements. The role of the saccule is critical for the perception of gravity cues. The information arising from the semicircular canals is more directly devoted to the stabilization of retinal images during head movements and to the stabilization of the head and body during three dimensional movements (Cullen 2012).

Vestibular Pathophysiology

Balance problems are a common cause of consultation especially in otology clinics (Brandt 2013). The complexity of the multi-modal system described in the previous section explains the multiplicity of ear diseases and other medical conditions that can cause vertigo or dizziness. It also explains the very rich and complex descriptions of their symptoms made by the patients: sensation of body rotation, modification of body perception, sensation of rotation of the visual scene, illusion of linear displacement, vegetative reactions, and anxiety or depression states. However, vestibular symptomatology mainly depends on the vestibular structures lesioned (otolithic receptors, semicircular canals, and vestibular nerve or central structures), but also on the time course of the disease (sudden, progressive or fluctuating) and on the concurrent medical conditions. It is out of the scope of this article to further explain the diagnostic and therapeutic approaches of vestibular disorders. But it seems useful to stress the importance of an overall evaluation of the visual, proprioceptive and vestibular afferences by the means of static and dynamic posturography (Mbongo 2005) and of an appraisal of the subjective vertical because these evaluation techniques have already been used in the neuroaesthetic domain (Kapoula 2011).

From the Artist's Point of View: Painting, Movement and Vestibular Dysfunction

Indeed the issue of movement representation is a common trend in the history of modern painting. For example, the French painter Théodore Géricault (1791–1824) aimed at showing galloping horses' movements in his canvas entitled "Course de chevaux, traditionally called Le Derby de 1821 à Epsom" (1821) (Fig. 1). And so even if the position of the horses' legs displayed in this painting, with both front and hind legs simultaneously extended, is never actually present while galloping as this has been demonstrated by the chrono-photography techniques developed shortly after in the 19th century by the English photographer Edward James Muggeridge (1830–1904) and by the French physiologist Étienne-Jules Marey (1830–1904). Similarly Edgar Degas (1834–1917) has purposefully induced an illusion of movement in the canvas "Danseuses en bleu" (1890) (Fig. 2) by showing dancers in four different positions, figuring four "snapshots" of the ballet moving scene. The postural consequences of a similar illusion have been scientifically investigated by the means of pictures reproducing two Degas' sculptures of dancers: the first in a stable and still position, the second in a dynamic and potentially unstable dance step execution. Observing a dancing ballerina induced a significantly greater body sway when compared to the stable image, thus demonstrating that images of bodies in movement internally generate unconscious body oscillations in the viewer (Nather 2010). Indeed the multi-modal

Fig. 1 Théodore Géricault (1791–1824). "Course de chevaux, traditionally called Le Derby de 1821 à Epsom" (1821)

visuo-vestibulo-somato-motor integration of such behavioral response and the role of the vestibular system (internal model of vertical perception, real-time postural control, emotional load…) in this instability produced by an aesthetic experience remains to be understood. Although is not known if this effect has been willfully sought by the artist, the induced instability in the beholder should be taken as a relevant part of the aesthetic pleasure given by the canvas, the image or the sculpture. Later on the specific issue of figuring movement and speed in arts has also been extensively challenged by the "Movimento Futurista" (Futurists), led by Filippo Tomaso Marinetti in Italy at the dawn of the 20th century. Indeed, movement and its related concept speed constitute the very heart of the manifest published the 21th February 1909 in the French journal "le Figaro" where Marinetti stated that "the splendor of the world has been enriched by a new kind of beauty: the beauty of speed". The works of Luigi Russolo (1885–1947) such as "La rivolta" (1911) (https://en.wikipedia.org/wiki/Luigi_Russolo) or Giacomo Balla's (1871–1958) "Dinamismo di un cane al guinzaglio" (1912) (https://en.wikipedia.org/wiki/Giacomo_Balla) are some illustrative examples of such attempts aiming at giving the viewer the sensation of a moving scene via the medium of a static pictorial image. More recently a rather similar technique of overlapping images, also common in art photography, has been used by a contemporary artist Lee Horyon (http://www.horyonlee.com) to elicit a quite spectacular, elegant and erotic representation of body motion. But it is probably Op Art who has more methodically questioned the perception and induction of motion illusions by paintings. The term Op Art

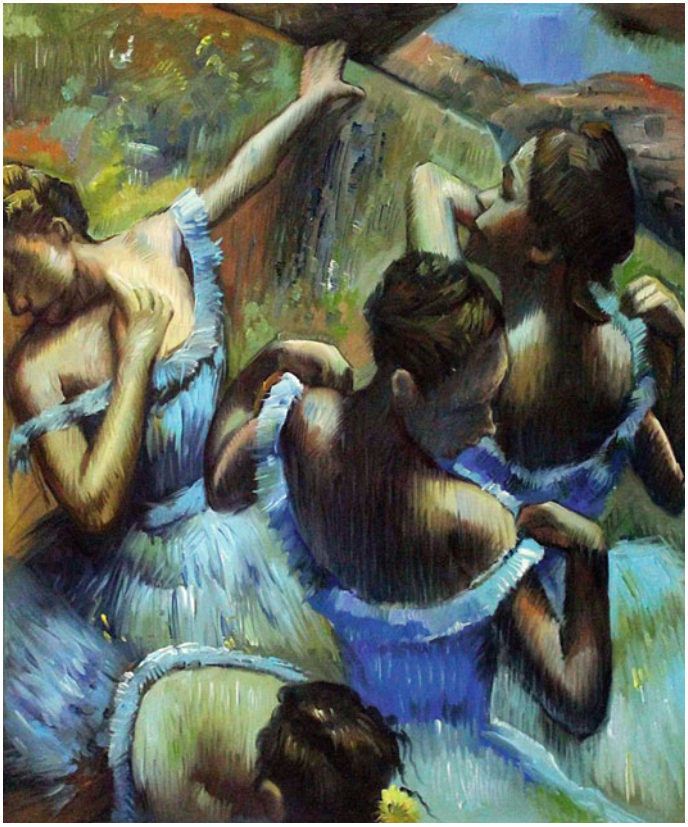

Fig. 2 Edgar Degas (1834–1917). “Danseuses en bleu” (1890)

(contraction of Optical Art) has been coined in an article of Time Magazine (1964), in reference to Julian Stanczak’s exhibition “Optical Paintings”. Op Art is a form of abstract art that uses black and white or colored geometrical patterns (lines, stripes, shapes and contours) in order to induce an optical illusion of movement produced by a tension between the foreground and the background e.g. “Cataract 3” by Bridget Riley (1967) (https://en.wikipedia.org/wiki/Bridget_Riley). The physiological causes of Op Art optical illusions are still a matter of debate (Hermens 2012; Fleming 2011). But their complex consequences on postural control (Kapoula 2015) could either be explained by the direct influence of unimodal pre-attentive visual analysis (micro or macro saccades, vergence drifts) of depth cues on body sway or by higher level conscious mechanisms (i.e.; explicit motor correlate of the perception in depth, virtual displacement in the pictorial frame). Yet this implication of a direct causal relationship between the degree of pictorial depth and body sway is challenged by other studies (Ganczarek 2015) which put forward other explanations linked to fixations to background elements in paintings or to higher embodied mental imagery (mental rotation) that induce reactions alike those experienced facing natural non-fictional stimuli. But in any case these pieces of artworks give a unique opportunity to interrogate the multisensory visuo-vestibular and proprioceptive integration and its correlation to one's individual cognitive and emotional aesthetic experiences.

On the other hand, vestibular disorders do not only induce the classical symptoms on balance, eye movements and posture control usually seen in the otology clinics. They have also been related to a wide variety of more complex cognitive deficits like spatial navigation, memory, planning or self-perception (distorted body image, out of body experience, depersonalization, and altered sense of agency…). For the latter it has been suggested that vestibular dysfunctions could create, via the vestibular system projections to the multisensory cortices that are key for embodied self-consciousness, a sensory conflict or a mismatch in multisensory integration. This might be the cause of this perceptual incoherence and abnormal body perception (for a review Lopez 2013) in vestibular impaired patients. Another striking evidence of the importance of the vestibular system input in the perception of self is that caloric or galvanic vestibular stimulation is able to restore near normal ego-centered and object-centered components in visual neglect after stroke (Oppenländer 2015) hence improving space, body and self-awareness. Moreover, vestibular disorders might also be able to alter other crucial cognitive circuitries involved in emotion processes hence inducing emotional disorders (Smith 2013).

Analogous issues, and their consequences on artists' work, have been demonstrated for a range of other medical conditions. For example, the series of self-portraits produced by the American painter William Utermohlen (1933–2007) during the evolution of his Alzheimer disease has drawn attention on the major consequences of cognitive deficits on self-perception and then on art making (Harrison 2013). It has even been suggested that different types of dementia (Alzheimer's disease, fronto-temporal dementia and dementia with Lewy bodies) could display a specific artistic signature. This, because each of these cognitive impairments impacts in a different way the widely distributed brain systems associated to perceptual and cognitive functions involved in artistic production (Gretton and Ffytche 2014) On the other hand, various ophthalmological conditions such as cataract for Claude Monet (Marmor 2015) and neurological conditions such as Parkinson disease (Shimura 2012) have been put forward to explain major changes in art production. Conversely, little is known about the potential consequences of vestibular system impairment on artistic output especially for painters. Nonetheless it has been suggested that very famous painters may have suffered from vestibular disorders. Two examples come immediately to mind. The first one is Vincent van Gogh (1853–1890) who has supposedly been affected by a Meniere's disease, even if he has been diagnosed with temporal lobe epilepsy by his doctor, Dr. Felix Rey (1867–1932), in the hospital of Arles (Wilfred 2004), diagnosis later confirmed by the French neurologist Henri Gastaut in 1956 (Martin 2011). However, based on the review of 796 personal letters written by the painter, van Gogh's symptoms actually included periodic severe vertigo spells, chronic imbalance and dizziness, hearing impairment, tinnitus and induced psychological problems which are all part of the classical clinical description of Menière's disease (Arenberg 1991). But, whatever

Fig. 3 Vincent Van GOGH (1853–1890). "Auto-portrait" (1887)

the actual cause of his symptoms, one could incriminate either the peripheral vestibular receptor or the central vestibular pathways in part of Vincent van Gogh's complaints. Stabbing his ear is obvious evidence that, in some ways, van Gogh also directly incriminated his (inner) ear as a cause of his impaired quality of life. Undoubtedly some of his late paintings shed light on this assumption with distorted self-portraits ("Auto-portrait" 1887) (Fig. 3) and whirling landscapes as "Paysage d'Oliviers" (1889) (Fig. 4) and "La nuit étoilée" (1889) (Fig. 5) that can be interpreted as a consequence of an abnormal perception of his self and of the environment induced by the vestibular dysfunction. The second example is the illustrious Spanish painter Francisco de Goya (1746–1828). Goya became seriously ill in 1792 during a stay in Seville where he complained of recurrent vertigo spells, incapacitating tinnitus and sudden onset profound hearing loss (Felisati 2010). It has been suggested that he also became depressed as a consequence of these symptoms, and moreover that he suffered auditory hallucinations and stupors states. Up to now, the etiology of such a severe audio-vestibular impairment has still been unknown. But according to the 18th century medical knowledge it has been postulated that Goya may have been affected by neuro-syphilis or by a heavy metal

Fig. 4 Vincent Van GOGH (1853–1890). “Paysage d’oliviers” (1889)

Fig. 5 Vincent Van GOGH (1853–1890). “La nuit étoilée” (1889)

poisoning (lead or mercury). More recent analysis of his symptoms has put forward the hypothesis of a Vogt-Koyanagi-Harada syndrome even if this diagnosis does not fit with the vestibular dysfunction and with the very abrupt hearing loss onset

Fig. 6 Francisco de Goya (1746–1828). "Don Manuel Osorio Manrique de Zuñiga" (1788). "Saturn Devouring his son" (1819–1823), 1788

(Vallès 2005). In any case, there is no doubt that the course of his disease, in which the vestibular system has been clearly involved, has profoundly modified Goya's artistic output especially in the late period known as the "Black Paintings". Indeed, at that time, dark, distorted, ghosted and miserable characters substitute the previous bright, sweet and joyful ones he had been painting in his earlier years (Fig. 6). There is little doubt that it would be a fascinating domain to study the production of contemporary artists suffering of vestibular deficits. Firstly in order to be able to confirm that there is indeed a link between vestibular impairment and quality of artistic production. And secondly in order to decipher both from a neuroscientific and an artistic point of view the induced changes in painting techniques (brushstrokes, choice of colors, vertical, horizontal and perspective rendering…) and in choice of subjects (emotional load).

From the Viewer's Perspective: Seeing and Moving

A recent study (Kapoula 2014) has shown that looking at Richard Serra's "Promenade" monumental sculptures (five very high rectangular solids pitched at a 1.69° angle) had the ability to significantly increase the overall medio-lateral stability (in terms of spectral power) and to improve the performances for subjective vertical evaluation in a series of normal non-vestibular subjects. Even if plausible, the relevance of such a behavioral response in terms of aesthetic experience is not known. Indeed one cannot exclude that ordinary objects, without aesthetic value but with comparable physical properties, would lead to similar physiologic beneficial impact in terms of balance and posture. Conversely, it is a very common experience to have been disturbed by a canvas or image which is displayed in a tilted position. For some subjects and in some situations, especially exhibitions, this may lead to very uncomfortable body tension and neuro-vegetative reaction inducing an urgent need to replace the frame in the proper and aligned position in order to be able to fully enjoy the artwork. Indeed, this sensory conflict actually involves the internal representation of the subjective vertical and subjective horizontal (Luyat 2012) for which the vestibular system (otolithic receptors) plays a crucial role. And so, even if the internal models of verticality are also dependent on multiple bottom-up sensory inputs (visual, somatosensory) and top-down cognitive modulations including attention, awareness of body orientation, spatial representation (Barra 2013). Some contemporary paintings apparently seem to question this very issue. As an illustration, the two paintings Le "Parc de Sceaux" (1952) and "Paysage du Vaucluse n°3" (1953) by the French painter Nicolas de Staël (1914–1955) (https://en.wikipedia.org/wiki/Nicolas_de_Stael) which artistically challenge the perception of subjective vertical and horizontal respectively. In line with this issue, some data suggest an actual activation of the limbic system, especially hippocampal neurons, according to the head position and orientation (Wiener 2002). These structures within the so-called "Papez circuit" are involved in the integration of signals coming both from external sources (environmental cues) and internal origin (vestibular and musculo-skeletal receptors) but also in the cognition of emotions. This could explain why, at a subconscious level, vestibular input could be key in aesthetic judgment and why and how vestibular deficits may interfere with aesthetic experience. Studying the consequences of an active or passive viewing of such artworks on posture and on horizontal/vertical subjective evaluation could be certainly informative in terms of aesthetic cognitive psychology. A quite similar issue has already been studied by analyzing the effects on postural stability of pictorial motion cues and lateral organization in two paintings by Claude Monet (1840–1926) (Locher 2011; Kapoula 2015). These two canvasses are similar in terms of visual and graphic content (color, size, painting technique) and overall structure (a woman on the top of a hill facing into the wind with her umbrella for the first one, a woman having her back to the wind for the second), but different in the strength of depicted motion, the first having more important motion cues: "Essai de Figure en plein air. Femme à l'ombrelle tournée vers la droite" and "Essai de Figure en plein

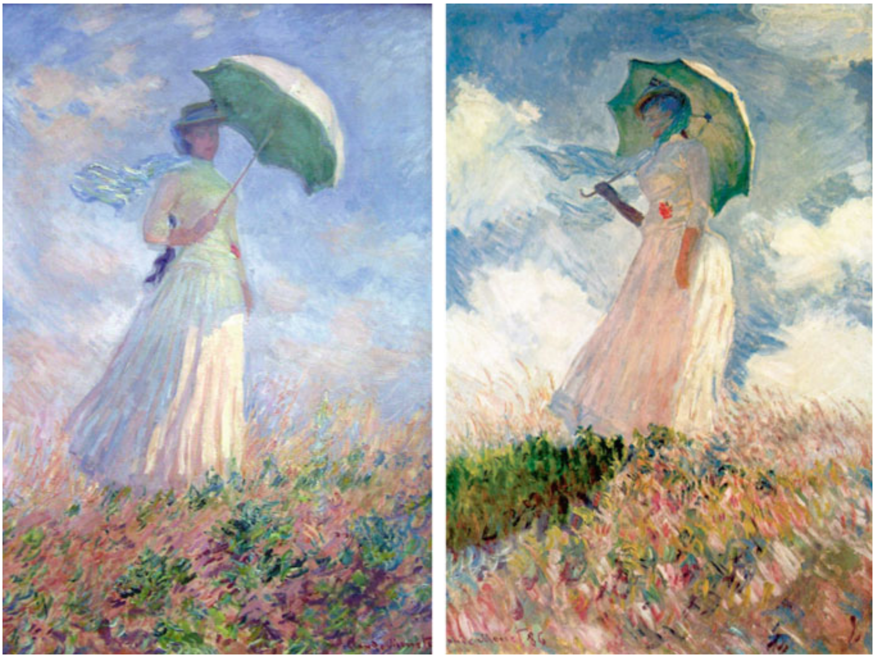

Fig. 7 Claude Monet (1840–1926). Essai de Figure en plein air. Femme à l'ombrelle tournée vers la droite. Essai de Figure en plein air. Femme à l'ombrelle tournée vers la gauche (1886)

air. Femme à l'ombrelle tournée vers la gauche" (1886) (Fig. 7). The variance of speed of body sway is increased while viewing each painting compared to a baseline control condition. Moreover the postural changes were significantly enhanced when viewing the composition containing a higher degree of depicted motion. Intriguingly, for one painting but not the other, body sway measures showed significant differences when comparing the original painting and its mirror-reversed image. This suggests that the mechanisms responsible for postural stability can be, in some cases, differentially sensitive not only to depicted motion cues but also to the laterality of the composition. It is well known that our attention processes are unequally allocated across space and that our emotional states are able to subtly modify the way we interact with objects and move in our environment because of the laterality biases they induce (Weick 2016). Indeed an in depth study of these aesthetic and emotional interactions between the viewer and different kinds of painting could represent a very promising opportunity to better understand and decipher the intertwined relationship between sensory inputs, self-perception and emotion.

Conclusion

As a conclusion, it might be stated that viewers can be literally "moved" by an artwork, even by a merely static painting. Referring to the etymology of the word emotion (Oxford dictionary: from French *émotion*, from *émouvoir* 'excite', based on Latin *emovere*, from *e-* (variant of *ex-*) 'out' + *movere* 'move') we are strongly encouraged to consider further the multifaceted interconnections between the vestibular system, posture, movements, emotions and aesthetic practice. Without going too far into a rather complex philosophical controversy, one might even argue that any emotion, included the aesthetic one, holds within its structure some potential for an actual movement or, at least, for a latent one (James 1884). Indeed questioning the differences between normal and vestibular impaired beholders or artists in the way they perceive, experience, or produce artworks, especially paintings, could be of great interest both in terms of vestibular physiology, self-consciousness, and neuroaesthetic knowledge.

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Heuraesthesia: When Synaesthesia Fertilizes the Mind

Vincent Mignerot

Abstract Heuresthaesia, a neologism composed of the terms "heuristic" and "synesthesia" is proposed here as a concept that can assist the comprehension of a specific field of intuition. In certain creative subjects, heuresthaesia would facilitate the access to objective knowledge and skills, thanks to elementary sensory processes incorporated into multimodal conscious representation. This chapter will sketch the theoretical framework of heuresthaesia and detail some intuitive supports for this concept, leaving to future works the task of assessing its scientific validity.

> What is the purpose of all that? asks Anthony.
>
> The Devil:
>
> The knowledge of things comes to thee only through the medium of thy mind. Even as a concave mirror, it deforms the objects it reflects; and thou hast no means whatever of verifying their exactitude. Never canst thou know the universe in all its vastness: consequently it will never be possible for thee to obtain an idea of its cause, to have a just notion of God, nor even to say that the universe is infinite,—for thou must first be able to know what the Infinite is! May not Form be, perhaps, an error of thy senses,—Substance a figment of thy imagination? Unless, indeed, that the world being a perpetual flux of things, appearance, on the contrary, be wholly true; illusion, the only reality. But art thou sure thou dost see?—art thou even sure thou dost live? Perhaps nothing exists!(…)
>
> St. Anthony:
>
> But Substance being unique, wherefore should forms be varied? Somewhere there must be primordial figures, whose bodily forms are only symbols. Could I but see them, I would know the link between matter and thought; I would know in what Being consists.»
>
> Gustave Flaubert (1910), The temptation of Saint Anthony (1874).

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The White Noise of the Universe

We would be strained if we had to imagine a living body that would simultaneously and without order perceive all the information it captures through its senses. At once sounds, images, tastes, cold and hot sensations, multiple textures, movements, would all be added together and intermingled to compose the picture of the world as it would stand if we were not able to sort, categorize, or make sense of the information. What would most resemble this incomprehensible amount of stimuli could be the “white noise” that we sometimes hear between radio frequencies: a kind of breath or crackle that may also have been experienced on the old poorly tuned TV sets as an incomprehensible fog. White noise is the random and simultaneous transmission of a wide spectrum of sound or visual frequencies. Something is noticeable, but we cannot know exactly what it is.

In Physics today, randomness seems to be the proper description of the fundamental state of the Universe in its innermost structures (on the quantum scale). The objects we know, with which we interact, are merely the result of the permanent measurement the Universe makes of itself, the linking of stable objects producing the “decoherence” of the first undifferentiated entities. This understanding of the deep structure of the world invited philosophers and epistemologists to compare the process of physical decoherence to the processes of thought and interpretation of reality (Bitbol 2009). The analogy is possible and surely fertile. Constructing the object for reality, for the body or for the mind would perhaps stem from the same formal movement: property does not precede measurement or objectivity, the relevance of the world is only fathomable in the permanent verification of the quality of the established link.

We are subjected, as living beings, to this constraint of relation and of measurement, the only way for objects to attest the possibility of their own existence. If the undifferentiated comes first and cannot be known beforehand, its comprehension arises from the history of interactions between our perceiving bodies and reality, which does not say anything spontaneously of itself.

Shape[1] is always a reconstruction.

> Almost every thinker that reflects and meditates notices in himself (in other words, in the universe, man being a microcosm) a kind of void, terrible at first, all the hypotheses of philosophies and religions superimposed as shadowy vaults, causality, substance, essence, the amorphous dome of abstraction, mysterious doorways open to infinity, and at the bottom, a glow. Little by little, lineaments take shape in this mist, promontories appear in this ocean, fixities rise in this depth; a sort of affirmation slowly emerges from this chasm and this vertigo. This phenomenon of inner vision is intuition.
>
> Victor Hugo (1860), excerpt from Proses Philosophiques

[1]The terms “shape” and “meaning” (signification, causality) will be used in the same way to designate the sets of information enabling the relevant integration of reality for adaptation. Shape is always a carrier of meaning.

Shape Emerges from Probability

> Doubtless, my present state is explained by what was in me and by what was acting on me a moment ago. In analyzing it I should find no other elements. But even a superhuman intelligence would not have been able to foresee the simple indivisible form which gives to these purely abstract elements their concrete organization. For to foresee consists of projecting into the future what has been perceived in the past, or of imagining for a later time a new grouping, in a new order, of elements already perceived.

> Henri Bergson (1911)

Our species, in line with other species gifted with the ability to represent the world they perceive, must make a formal sense of the world in order to understand it and to be best adapted to it. We know how to foster perceptions that lead to a relevant response, we know how to inhibit parasitic and secondary sensations (Sacchet 2015). We know how to shape the white noise of our senses.

Subject to the constraint of performance, the human being also inherits from his filiation the optimization processes of his adaptation, especially in terms of speed of response and energy saving criteria. During its development and based on the screening and selection of relevant information from the world, which is already a primitive shaping, our brain executes probabilistic calculations in order to determine, ahead of the upcoming action, a statistically coherent "picture" of what may happen (Frith 2007). Our nervous system predicts the dynamics of reality as best as it can from its own statistic reality, accelerating and specifying its adaptive response.

For human beings and surely for other species as well, low-pitched sounds are predicted as coming from below and high-pitched as coming from above. This originates from what we have engrammed from statistical reality: in nature, high-pitched sounds come more often from above whereas low-pitched come from below (Parise 2014).

The result of this perceptual anticipation is relevant and efficient for adaptation because only our nervous system's probabilistic calculations that allow the perpetuation of relevant probabilistic calculations are preserved. Sense (meaning) is a continuous construction that is perpetually confirming itself, eschewing possible errors by correcting the process as it goes.

This comprehension of brain function and of the anticipatory construction of representation foreshadows a new ecology of shape. Visual perception can now be understood as a more complex perceptual phenomenon than a simple "stimulus-response" one. It is the permanent production of a highly multimodal representation that would only make sense in a relational context:

> The ecological approach of visual perception stems from the fundamental principle that the object of perception is the same as that of action, otherwise the animal would be unable of finding his bearings in its environment and survive: this object is not a phenomenon "in the head" or "in consciousness", but it is the actual environment itself, that which the animal shares with his fellows and with the members of other species.

> Claude Romano, postface to Gibson (2014)

Reality has stable intrinsic properties. The probability of events occurring can be predicted and living and human beings construct in advance an ensemble of representations, as isomorphic to reality as possible, in order to obtain a correct adaptive response.

Synaesthesia: An Aesthetics of Probable Shape

> First, from a physiological standpoint, each of us is a model republic whose parts are interdependent, and in which 'he who affects one, affects the other'. Nothing could therefore happen in our body, and especially in our nervous system, that the whole would not feel to some degree.
>
> Théodore Flournoy (1893)

Synaesthesia is a particular neurological condition that displays to consciousness, for about 4 % of the population, the common work of the different sensorial and cognitive integration modalities. It can be understood as the conscious manifestation of the low levels of information processing, in all the richness of their multimodal expression. Some synaesthetes combine letters or numbers with colors, some perceive temporal sequences in abstract and geometric forms. Other "see" or "taste" sounds or even visualize geographically and tridimensionally time and the most abstract of thoughts. Studies on synaesthesia confirm that it is not associated with any pathological profile and that it accompanies adaptation without ever hampering it or only on rare occasions, its difficulties frequently arising from the association with disorders of another kind: autism (Baron-Cohen 2013), schizophrenia…

If today's models struggle to explain the reason for the conscious and irrepressible presence of these synaesthetic objects in a portion of the population, the fact that they follow the process of making sense of reality with the aim of a coherent adaptation suggests that they are also the products of a relevant formal and causal treatment (Mroczko-Wąsowicz 2014). Synaesthesia may be the evidence of low level integration processes in the subject, invisible to most of the population but who are at work in everyone. They are perhaps the persistence of multimodal associative scaffolding processes of knowledge and skills, which operate at an early age and usually become more discrete with the maturation of the nervous system.

We can especially understand the categorical, linguistic and cognitive (such as visual thinking) synaesthetic associations, as both the permanence of combinations of percepts associated during learning (an A is yellow because it is associated with a specific game or schoolbook on which it was written in yellow) and as the associative engram of these learning experiences on a multimodal organization matrix, which carries the history of the efficiency in relating to the world. A study also shows that the synaesthetic shape could originate from a topographic matrix that would be visible as far as the level of brain tissue structure. Indeed, IRM observations have managed to show that some neural populations had a topography that was exclusively devoted to numbers, similar to the neural topography that enables the treatment of information coming from the different senses (Harvey 2013).

In any case, synaesthesia seem to accompany in a perfect, solid and stable way the work of probabilistic interpretation performed by the brain. The synaesthetic shape always makes sense (Nikolic 2009).

We may all hold a formal prototypical associative pattern (not conscious to the neurotypical and more or less accessible to the synaesthete), originating from both our phylogeny and our own experience, that would have an automatic function of accelerating our reactions all the while ensuring them, thus facilitating and optimizing our adaptation. For a synaesthete, it is not possible to interfere in the automaticity of combinations, to modulate their responses or to willingly act upon them. They are so faithful to the meaning of the world that they could sometimes assist in better understanding it. This prototypical pattern not only optimizes instantaneous adaptation but it is useful, for some people, to acquire skills or intricate knowledge of the world.

Heuraesthesia: An Aesthetics of Discovery

Heuraesthesia (a contraction of the Greek word εὑρίσκω (eurisko) meaning "I discover" and of αίσθησις (aisthesis) "perception from the senses") is a particular condition that, in some subjects, brings together the abilities of shaping perceived natural elements (sounds, shapes, colors, textures, movements, raw percepts…) shared with animal filiation, with cultural elements (languages, elaborate and exclusive concepts…) that compose human singularity. It is this common work of the senses and the mind that supports the heuraesthete in acquiring knowledge or an objectifiable skill.

Here is what Richard Feynman, Nobel Prize in Physics, said of the link between thought and shape:

> When I see equations, I see the letters in colors – I don't know why. As I'm talking, I see vague pictures of Bessel functions from Jahnke and Emde's book, with light-tan j's, slightly violet-bluish n's, and dark brown x's flying around. And I wonder what the hell it must look like to the students.
>
> Richard Feynman (2001)

The objects we think about, sometimes highly complex and appealing to the highest elevations of the mind, were all acquired first through sensory channels. When R. Feynman questioned reality to extract clues about its physical qualities, his thoughts manifested to him not as numerals and signs arranged from left to right as they are usually arranged on paper. These objects seem to emit their own aesthetic clues that are compatible with the meaning of the calculations and which could even provide information on the natural properties that govern the interactions.

> In the brain, the rules are entangled with the symbols themselves whereas, on a sheet of paper, symbols are static entities manipulated according to rules that are in our heads.
>
> Douglas Hofstadter (2000)

Claire Petitmengin proposes to consider adaptation in general as a transmodal treatment performed by the nervous system and the body "of the smallest common informational multipliers" from reality: rhythm, movement, intensity, shape.

Sounds, scents, colors, vibrations etc. are first “syncretized” into subsets of basic information, and the deployment of these data subsets for each modality would be enough to obtain a valid response from the whole body (Petitmengin 2001).

Heuraesthesia stands as a support for this integrated treatment of “basic units of meaning” (Mignerot 2014) that, when certain events manifest as synaesthesia to consciousness, would take part in the discernment of the response, not only for the body this time, but for the entirety of the adaptation project of body and mind. Laurent Mottron names “veridical mapping” this first matrix on which knowledge is arranged and structured among itself (Mottron 2013), when Daniel Tammet mentions the “unique weaving” of his own perception (Tammet 2007).

Subjected to the need for optimization, as every processing tool for information coming from reality, heuraesthesia has an economic target in adaptation. The formal result generated by the joint work of the basic representations and the elaborate functions of the mind seeks to achieve the manifestation of a perceptual balance, in hopes of homeostasis. The heuraesthete is a shape optimizer and heuraesthesia favors creativity because it aids the correction of the disharmony of the perceived shape, by the implementation of basic, simple, probabilistic and automatic treatment levels.

The aesthetic experience of heuraesthesia, initially intimate and impossible to share as such, must be confirmed by way of a structured, transmissible and verifiable production in order to be qualified as heuraesthesia. A heuraesthesia makes sense for the one who experiences it as well as for the community who receives its result. It is the result of the joint work of the brain and of statistician senses, which provides relevant information to make it available as it is itself statistically relevant to someone else.

Scientific Heuraesthesia

Among the most brilliant and fertile intuitions in the history of science, many have authors that attest having experienced them first in presymbolic forms, inaccessible to languages, very sensorimotor and abstract. The heuraesthesia one can qualify as scientific are those whose result, after transcription of the multimodal experience, can be verified by a neutral third party, following objectifiable and generalizable methods.

Certain mental calculators such as Daniel Tammet seem to be authentic heuraesthetes: they are capable of executing complex calculations much faster than the time needed for retrieving the results from a calculator. Daniel Tammet says about an operation performed “in his head”:

> So, when I raise 37 to the fifth power ($37 \times 37 \times 37 \times 37 \times 37 = 69\ 343\ 957$), I see a big circle, composed of small circles rotating clockwise, from its top. When I divide two numbers, I see a spiral that expands downwards in circles that are increasingly concentric and deformed. Each division produces spirals of different shapes and sizes. (Tammet 2007)

For Paul Lidoreau, also a prodigious calculator, a mental operation appears as "a sort of spatial layout where numbers are the elements of a multi-link network, and where networks and links allow a kind of immediate consciousness of all possible relations." (Michel 1964)

Even if we may never be certain that the thinkers that have left only written or reported records were authentic synaesthetes and heuraesthetes, we can investigate the value of what they expressed of their intuitive experience.

The creative experience of Giordano Bruno also invites questions:

> If one talks about 'magic', one must talk about 'mental magic', in other words this particular type of genius ability of seeing the world through a different eye: an eye that captures images and knows how to transform them into active mental structures. These structures will have the capacity of informing (even in the sense of 'giving form, shaping'; from the latin in- [inductive] and forma) the world, in a process that amplifies all the reflections in a spiral. This is, ultimately, that extraordinary thinking activity that transforms the disorder of sensory impressions into lucid and ordered knowledge.
>
> Giovanni Fontana (2007)

Albert Einstein himself said that he did not develop general relativity by using only the regular mathematical language:

> Words or language, written or spoken, do not seem to play any role in my mechanism of thought. The psychic entities that serve as elements to thinking are, in my case, of a visual and sometimes muscular type. Conventional words or other signs must be laboriously searched for in a second stage…
>
> Albert Einstein (1959)

The difficulty Einstein felt in describing on paper what he perceived internally during the sensory manifestation of his thought is in line with the frustration of the artist that only rarely finds in what he has done all the richness and the infinite dimensions of what he has felt.

Artistic Heuraesthesia

Artistic heuraesthesia are perhaps more difficult to authenticate than scientific heuraesthesia because their result is not objectifiable, in so far as it is by nature not generalizable, art falling within a context of varied appreciation. Art is never really universal, nor is it permanent. The expectation of the public evolves, similarly depending on what artists may have produced in the past. But if the brain performs probabilistic calculations based on past experience and it tries to obtain a coherent result for adaptation, the relevance of this result is also subject to the quality of the setting and the natural variability of the environment… even if this environment is only cultural, local and variable.

The process of heuraesthetic intuition remains pertinent, especially since artists' accounts are often similar to those of scientists. What is perfectly comparable is the course of the creative act: a multimodal sensorimotor preform presents itself to the conscious perception and guides pen or brush, a composer's ear or a musician's gesture.

> It is almost impossible to express in their exact limits the abstract evolutions of the brain. The inconvenience of words is that they are more marked in form than ideas. All ideas have indistinct boundary lines, words have not. A certain diffused phase of the soul ever escapes words. Expression has its frontiers, thought has none.
>
> Victor Hugo (1869)

The dimensions of the heuraesthetic experience, shared with those of synaesthetic experience, are similar to those described by Victor Hugo. Sensory objects do not have the bounded nature of languages and concepts. They evolve in an edgeless space and naturally, by their appearance, lead to a connection to objects other than themselves. Their mere manifestation to the mind is enough to engage an opening movement, an exploration. From a multimodal object perceived, the impetus towards another is irrepressible, satisfaction attained only by following the global shape mentally from link to link until the picture obtained is sufficiently harmonious so we could stabilize the movement.

The terms "picture" and "movement" describe in this case both the inner experience of the creator as well as the result produced, especially by a painter. A pictorial heuraesthetic work will be that for which the author will have followed the directions of the multimodal shapes (colors, textures, movements…) statistically selected according to their relevance to produce the result that will be most likely to please the cultural context that will receive the work.

Vassily Kandinsky was maybe not a synaesthete, at least not according to the still rigid definition of the neurologic condition that this text may help evolve, yet certain of his works are, to him, the pictorial shaping of the impalpable, of the musical invisible, and the result moves the public in the sense of rhythm, of texture and movement. A multimodal inspiration seems to make sense and be aesthetic to both artist and viewer.

As painted by Kandinsky, heuraesthesia in music could be the preformation of the structure, as it is presented before composition as a complete sensorimotor object, non-linguistic but perfectly coherent as a perspective of rhythmic and melodic production. We may also never be certain that Mozart was a synaesthete. But we can recollect his words qualifying the pictorial representation of a musical composition:

> Even if it is a long piece, I embrace it all in my mind in a glance, as if I saw a beautiful picture or a beautiful human being: in my imagination I do not hear it in order of succession, as it should come after, but I take everything so to speak in one shot.
>
> Wolfgang Amadeus Mozart (1789)

Some contemporary musicians give evidence that their synaesthetic perceptions guide them to what they call a satisfactory result, as opposed to other times when synaesthesia does not occur to them which they feel as less satisfactory. Franck Avitabile, pianist and composer, as soon as he plays his instrument of choice and the acoustics of the room are good, “sees” the notes and chords on top of the piano. He himself says that the perceived shapes and the emotions he feels match the generated harmonics, which “guide” his improvisation to build a coherent play on the fly.[2] If we can ask whether such an experience is truly a heuraesthesia, it would be interesting to study whether the public also perceives a qualitative difference in listening to an improvisation of Franck Avitabile when he himself follows synaesthesia and when he does not.

Musicians may also allow the characterization of an artistic heuraesthesia with near scientific value. It has been shown that having a perfect pitch is frequently associated with synaesthesia (Loui 2012). The richness of the potential multimodal association and the strength of the engram between the sensory information (the note) and the object of knowledge (the name of the note) suggest that perfect pitch is an almost prototypical experience of heuraesthesia. The solidity of the occurrence probability of phenomena in the world (a frequency of 440 Hz is always an A) is perfectly intuited in both perception and language. For some musicians, a note is a color, a texture (always the same for the same note), a proprioceptive position in the body (that sometimes helps distinguish between a high-pitched and a low-pitched A) and the name of the note, the whole constituting a single indivisible object, perfectly coherent and still formally connected to all the other notes. The verifiability of the accuracy of this experience by a third party allows the comparison of this heuraesthesia with that of the prodigious mental calculators mentioned earlier. It certainly contributes to the talent of many musicians.

> However is there not something else? The emergence on the screen (of the work) of non-linear forms, three-dimensional sculptures which are neither only curves or surfaces, but which are as objects recalling the physical and mathematical mental representations (potential wells, tori and topological handles), infuses the idea of a topology of the mind or thought. As if one perceived the world at the Planck scale. Below this scale (10^{-33}), it becomes chaotic, fluctuating, ceasing to be a smooth space-time. Thought and mind are necessarily coupled (we do not know how) to the physical Universe. He, who can achieve the junction between these diverse and complementary concepts, can produce a work.
>
> Louis-José Lestocart (Kapoula 2011)

Heuraesthesia proposes a path to explore the unknown elements of this particular coupling of body and mind, so frequently mentioned in the creative act and which cannot be neither magical nor incoherent.

Generalization

Following the link between probabilistic aesthetics, creativity and heuraesthesia, we can mention a recent study that seems to show that the feeling of beauty generated by mathematical logic activates the same cerebral regions as the feeling of artistic

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[2]Interview by the author.

beauty (Zeki 2014). A common intention could motivate every creative movement: following a logic that is intrinsically carried by the adaptation process, whose functional ambition would be the quest for an aesthetic coherence providing pleasure once it is achieved, regardless of the field in which it is expressed.

We are progressing then towards the reconstruction of an "ecological theory of the mind" (Mignerot 2014), which would allow to reinsert the aesthetic experience among the behavioral attractors of the subject, enabling him to determine from the information reaching him which is most favorable to maintain satisfactions and stimulation of the brain reward areas at their highest level. Certain artworks "obtain access to the neural substrates concerned with the self-access which other external stimuli normally do not get" (Edward 2013). Synasthetes give evidence of this feeling of intimate relation with their synaesthesia. They are at the same time entities of which they have no control, coming from outside the subjective sphere, and also an integral part of the definition of the self: it would be difficult to be defined without them.

> I think, in fact, that to understand what consciousness is, one must discover the nature of the 'isomorphism' upon which meaning depends.
>
> Douglas Hofstadter (2000)

Conclusion

Heuraesthesia is the implementation of the ability to infer coherence to representation based on the expectations of the context (of knowledge or, in a more general perspective, of culture). It proposes shape and meaning to the subject where there is none yet, according to the most probable correct outcome based on what already exists and the new fitting configuration. This process of multimodal meaning implementation seems relevant for the mathematician, the physicist and the philosopher as well as the novelist, painter and musician.

Heuraesthesia opens a way for the exploration of the phenomena that occur upstream of us, over which it seems we have little control but which are pertinent to our adaptation and even benefit the community. Heuraesthesia also intends to distinguish the intuitions whose result leads to heuristics from those that are akin to fantasy, sometimes esoteric, that push some to charlatanism.

The rules governing communication between perceptions and thoughts, which seem to be the source of all creative movement, may remain forever imperfectly known. But the processes involved in intuition are not irrational nonetheless and certain—incredible—skills, often discredited for lack of a means of legitimizing them, can henceforth be studied: heuraesthesia is an eminently rational process.

Indeed, the proposed interpretative framework invites consideration of object, meaning and their investment in the creative movement as being subjected to a deterministic project that goes beyond the individual. Creation is finally just a product that is statistically optimized according to an external requirement, and it is also subjected to the need of making sense out of the "white noise" of undefined reality in a relevant way. The heuraesthetic process exceeds perhaps the whims of intentionality and free will. The fact remains that any creative act, whatever the secret intuition may keep to itself, is always carried by an emotion (Palmer et al. 2013), and it is this emotion that transports us far beyond the sole logic and the sole determinism.

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Dyslexia, Education and Creativity, a Cross-Cultural Study

Zoï Kapoula and Marine Vernet

Abstract Are dyslexic children and teenagers particularly creative? Although controversial, several theories hypothesized putative neuro-physiological mechanisms: disequilibrium of magno- and parvo-cellular systems, the latter compensating weakness of the former, and inter-hemispheric connectivity difference. In this study, we further hypothesized a role of the educational approach. Creativity in dyslexic and non-dyslexic children and teenagers from different schools in France and in Belgium, as well as in students from different universities, were evaluated with the Torrance Test of Creative Thinking (TTCT). The results show that dyslexic children and teenagers can be highly creative in the TTCT. Yet, expression of creativity can be modulated by educational approach, revealing a probable advantage for personal follow-up compared to normalizing.

Introduction

Are people with dyslexia particularly creative? What could be the underlying source of such enhanced creativity? Dyslexia is defined as a developmental disorder and hence associated with impairment. Reading ability in dyslexic individuals is significantly lower than what could be expected from the intelligence quotient. However, the existence of superior skills in dyslexic individuals has been hypothesized. Examples of particularly creative individuals who happened to be dyslexic are abundant (see e.g., Rack 1981) and a high prevalence of dyslexia among art students have been observed (Wolff and Lundberg 2002). However, it remains unclear in which domains dyslexic individuals might be superior and what could be the basis of such enhanced skills. Moreover, it has been hypothesized that

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higher creativity is only expressed in dyslexic adults and hence results from compensatory mechanisms initiated in response to the specific difficulties associated with dyslexia (Everatt et al. 1999).

Creativity is difficult to define. Nevertheless, it is generally agreed that creativity is "the ability to produce work that is both original (new, unusual, novel, unexpected) and valuable (useful, good, adaptive, appropriate)" (Dietrich 2004; Sternberg and Lubart 1999). Paul Torrance is known for developing the Torrance Test of Creative Thinking (TTCT) in 1966 (Torrance 1966). This American psychologist defined creativity as: "a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results". The norms for his test have been adjusted four times (1974, 1984, 1990, and 1998) and the test has been translated into more than 35 languages. There are two forms (A and B) of the TTCT-Verbal and two forms (A and B) of the TTCT-Figural tasks. For each task, the stimulus is an image to which people respond by writing (TTCT-Verbal) or drawing (TTCT-Figural). The TTCT measures four factors: *Fluency* shows the ability to produce many figural images (number of relevant ideas). *Flexibility* shows the ability to produce different ideas (number of ideas' categories). O*riginality* shows the ability to produce uncommon responses (number of statistically non-frequent ideas). Finally, *elaboration* shows the ability to develop and elaborate an idea (number of added details, ideas).

In the present study, we examined the potentially higher creativity in dyslexic children and teenagers taking into account the type of education (considering the specificity of each child vs. trying to normalize the performance). In line with previous suggestion (Chakravarty 2009), we hypothesized that schools, which adapt their education approach to the need of dyslexic children and teenagers would promote creativity as measured by the TTCT. The present study was conducted with children and teenagers from three different schools in France and Belgium with different educative approaches. As a comparison, we also measured creativity in students from three universities, which promote different types of creativity (decorative art, industrial creation and design, and engineering).

Materials and Methods

Participants

The first part of the study was conducted with three groups of students (young adults) from three universities in Paris, including a university devoted to decorative art: *Ecole Nationale Supérieure des Arts Décoratifs* (ENSAD), a university devoted to industrial creation and design: *Ecole Nationale Supérieure de Créations Industrielles* (ENSCI), and an engineering university: *Ecole Nationale Supérieure des Techniques Avancées* (ENSTA-ParisTech). The second part of the study was conducted with children and

Table 1 Demographic data

University/school	Mean age	STD age	Min age	Max age	Males	Females
ENSAD	**26.3**	**2.9**	**20**	**27**	**6**	**3**
ENSTA	**22.6**	**1.4**	**21**	**25**	**6**	**2**
ENSCI	**21.3**	**1.8**	**18**	**24**	**3**	**5**
PARIS	**12.5**	**0.8**	**11**	**14**	**47**	**19**
Dyslexic	*12.5*	*0.9*	*11*	*14*	*38*	*16*
Other dysfunctions	*12.3*	*0.8*	*11*	*14*	*9*	*3*
Bruxelles	**13.3**	**0.9**	**12**	**15**	**20**	**21**
Dyslexic	*13.7*	*1.0*	*12*	*15*	*8*	*7*
Non-dyslexic	*13.3*	*0.9*	*12*	*15*	*12*	*14*
OISE	**10.3**	**1.3**	**8**	**12**	**9**	**1**
Dyslexic without comorbidity	*10.5*	*1.3*	*9*	*12*	*4*	*0*
Dyslexic with comorbidity	*10.2*	*1.3*	*8*	*12*	*5*	*1*

The young-adult students (in ENSAD, ENSTA, ENSCI) were never diagnosed as dyslexic. However, several students (3/9) from the ENSAD expressed having had school difficulties when they were young such as: mixing up letters, reading difficulties, attention deficits, pronounciation difficulties. In the PARIS school, children and teenagers had either dyslexia (n = 54) or other dysfunctions (n = 12, including 4 with single and 8 with multiple difficulties: dyspraxia (2), dysphasia (2), attention deficit (3), dysgraphia (1), written language difficulties (5), oral language difficulties (2), cognitive inhibition (1)). In the BRUXELLES school, children and teenagers were either dyslexic (n = 15) or non-dyslexic (n = 26). In the OISE school, all recruited children had dyslexia, some without (n = 4), and some with comorbid dysfunctions (n = 6; 3 with dysphasia, 2 with attention problems and 1 with dyscalculia)

teenagers from three schools in France and Belgium, including a school in Paris, France (the school will be simply referred to here as PARIS), in which we recruited children and teenagers with dyslexia and with other dysfunctions, a school in Bruxelles, Belgium, (the school will be referred to as BRUXELLES), in which we recruited dyslexic and non-dyslexic children and teenagers, and a school in Oise, France (the school will be referred to as OISE), in which we recruited dyslexic children with or without comorbidity. Demographic data can be found in Table 1. The schools were selected because they offered special programs for dyslexic children and teenagers and the teachers were open to participate in our research study. Sample size of each group was limited by the number of children, teenagers, and students, who agreed to participate in the study. Previous studies were able to show differences between groups in creativity using the TTCT test with approximately 10 participants in each group (as low as 7 in some cases) (Drago et al. 2009; Horne 1988; Orme-Johnson and Haynes 1981); all our statistical analyses, except one, which will be indicated, were performed with a larger sample size. Written informed consent was obtained from the students and from both the children/teenagers and their parents. The study was approved by the local ethical committee C*onseil d'évaluation éthique pour les recherches en santé* (CERES) and was conducted in adherence with the Declaration of Helsinki.

Children and teenagers were classified as dyslexic independently from the research team by specialized schools, medical centers, or children's hospital services according to criteria commonly used in France and Belgium. The dyslexia classification was based on an extensive examination including neurological, psychological, and phonological capabilities, performed less than a year before being included in the present study. Inclusion criteria were: (1) scores in the L2MA test, which is a standard test commonly used for French-speaking children in France and in Belgium (Chevrie-Muller et al. 1997), were two standard deviations below the normal score, (2) a normal intelligence quotient, and (3) no neurological symptoms or ophthalmologic pathology.

Tests of Creativity

The tests were run by school personnel, who were trained by the investigators., Participants of each university/school were simultaneously administered the TTCT—Figural Form test in a quiet room. The paper-pencil test was handed out to each participant, together with clear instructions. The test was started after everyone had understood the instructions. The TTCT—Figural Form test, is an age-normed (up to 18 years old) test composed of three tasks, each lasting 10 mins; all require producing unusual drawings starting from standard shapes (e.g., a pair of straight lines or an oval, see Fig. 1). The results were analyzed by three students in psychology who were trained in the analysis of the Torrance test; they knew which school the children attended, but were blinded to their classification as being dyslexic or non-dyslexic. The scores assessed four different cognitive components of creativity: fluency (the quantity of relevant productions), flexibility (the number of different categories of productions), originality (the degree to which productions are uncommon), and elaboration (the degree of enrichment of productions). Each component yielded a raw score, which was then converted into a standard score with a calibrated chart.

Data Analysis

One-way ANOVAs were separately performed for each creativity score (fluency, flexibility, originality, elaboration, and finally the total score) for testing the effect of each factor separately (university, dyslexia, school, age, type of dysfunction and comorbidity problems). ANOVAs were also used to compare the most creative dyslexic children and teenagers (i.e., from the BRUXELLES school, see results) with the most creative students (i.e., from the ENSAD university, see results). Post hoc analyses were performed with the Least Significant Difference (LSD) test. Tests were two-tailed. Statistical significance was set at $p < 0.05$. Confidence intervals (CI) and Cohen's d effect size are indicated.

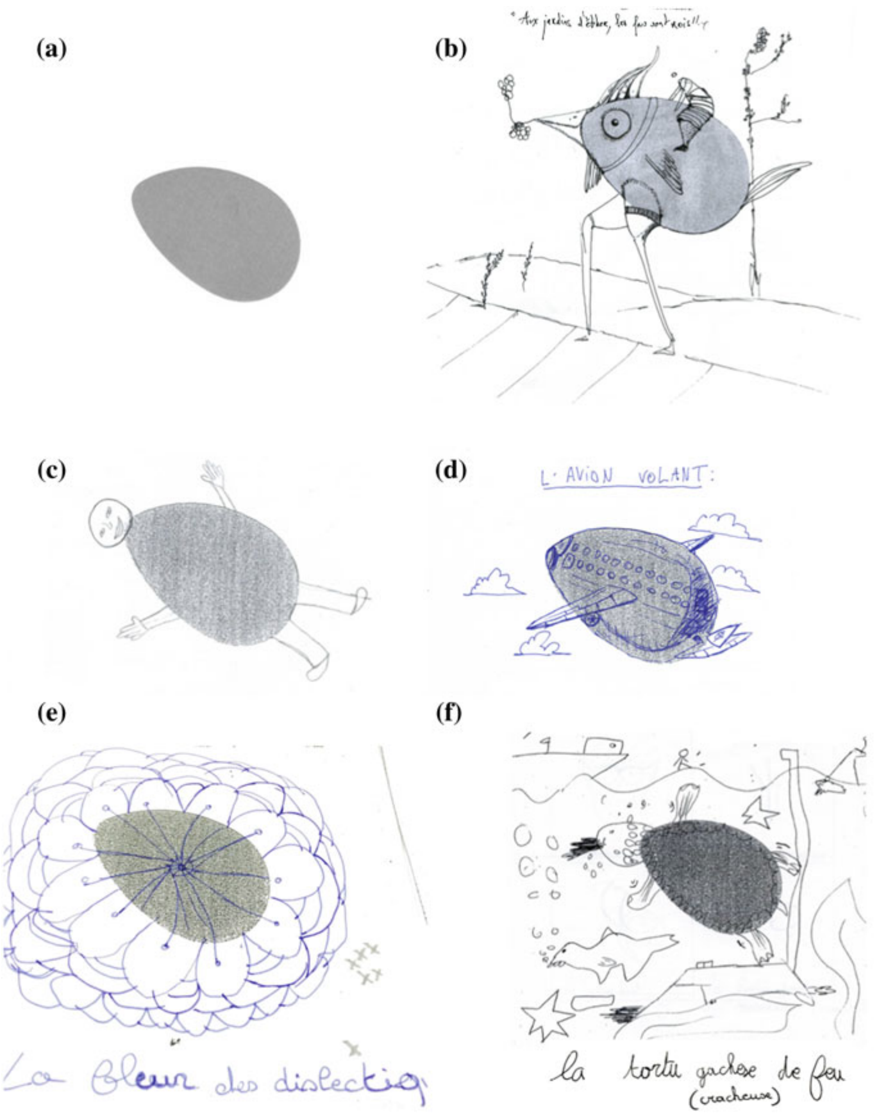

Fig. 1 Illustration of the TTCT completion for representative participants. **a** Original form to be completed. **b** Completion of a student from ENSAD (fluency: 55; flexibility: 45; originality: 60; elaboration: 75); title “*Aux jardins d’éther, les fous sont rois*”. **c** Completion of a non-dyslexic 14 years old teenager from BRUXELLES (fluency: 35; flexibility: 35; originality: 35; elaboration: 40); title “*Garçon*”. **d** Completion of a dyslexic 13 years old teenager from BRUXELLES (fluency: 65; flexibility: 65; originality: 65; elaboration: 75); title “*L’avion volant*”. **e** Completion of a dyslexic 12 years old child from PARIS (fluency: 40; flexibility: 30; originality: 40; elaboration: 50); title “*La fleur des dislectiq*”. **f** Completion of a dyslexic 12 years old child from OISE (fluency: 60; flexibility: 65; originality: 70; elaboration: 55); title “*La tortu gachese [cracheuse] de feu*”

Results

One part of the study was conducted with students from three universities in Paris, attending courses on decorative art (ENSAD), industrial creation and design (ENSCI), and engineering (ENSTA-ParisTech). The second part of the study was conducted with children and teenagers from three schools in France and Belgium, hereafter named PARIS (pure dyslexia and dyslexia with other dysfunctions), BRUXELLES (with and without dyslexia) and OISE (dyslexia with or without comorbidity problems). Creativity of all participants was tested with the TTCT—Figural Form test. The grading assessed four different cognitive components of creativity: fluency, flexibility, originality, and elaboration, and finally, a combined total score.

Effect of the University on the Creativity of Students

The one-way ANOVAs performed to test the effect of university (i.e., to compare the scores of the students from the 3 different universities, Fig. 2a) revealed a marginally significant effect of the university on the total score of the TTCT test ($F_{(2,22)} = 3.02$, $p < 0.0696$) and a significant effect on the elaboration score ($F_{(2,22)} = 11.58$, $p < 0.001$), but not on other scores (all $p > 0.250$). For the total score, the score for ENSTA students was significantly lower than the score for ENSAD ($p = 0.0206$, [1.74 18.00]). For the elaboration score, the score for ENSTA students were significantly lower than the score for ENSAD ($p < 0.001$, [15.99 39.84]) or ENSCI ($p = 0.0058$, [5.95 29.05]). Recall that the TTCT is calibrated up to 18 years, and the students tested in the present study were beyond this age. Yet, the observed differences are of interest, and in line with Kim's suggestion (Kim et al. 2006) that such a test can be useful for research as it has the capacity to differentiate between groups. Thus, students attending a university emphasizing artistic or industrial creation displayed higher creativity than students enrolled in engineering.

Dyslexia and Creativity

The one-way ANOVAs used to test the effect of dyslexia (i.e., comparing the scores of dyslexic and non-dyslexic children and teenagers from the BRUXELLES school, Fig. 2b) revealed a significant main effect of dyslexia on all parameters measured: total score ($F_{(1,39)} = 11.35$, $p = 0.0017$, [4.28 17.12]), fluency ($F_{(1,39)} = 6.46$, $p = 0.015$, [2.00 17.63]), flexibility ($F_{(1,39)} = 7.00$, $p = 0.012$, [2.03 15.22]), originality ($F_{(1,39)} = 6.28$, $p = 0.017$, [2.20 20.59]) and elaboration ($F_{(1,39)} = 21.21$, $p < 0.001$, [7.30 18.73]) with higher scores for dyslexic than non-dyslexic children and teenagers. Note that both groups were very comparable in age (see Table 1). Thus, the dyslexic children and teenagers were evaluated as more creative than the non-dyslexic participants.

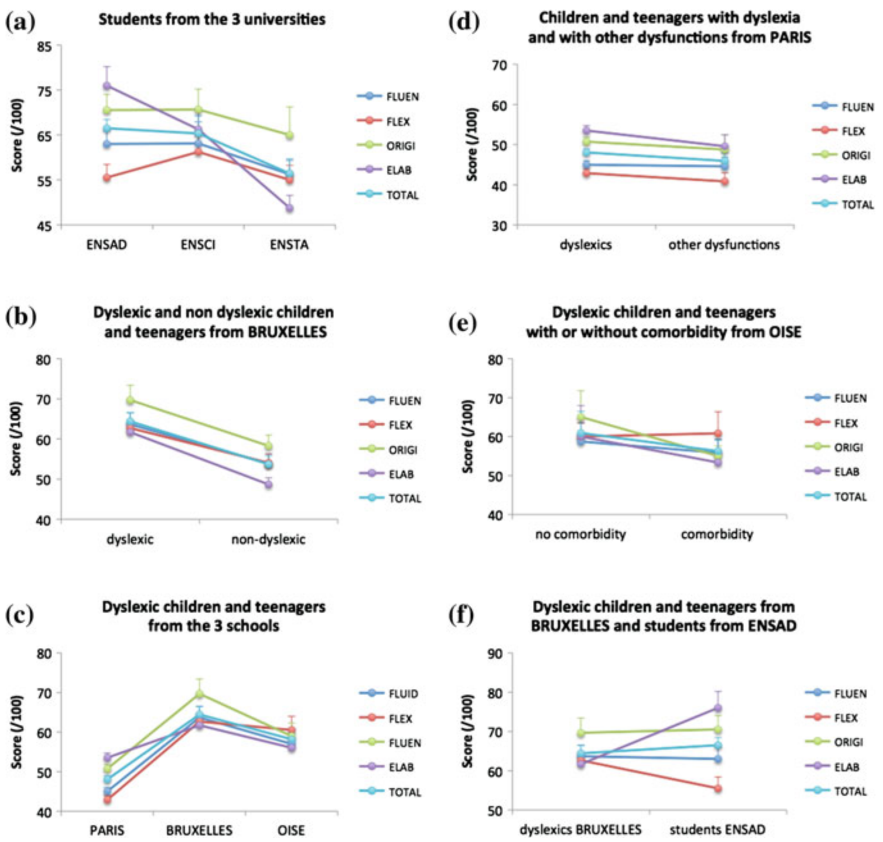

Fig. 2 TTCT results for each components of creativity: fluency (FLUEN), flexibility (FLEX), originality (ORIGI) and elaboration (ELAB) as well as total score (TOTAL) when testing for university effect among students (**a**), when testing for dyslexia effect among children and teenagers (**b**), when testing for school effect among dyslexic children and teenagers (**c**), when comparing children and teenagers with dyslexia and with other dysfunctions (**d**), when comparing dyslexic children and teenagers with and without comorbidity (**e**) and when comparing dyslexic children and teenagers from BRUXELLES with students from ENSAD (**f**)

Effect of the School on the Creativity of Dyslexic Children and Teenagers

The one-way ANOVAs used to test the effect of school (i.e., comparing the scores of dyslexic children and teenagers from the 3 schools, Fig. 2c) revealed a significant main effect of school on all parameters measured: total score ($F_{(2,76)} = 35.88$, $p < 0.001$), fluency ($F_{(2,76)} = 34.69$, $p < 0.001$), flexibility ($F_{(2,76)} = 42.53$, $p < 0.001$), originality ($F_{(2,76)} = 22.41$, $p < 0.001$) and elaboration ($F_{(2,76)} = 4.11$, $p = 0.020$). All scores were significantly higher in BRUXELLES than in PARIS (total score, $p < 0.001$, [12.44 20.29]; fluency, $p < 0.001$, [13.91 23.43]; flexibility, $p < 0.001$, [15.06 24.53]; originality, $p < 0.001$, [13.24 24.62]; elaboration, $p = 0.0026$, [2.96 13.34]). All scores except the elaboration score were significantly higher in OISE than in PARIS (total score, $p < 0.001$, [5.42 14.76]; fluency, $p < 0.001$, [6.93 17.07]; flexibility, $p < 0.001$, [11.60 23.65]; originality, $p = 0.0063$, [2.42 14.10]; elaboration, $p > 0.250$, [−4.36 9.32]). Finally, none of the score were significantly different in BRUXELLES than in OISE (total score, $p = 0.074$, [−0.67 13.22]; fluency, $p = 0.12$, [−1.84 15.17]; flexibility, $p > 0.250$, [−5.34 9.67]; originality, $p = 0.057$, [−0.35 21.68]; elaboration, $p = 0.24$, [−4.01 15.43]). Note that test scores were normed according to the age and were therefore not biased by age. Thus, the educational approach had an impact on creativity in dyslexic children and teenagers.

Influence of Age in Creativity

The one-ways ANOVAs used to test the effect of age (i.e., comparing 4 or 8 age groups, see Fig. 3) showed that, indeed, there was no age effect on any of the scores in the non-dyslexic children and teenagers from BRUXELLES (total score, $F_{(3,22)} = 0.6$, $p > 0.250$; fluency, $F_{(3,22)} = 0.5$, $p > 0.250$; flexibility, $F_{(3,22)} = 0.87$, $p > 0.250$; originality, $F_{(3,22)} = 0.6$, $p > 0.250$; elaboration, $F_{(3,22)} = 1.13$, $p > 0.250$; Fig. 3b).

On the contrary, for dyslexic children and teenagers from the 3 schools, there was a significant effect of age on total score ($F_{(7,71)} = 3.09$, $p = 0.0066$), flexibility ($F_{(7,71)} = 2.33$, $p = 0.034$) and originality ($F_{(7,71)} = 2.85$, $p = 0.011$) and but not on fluency ($F_{(7,71)} = 1.7$, $p = 0.12$) and elaboration ($F_{(7,71)} = 1.64$, $p = 0.13$). In brief, there are critical time periods in dyslexic children and teenagers during which higher scores are obtained: 10 and 15 years old (Fig. 3a). Most probably, such age effects did not affect the fact that they were higher scores for dyslexic children and teenagers in the BRUXELLES school than in the PARIS school (see previous section): the average age of both groups was between 12 and 14 years old, i.e., the age ranges with the lowest creativity score in dyslexia.

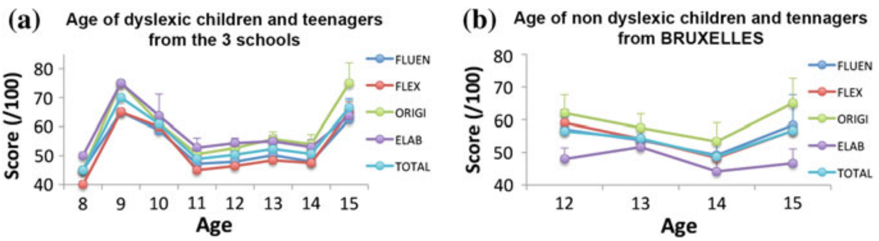

Fig. 3 TTCT results per age category for dyslexic children from the 3 schools (**a**) and for non dyslexic children from BRUXELLES (**b**)

Comparison of Creativity in Children with Dyslexia and/or Other Associated Dysfunctions

The one-way ANOVAs used to test the effect of the type of dysfunction showed that in the PARIS school, the children and teenagers with dyslexia and those with other dysfunctions had similar creativity scores (total score, $F_{(1,64)} = 1.03$, $p > 0.250$, [−2.02 6.21]; fluency, $F_{(1,64)} = 0.03$, $p > 0.250$, [−4.25 5.08]; flexibility, $F_{(1,64)} = 0.61$, $p > 0.250$, [−3.17 7.25]; originality, $F_{(1,64)} = 0.48$, $p > 0.250$, [−3.77 7.75]; elaboration, $F_{(1,64)} = 1.83$, $p = 0.18$, [−1.87 9.74], Fig. 2d). The one-way ANOVAs used to test the effect of comorbidity problem showed that in the OISE school, dyslexic children and teenagers without or with comorbidity problems also had similar creativity scores (total score, $F_{(1,8)} = 0.67$, $p > 0.250$, [−8.51 17.89]; fluency, $F_{(1,8)} = 0.28$, $p > 0.250$, [−9.86 15.70]; flexibility, $F_{(1,8)} = 0.01$, $p > 0.250$, [−18.05 16.39]; originality, $F_{(1,8)} = 2.56$, $p = 0.15$, [−4.41 24.41]; elaboration, $F_{(1,8)} = 0.47$, $p > 0.250$, [−15.87 29.20], Fig. 2e). However, the sample size of this last analysis might have been too small to allow detecting differences between children with or without comorbid dysfunctions. If confirmed in larger groups, those results would indicate that the specific type of developmental dysfunction does not impact creativity. Such findings would reinforce the probable importance of the educational approach taken by the school.

Comparison of Creativity in Belgian Dyslexic Children and Teenagers with Creativity in Art Students

Finally, the one-way ANOVAs used to compare the most creative group of students (i.e., from ENSAD) and the most creative group of dyslexic children and teenagers (i.e., from BRUXELLES) (Fig. 2f) showed only the following significant differences: higher flexibility for dyslexic children and teenagers than art students ($F_{(1,22)} = 4.87$, $p = 0.038$, [−14.87 −0.46]) and higher elaboration for the art students than the dyslexic children and teenagers ($F_{(1,22)} = 10.38$, $p = 0.0039$, [5.34 24.66]); there were no significant difference for total score ($F_{(1,22)} = 0.36$, $p > 0.250$, [−4.57 8.33]), fluency score ($F_{(1,22)} = 0.02$, $p > 0.250$, [−10.99 6.97]), and originality score ($F_{(1,22)} = 0.02$, $p > 0.250$, [−10.97 12.75]). It is worth noting that several students (3/9) from the ENSAD school expressed having had school difficulties such as: mixing up letters, reading difficulties, attention deficits, and pronounciation difficulties. Thus, dyslexic children and teenagers in some schools might display the same level of creativity than students in art. Conversely, it is possible that some of the art students experienced dysfunctions similar to dyslexia when they were young.

Discussion

Our study showed that art students obtain higher scores in the TTCT than engineering students. Therefore, in addition to its capacity in differentiating groups, the TTCT reflects some type of artistic creativity expressed by art-trained students. Even if they were not diagnosed as dyslexic, one third of the art students expressed having had learning difficulties at school. This observation is in line with prior studies showing a high prevalence of dyslexia among art students (Wolff and Lundberg 2002).

Of interest, similar scores of creativity were obtained by art-trained students and dyslexic children and teenagers from the BRUXELLES school, suggesting that dyslexic children and teenagers can be as creative as the student population selected for their creativity and trained to further develop it. Furthermore, our analyses reveal a tendency that, on the one hand, children and teenagers with dyslexia and/or with other similar dysfunctions obtain higher creativity scores than non-dyslexic children and teenagers and that, on the other hand, the educational approach a school chooses can further enhance creativity in dyslexic children and teenagers. Further studies with higher sample sizes would be required to confirm the role of educational systems in enhancing the creativity of dyslexic children and teenagers.

The first result of our study is the finding that dyslexic children and teenagers can possess higher creativity. We therefore moderate the statement that higher creativity is only expressed in dyslexic adults and hence results from compensatory mechanisms initiated in response to the specific difficulties associated with dyslexia (Everatt et al. 1999). Indeed, dyslexic children around the age of 10 years old were found to be particularly creative in our study, presumably before compensatory mechanisms could be fully developed. We thus suggest that higher creativity in dyslexia partially relies on a neurophysiological basis [e.g., developmentally different balance/interactions between right/left hemispheres or between magnocellular and parvocellular systems (Chakravarty 2009; Stein 2001, 2012; Stein and Walsh 1997)], possibly mediating higher holistic visuo-spatial processing skills (Attree et al. 2009; von Karolyi et al. 2003).

The second result of our study is that the educative environment plays an important role in the development of creativity in dyslexic individuals, a finding that is in line with previous literature (Chakravarty 2009). What could be the main reasons explaining differences between schools? General cultural or educational policy most likely differ between France and Belgium, but note that creativity remained higher in the dyslexic when compared with the non-dyslexic population in BRUXELLES. In addition, creativity was similar in the BRUXELLES (Belgium) and OISE (France) schools, and larger in these two schools than in the PARIS school (France) in dyslexic children and teenagers. Our interpretation of the present study’s results is rather that the educational approach targeted to the dyslexic population has an impact on creativity. In terms of educational program, the three establishments are driven by programs that take into account the specificities of the dyslexic population, providing additional help for reading performance. However, some differences in the different establishments may account for differences.

For instance, the PARIS school mostly aims at normalizing reading and academic performance. In order to acquire standard levels of performance in language, dyslexic children and teenagers attend special classes with small numbers of pupils (less than 18), where they benefit from additional hours of training in language skills. Furthermore, orthophonists assess progress outside normal school hours and regular meetings between teachers, parents, othophonists, and school psychologists are scheduled to evaluate the progress.

In the BRUXELLES school, educational emphasis is placed on the specific needs of the individual rather than on a normalization process. The goal is to not discriminate between pupils with and without learning difficulties and to provide a general education approach that takes into account individual differences. For instance, pupils learn how to set their own objectives, and are helped to discover their limits and abilities, and to mobilize their resources to overcome difficulties. Most of the teachers in this school received further training (e.g., in coaching, relaxation, and other techniques).

The OISE school is driven by a similar educational approach. Professionals at this school pointed out the importance of individually pacing and following up each child and teenager in order to improve their reading skills. In order to reconcile dyslexic children and teenagers with school, they attend regular classes where they are not separated and stigmatized. In addition, they attend special classes where they receive additional help from orthophonists, ergotherapists, and psychologists. The teachers in this school included persons educated to teach the general population as well as persons specialized in teaching pupils with dyslexia. Importantly, both the teachers running regular classes and specialized teachers were interacting within the same school, aiming for a common educational goal to improve the performance of dyslexic children and teenagers based on a personalized follow-up.

We believe that all these aspects are of importance and could condition the expression of creativity as measured by the TTCT in different populations. From the present study, we cannot estimate which of these factors could be crucial for potentiating higher creativity in dyslexic children and teenagers, and we cannot rule out other confounding factors, such as class size. Nevertheless, our interpretation in terms of education is in line with the theory of Sternberg (Sternberg 2006) suggesting that creativity is also a "decision" and that society can play a role by teaching creative thinking especially to children who profit less from conventional educational approaches.

In conclusion, our study demonstrates that education, which is specifically adapted to the needs of subjects with dyslexia, can enhance creativity in dyslexic children and teenagers. We hope that this study will stimulate further multidisciplinary studies in order to better assess the differences in educational approaches and their impact on expressions of creativity.

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Part II
Neurophysiology of the Artworks' Observer

The Theatrical Stage Setting: A Tool for Neuropsychology and Cognitive Neuroscience

Yannick Bressan

Abstract The field of live performance offers to cognitive neuroscience precious resources and novel experimental designs with unsuspected potential. Based on an innovative interdisciplinary experiment realized in 2008 at the Laboratory of Imaging and Cognitive Neurosciences, Strasbourg hospital, in partnership with the National Theatre of Strasbourg, this chapter narrates how such an experimental protocol tightly mixing neuropsychology and live performance allows obtaining disturbing and meaningful results and paves the way towards other experimental protocols. In this experiment, direct intervention of the stage director into the theatrical story carried out by the comedian induced correlated changes in neurological and physiological states. Moreover, the specific neuropsychological activations were similar to the ones observed in hypnotic states. Thus, this chapter shows how much staging, from a systemic and interdisciplinary perspective, offers fertile fields of investigation for cognitive science and neuropsychology.

Theatre: The Emergence of a New Reality

Neuro-aesthetics applied to theatre performance recently allowed a better understanding of the emergence of fictional reality and hence of the "mental images" composing it, allowing it "to take reality". Indeed, the interdisciplinary study (cognitive neuroscience, neuropsychology, aesthetics, theatrical studies and cognitive psychology) that will be described in this chapter will highlight the principle of emergentist adhesion (*émergentiste adhesion*[1]) and the fundamental link between

[1]The *emergentist adhesion* is an additional degree to the "simple adhesion" which is well known in psychology. The *emergentist adhesion* is a neuropsychological and cognitive phenomenon, which gets activated following an important commitment from a subject adhering to a new reality (induced for example by a stage director, a political, or a religious authority), brought to the foreground and becoming the whole reality of the adhering-subject, for varying duration and strength.

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this principle and the stage director's will "to show beyond the visible" and to emotionally affect the spectator.

The representation perceived by the spectators activates specific cognitive processes leading them to perceive a character in a fictional universe while they see a comedian on stage. The strength of the scenic images, built by the director and the team of the show, occasionally produce in the spectators an adhesion to the fiction, sometimes in parallel of their "proximate reality" or sometimes even replacing their direct perception, in any case often emotionally affecting the spectators.

The evocative (metaphoric, empathic) power of these images and scenic constructions drives the spectators to bring to the foreground of their mind the theatrical reality, which acquires some kind of full existential autonomy. In other words, if the *percept* is lower than the *mental object*, the subject adheres to *one* representation of *one* reality built via the emergentist adhesion.[2]

Which neurocognitive processes underlie the build-up of the subject's adhesion to a representation? Answering this question may help us to better understand the fascination that certain images have on a spectator's mind.

Cognitive Processes

The adhesion to *one* reality is the fundamental condition for the emergence of this reality. Without adhesion, no reality—whatever the reality—can emerge. This naturally applies to the field of aesthetics. Obviously, the absence of the spectator's adhesion could only lead to a laborious display of techniques. This sometimes happens! Other times, however, a performance can "take us away" and deeply move us.

The phenomenon of a subject adhering to an object, whether conscious or not, is a meta-phenomenon encompassing all the phenomena involved in the emergence of a reality.

The *principle of emergentist adhesion* (PEmA) can better be approached when isolating the adhesion phenomenon. For this, theatre is an excellent test tube. Indeed, this type of reality, confined in space and time, will come into existence thanks to the adhesion of a subject (the spectator). Performances that are proposed to the spectator temporarily acquire a real emotional and psychoactive load.

From a pure introspective point of view, when a spectator sees the performance of a drama, her/his mind generates representations, which do not reflect the reality of the stage but the intentions of the author, stage director and actors. The adhesion to the theatrical artwork and its images would call for the "Theory of Mind", i.e., the ability to explain and/or predict one's own actions and those of others.

Another psychic construction, involved when seeing a drama performance, concerns the empathy allowing the subject to adopt others' point of view.[3] According to the special circumstances of attending to the performance of a

[2]Percept $\leq$ mental object (mental representation): *Emergentist adhesion to a representation*.

[3]See Batson et al. (1997).

dramatic work, the spectator is prone to understand and even share the physical or emotional experience of the character and not that of the actor. The character acted by the performer sometimes acquires, via the emergentist adhesion, an existence that is above the simple fiction. This could be related to a complex cognitive mechanism, which allows the spectator to see beyond the physical reality and to adhere to the one proposed by the theatre performance.

A final cognitive process, which could be involved in the adhesion to the images and reality suggested by the play, relates to the treatment of metaphors, which are rhetorical artifices through which meaning of words slides towards a new sense. In *The Poetics*,[4] Aristotle considered that metaphor was fundamental in the theatrical art. Stage set and actors' actions, based on the text and its interpretation, intend to represent a reality other than the one resulting from real sensory inferences. This is the case for classics and for contemporaries, for medieval theatre and for Calderon de la Barca. Thus, when the percept is inferior or equal to in the mental images built in the spectator's mind, the *emergentist adhesion* to the fictitious reality can really start.

Such past, current and future works are offering new research perspectives that are particularly relevant for cognitive science and neuropsychology, in various domains such as knowledge transmission (educational staged setting), health (therapeutical staged setting) or else defence and intelligence.[5]

Neural Correlates

To highlight the neuronal and physiological correlates of the emergentist adhesion and better understand the processes leading to the emergence of the reality carried by fictional representations juxtaposed to the reality of the perceiving subject, we realized an interdisciplinary experiment[6] (neuropsychology, cognitive neuroscience, and theatrical studies). This experience was introduced and led by the author, Yannick Bressan, managed from a medical point of view by the neurologist Marie-Noëlle Metz-Lutz and performed under the technical control of Hélène Otzenberger, at the civil hospital of Strasbourg (Laboratory of Imaging and Cognitive Neurosciences, CNRS) with the cooperation of the National Theatre of Strasbourg.

The success of the experiment crucially depended on the integration of the technical and of the artistic devices into the same protocol (Fig. 1). The stage director had to deal with the heavy medical environment of the fMRI scanner[7] and

[4] Aristote, *Poétique,* 21, 1457b 7–8, trad. fr. J. Lallot et R. Dupont-Roc, Seuil, 1980.

[5] For details and applications of "mental images" in the field of Intelligence, see Bressan (2015).

[6] See for more details of this experiment Bressan (2013) and all the technical and scientific details in Metz-Lutz (2010).

[7] Functional Magnetic Resonance Image. Neuroimaging technique using nuclear magnetic resonance (MRI) and allowing the mapping of functional activities of the brain. The principle consists in measuring the oxygenation of blood (oxyhemoglobin/deoxyhemoglobin ratio), which locally increases in brain areas activated by a cognitive task.

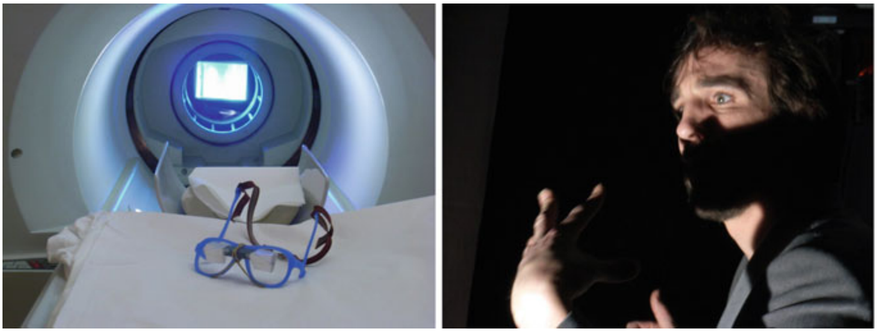

Fig. 1 *Left* MRI scanner and internal broadcasting dispositive. *Right* An image of a theatrical event selected from the play

integrate it into the performance, in order to blur the border between reality and fiction. A theatrical design (black walls, lights, sounds) was thus created within the laboratory. For each of the 20 subjects/spectators, representations of *Onysos le furieux*, of Laurent Gaudé, were broadcasted in real time in the fMRI scanner situated in the adjacent room. During the 14-mins performance the experimenters acquired both neuroimaging (with the fMRI) and neurophysiological (with an electrocardiogram—ECG) data, according to a precise experimental protocol.

In neuropsychology, the researcher can't avoid exploring the relationship between the subject and her/his environment, especially when the researcher intends to study how a subject perceptually integrates her/his environment (by exploring the relationship between the "seen"/physical reality and the "perceived"/mental images). Thus, all subjects had to answer a post-experimental questionnaire followed by an interview with a psychologist, to evaluate their subjective feelings and thoughts concerning the performance. Such evaluations were compared to objective measures (fMRI and ECG).

What are the psychocognitive and neurological processes allowing the spectator to perceive Onysos within a fictitious world while seeing in reality a comedian on a theatre stage? The subject/spectator knows perfectly well that this world is only (re) presented. Nevertheless, she/he believes and temporarily adheres to the fiction as if it was true. This seems to be confirmed by the physiological and neurological data.

To be rigorous, let's not to underestimate the importance of the "first-person methodology" implemented during this experiment and in following approaches, based on the subject filling-up the questionnaire at the end of the performance: "the reinvestment of the phenomenological approach, inherited from Husserl, in a "neurophenomenological approach" places the author well within the first-person methodology.[8]"

The fundamental questions of our study could be defined as follows. First, do theatrical events (text or stage direction), which is a priori defined by the

[8]See Depraz (2001).

Table 1 Brain regions significantly activated by theatrical events

Brain regions activated by theatrical events	Cluster size	Z	Co-ordinates (mm)		
			x	y	z
R middle temporal gyrus (BA 21)	3352	5.20	**50**	**−28**	**−12**
R superior temporal gyrus (BA 22)		5.09	**64**	**−54**	**12**
R supramarginal gyrus (BA 40)		4.88	**62**	**−42**	**26**
L inferior frontal gyrus (BA 47)	1235	4.97	**−52**	**34**	**−10**
L inferior frontal gyrus (BA 47)		4.33	−26	24	−22
L inferior frontal gyrus (BA 47)		4.10	−48	20	2
L supramarginal gyrus (BA 40)	641	4.51	**−62**	**−46**	**30**
L inferior temporal gyrus (BA 37)		4.06	**−58**	**−66**	**2**
L superior temporal gyrus (BA 39)		4.01	−62	−56	24
R caudate tail	219	3.77	34	−16	−8
R putamen		3.65	30	−20	2
R claustrum		3.56	32	4	−2

Activation in reported brain regions was significant at $p < 0.001$ uncorrected at the level of voxel. It was significant at $p < 0.0001$ (except for the caudate cluster, $p < 0.005$) after correction for multiple comparisons at the cluster level. *L* left; *R* right; *BA* Brodmann's area; *Z* statistics at the voxel level; *x*, *y*, *z* MNI coordinates of the local maxima of the clusters. The anatomical labels of the activation foci were obtained using the Automated Talairach atlas labeling system (Lancaster et al. 2000). Coordinated in bold were used as the center of 5 mm-spheres for the ROI (Region Of Interest) analysis. The significant statements are bold

experimenters, coincide with a posteriori (first-person) statements, reflecting how they appear to the subject? Second, when such matching occurs, does it trigger (probably unconscious) physiological (recorded by the ECG) and neurological (recorded the fMRI) events? In other words, is there a correlation between, on the one side, the events that are defined both a priori (by the text and stage direction) and a posteriori (by the first-person statement) and, on the other side, the physiological and neurological data?

The results indicate a positive answer to both questions. First, theatrical events as reported by the spectators largely co-occurred with theatrical events as defined by the text or the stage director. Second, such theatrical events were associated with activation in specific brain areas when compared to "baseline" intervals without predetermined theatrical events (see in Table 1 results for the Region Of Interest selected based on their activation, in previous studies, related to theory of mind, empathy, metaphor and story processing). Finally and importantly, there was a significant correlation between the individual a priori and a posteriori events' matching and the activity in a subset of these cortical areas (see Fig. 2).

It is now possible to assert what was only an intuition so far: the more the subject/spectator adheres to the theatrical reality (i.e., the higher the matching between a priori and a posteriori events), the higher the physiological and neurological responses to such "events". Thus, the question of the power of the stage director on the spectator is legitimate. The choices of the stage director have a clear impact on the cognition of the spectator!

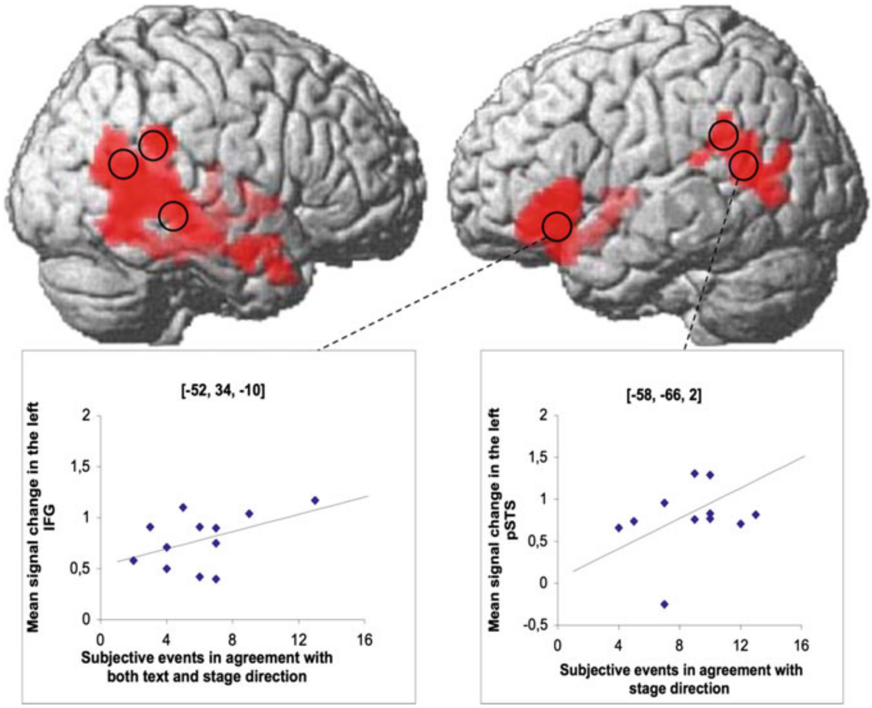

Fig. 2 *Top* Brain areas (*in red*) with increased BOLD signal for theatrical events, compared to non-theatrical events. The activated clusters are significant at the $p < 0.0001$ level, corrected (see Table 1). *Bottom* Significant correlation between the number of subjective events in agreement with both text and stage direction and the activation within the *left* anterior inferior frontal gyrus (IFG, *left*) and the *left* posterior superior temporal sulcus (pSTS, *right*)

Surprise!

The experimenters made another surprising observation. They noticed that the neurological (brain activation) and physiological (cardiac activity) states induced by the theatrical events were similar to the ones commonly observed during hypnosis. This result offers novel hypotheses to explain the phenomenon of *emergentist adhesion* and the dissociation between current mental perception and immediate physical experience.

The following citations might guide us in understanding what *emergentist adhesion* and hypnosis might have in common:

> The adhesion is inherent to the theatre, because the theatre tries to make the spectator adhere, and the spectator is allowing the theatre to delude him: he comes to be deluded. The theatre is maybe the ideal experimental situation where we introduce, into perception, a falsified, determined, and staged perception.

> It is the principle of any speech: introduce into the thought of someone else a movement of perception.[9]

To be more precise, our study showed that theatrical events induced a reduction of brain activity in an area named precuneus, known to be involved in various cognitive processes including self-awareness, and a correlated decrease of the cardiac variability. In the scientific literature, such phenomena have been associated to specific cognitive states. First, the decrease of the variability of the heart rhythm denotes a dominant vagal influence in the sympathetic/parasympathetic balance of the autonomous nervous system. Reliably observed during the relaxation associated to hypnosis, it is considered the most reliable measure of the depth of the hypnotic state.[10] Second, the de-activation of median parts of the brain has been observed during altered states of consciousness such as vegetative,[11] anesthetized[12] and hypnotic[13] states.

Could the *emergentist adhesion* to theatrical fiction be also a particular state of consciousness induced by the stage director?

The variation of the heart rhythm and deactivation of the precuneus suggest that Hamlet could emerge in the spectator's mind, while the spectator actually saw a comedian on stage, when reaching a "disinvestment of oneself" state close to the hypnotic state. This "disinvestment of oneself", within the framework of a theatre performance, is stimulated upstream by the intervention of the stage director on the representation. In consequence, the subject/spectator sees, at key moments of the performance, the object of the representation replacing the immediate perception supplied by direct sensory stimulation. Thus, the images perceived by the subject (e.g., the character) prevail on the images actually seen (e.g., the comedian). This idea is summarized in a simple, already-evoked, formula:

Percept $\leq$ mental object (mental representation): *Emergentist adhesion* to a representation.

In other words, when the mental construction is superior or equal to the primary sensory perception (sight, smell, touch, hearing, taste), the subject adheres to a representation and brings it to the foreground as a specific reality.

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[9]Interview with M.N. Metz-Lutz, neurologist. The entire of the interview is published in Bressan (2008).

[10]See Diamond et al. (2008).

[11]See Laureys et al. (2004).

[12]See Fiset et al. (1999).

[13]See Faymonville et al. (2006).

Meta Phenomenon

This neuro-aesthetic study on the *principle of emergentist adhesion* applied to the theatre performance sketched new leads towards understanding the dynamics of neural and physiological activity subtending adhesion to an event. The aim of this work was not to map the "brain areas associated to adhesion", but rather to reveal the psycho-cognitive and neuro-anatomical dynamic modifications occurring when a subject adheres to a representation and when the represented fiction exceeds the concrete scenic elements (comedian, stage set, etc.)

It is undeniable that the adhesion is fundamental in the construction of the theatrical experience. Nevertheless, a fundamental question, which was raised at the beginning of the chapter, remains: does the adhesion of a subject to a reality condition the emergence and the existence of such reality or, on the contrary, is it the reality which condition the adhesion of the perceiving-subject?

This applied neuro-aesthetics experiment could potentially interest multiple fields: communication, education, medicine, aesthetics, philosophy, etc. Maybe our place, as human beings within *a* reality, is anchored, beyond the physical world, in the emergence of cognitive states from biological and neurobiological foundations. The cornerstone of our representational system could find its roots in the *principle of emergentist adhesion*. This phenomenon would be the smallest neuropsychological common denominator, some kind of "Higgs boson of the thought". From there will emerge and will be shaped in our mind the images among which we live our lives.

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Aesthetic Impact of Anthropomorphic Figures in Art: The Case of Facial Expressions

Amel Achour Benallegue, Jérôme Pelletier and Gwenaël Kaminski

Abstract The impact on beholders of anthropomorphic representations depicting facial expressions undoubtedly plays a prominent role in societies, given the special place granted to these images through space and time, and their cultural and social importance. Here, we investigate this impact in terms of the perceptual and cognitive mechanisms behind the aesthetic experience. Given that face processing is universal among humans, this is necessarily a cross-cultural issue, and we therefore chose to tackle it from an interdisciplinary perspective, reviewing the artistic, ethnographic, anthropological and cognitive literature on figuration and facial expression processing. This review was informed by the results of an experimental pilot study. Our findings shed light on the relationship between the three dimensions of the aesthetic experience (attention, emotion, and aesthetic judgement), and show that figures share a common property that modulates the aesthetic impact.

Keywords Figuration · Aesthetic experience · Empirical aesthetics · Cross-cultural study · Social agency · Cognitive approach

Anthropomorphic representations, especially facial expressions, have featured heavily in artwork throughout human history and civilization, in artefacts representing cultural, social or religious themes. Here, *anthropomorphic* refers to all figures that are human-like in their visual appearance. These representations are realistic or stylized figures or even items that make up a human figure when put together. It is our

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relationship with such artefacts that generates aesthetic experience. The special place these images occupy and the important role they have played (and indeed still play) in societies raise the issue of the aesthetic impact they have on beholders. We can observe the functions of ethnographic sculptures and masks in both social and religious or spiritual contexts. Similarly, anthropomorphic figuration is known to have had an impact across religious, cultural and social spheres (e.g., in religious rites, drama, portraiture, caricature) across Eastern and Western cultures. In contemporary society, facial expressions maintain their powerful impact through comics, animated figures and robots. These observations raise questions about the nature and relevance of the relationship between individuals and facial images, and how this relationship affects individuals' life in society. One of these questions is whether the aesthetic experience triggered by representations of facial expressions has any cross-cultural properties. The processing of human facial expressions is widely assumed to be universal. All humans use facial expressions to communicate, and react to them similarly in terms of perception and recognition. But what about facial expressions in artistic representations? What impact does the perception of such images have on beholders' aesthetic experience and their life in society?

We can surmise that the aesthetic relationship between beholders and representations of facial expressions relies on facial perception processes. In this respect, our aesthetic investigation would therefore benefit from research on facial perception from neuroanatomical/physiological, cognitive and evolutionary perspectives. First, at the anatomical level, faces are processed in dedicated brain regions. These specialized regions respond more strongly to faces than to any other stimuli (e.g., cars, birds, houses). At the physiological level, face processing elicits a specific waveform component (N170). Second, models have been developed to cognitively explain the process that occurs in these anatomical substrates. Some of them extend the stimuli to non-human faces. For instance, through mind modularity hypothesis, Sperber and Hirschfeld (2004) described how cultural artefacts featuring faces are processed by the face recognition module. More interestingly, they stated that their recurrence can be attributed to their effectiveness, the latter being "explained by the fact that they rely on and exploit a natural disposition" (Sperber and Hirschfeld 2004). Third, according to the theory of evolution, facial expressions are universal and inborn (Darwin 1872). They are processed very early on in human life. Their usefulness as warning signals in dangerous situations may have promoted the development of the facial expression recognition process. Faces also play a major role in embodiment behaviour. Recent studies have shown that the perception of emotional expressions is characterized by their embodiment via unconscious and spontaneous mirroring (Dimberg et al. 2011; Dimberg et al. 2000; Künecke et al. 2014; Likowski et al. 2012). This is reflected in facial-muscle reactions that are regarded as a feedback system for the experience of emotion (Dimberg 1990).

The aforementioned research can complement philosophical and anthropological approaches, thereby helping us understand the aesthetic impact of facial expression representations. Interestingly, some theories have a cognitive grounding, such as Schaeffer's work on the aesthetic experience (2015) or Gell's reflection on the agency of art (1998). These two contributions could be viewed as being connected to the cognitive fields of psychology and neuroscience. Together, they form a network of viewpoints from which anthropomorphic figuration (see Fig. 1) can be addressed. Drawing on this network, we undertook an original interdisciplinary and cross-cultural reflection on the aesthetic impact of anthropomorphic representations (see Fig. 2). This conceptual reflection was informed by an experimental pilot study inspired by experimental results in psychology and neuroscience. Before setting out our conceptual and experimental findings, we provide a review of the literature in the relevant disciplines.

Hereafter, facial expression representations are also referred to as figures, which in this chapter denote artifactual images depicting facial expressions. We also indicate the degree of realism compared with natural faces, using the terms mimetic face for close resemblance (e.g., in Western classical art) and face-like representation for distant resemblance (e.g., in ethnographic art).

The Expressiveness of Anthropomorphic Representations and Their Reception

Interest in anthropomorphic representations varies according to the society. In the following section, we provide a review of the different forms of anthropomorphic expressions and how they are addressed in the relevant domains.

Overview

Almost every culture has an anthropomorphic visual heritage (see Tables 1 and 2). Around the world, anthropomorphic representations are not only very common but also very important. Their importance is manifested in their social and cultural contexts. However, just like any visual material, they draw their relevance from the impact they have on the persons with whom they form a relationship.

One of the most relevant properties of anthropomorphic representations is their strong expressiveness, that is, the variations in their expression through the shapes that depict human attributes. This expressiveness can attract the attention of any individual in the world, as it reflects a recognizable configuration and a relevant clue for humans. This allows artworks to escape their own history. Ethnographic art certainly attests to the efficiency of expression through space and time. It has proved an inspiration for many modern Western artists. Giacometti, for instance, marvelled at the vividness of expression of Vanuatu's sculpture arts, despite their lack of mimesis (Charbonnier 2000). In prehistoric and ethnographic arts, most anthropomorphic representations are distorted. This means that their configuration does not match the human anatomy. The same distortion of figures can be observed in modern art, in both Western and Eastern creations. Consequently, the Vanuatu sculptures are not an oddity, as all ethnographic arts (and some modern artworks) seem to obey the same rules of expressiveness and

shape economy.[1] By contrast, most human representations in classical Western and some Eastern traditional arts are realistic. That means that the appearance of the figures is highly reminiscent of the human anatomy.

The earliest traces of anthropomorphic representations date back to prehistory. The European Venus statuettes from the Palaeolithic Age (Vialou 1996) and the Saharan rock paintings (Muzzolini 1989) from the Neolithic Age are early examples of human figure representations.[2] Anthropomorphic representations are extremely prevalent in the ethnographic arts. Their functions range from magical-religious purposes to ornamental and everyday uses (e.g., Papuan hooks

[1]There are some exceptions involving realism and shape economy. Boas (1927) highlighted some very realistic representations that conflict with the main style of the region. These representations have specific functions in society, such as illusion in drama and caricature (e.g., Kwakiutl tribes) (Boas 2003).

[2]Some of them feature discernible faces.

◀ **Fig. 1** Examples of anthropomorphic representations ranked according to degree of realism and intensity of expression. (*1*) Luohan, 10–13th century, from China. Three-colors glazed pottery. H. 118 cm. (*2*) Mushaku by Unkei, around 1208–1212. Painted wood. H. 1.94 m. Hokuendō, Kōfukuji, Nara. (*3*) Mochica Vase portrait with a stirrup handle. (*4*) Gustave Courbet. *The Artist Portrait*, called the *Desperate Man*, 1841. Oil on canvas. 45 × 54 cm. Private collection. (*5*) Nicolas Poussin. Self-portrait, 1630. Red chalk. 25.6 × 19.7 cm. London, The British Museum. (*6*) Caravaggio. *A Boy Bitten by a Lizard*, 1593-1594. Oil on canvas. 65.8 × 39.6 cm. Florence, Longhi collection. (*7*) Franz Xaver Messerschmidt. *The Hangman*, around 1770. Alabaster. H. 38 cm. Vienna, Belvedere Gallery. (*8*) *Male Bust With Open Mouth*, 17th century. Guercino. Brown ink, brown wash, dip pen, 21.6 × 21 cm. Paris, Louvre Museum, Department of Graphic Arts. (*9*) Egon Schiele. *Male Nude* (self-portrait)—detail, 1910. Pencil, watercolor and tempera on paper. 55.7 × 36.8 cm. Vienna, Graphische Sammlung Albertina. (*10*) Jean-Michel Basquiat. *Self-Portrait As a Heel*, 1982. Private collection. (*11*) Niō by Unkei and Kaikei, dated at 1203. Painted wood. H. 8.38 m. The Great Southern Gate of Tōdaiji, Nara. (*12*) Funeral urn, or Zemi. Sierra de Bahoruco, Santo Domingo. Wood. H. 96 cm. D. 30 cm. Garcia Arevalo fondation, Santo Domingo. (*13*) Tupilak figure in walrus ivory by David Nakinge. Ammassalik, East Greelandic Eskimo, 1963. (*14*) Detail of a bowl with two figure supports. Middle/Late 18th Century. Hawaiian Islands. Wood, pearl shell, boars' tusk L. 46.5 cm. London. (*15*) Manga character. Fumiko Mikami. (*16*) Main character of the short film *Origins*. Directed by Robert Showalter, 2011. (*17*) MIT's Nexi MDS robot. (*18*) Mask-portrait in wood with fur pieces. Haïda, around 1880. (*19*) Civil servant (China), 7th century. Terracotta with traces of polychromy. H. 77 cm. Paris, Guimet National Museum of Asian Arts. (*20*) Human mask with incised design. Middle formative period. Jade. 16 × 15.2 cm. RÍo Pesquero, Veracruz. Museo de Antropologia de Salapa, Universidad Veracruzana. (*21*) Bartholomeus Van Helst. *Woman With Book*, 1665. Oil on canvas. (*22*) Jean-Louis Voilles (1744- around 1796). *Portrait of Michel Perrot*. (*23*) Vincent van Gogh. *Portrait of Armand Roulin*, 1888. Oil on canvas. 92.5 × 73 cm. Van Gogh Museum. (*24*) Greece. Keros-Syros culture. Ancient Cycladic II, around 2500 BC. H. 25.5 cm. (*25*) Giuseppe Arcimboldo. *The Vegetable Man*, around 1590. Oil on wood. 35.8 × 24.2 cm. Cremona, Museo Civico Ala Ponzone. (*26*) Giuseppe Arcimboldo. *Reversible Head With Fruit Basket*, 1590. Oil on canvas. 55.9 × 41.6 cm. New York, French and Company. (*27*) Metal mask. Aron Arabai. Temne, Sierra Leone. Brass. H. (without bells) 29 cm. (*28*) Kalunga figurine. Zaïre. Wood, pigments, raffia. H. 27 cm. (*29*) Kachina mask. Hopi, Arizona, 19th century. H. 26 cm. L. 34 cm. Berlin Ethnological Museum. (*30*) Detail from a manga board. Tukiji Iwata. Eyrolles Editions. (*31*) A robot unveiled at the International Conference of Humanoid Robotics 2014, Madrid

for food, Peruvian jars and kachina dolls for children's play and education; see Images 3 and 29 in Fig. 1). Table 1 provides a nonexhaustive description of different cultures and their ethnographic arts.

In Asia and Europe, figuration is more homogeneous than it is in ethnographic art. From India to Japan, Asian art was deeply influenced by the Buddhist faith. A great many anthropomorphic figures therefore depict Buddha and his disciples expressing all kinds of Buddhist teaching, although it is still possible to find Hindu figures and secular representations (see Table 2). Mention can be made of Kuniyoshi's paintings.[3]

From Ancient Greek art to 19th-century academic art, through Roman and Christian iconography (see Table 2), European art adhered to the principle of

[3]Especially when characters are composed from several naked bodies similarly to Arcimboldo's portraits.

mimesis (Giovannangeli 2002), which leaves few opportunities for twisting figures in the way they are in ethnographic art. In the wake of this long tradition of mimesis, however, modern artists claimed their freedom and finally introduced twisted figures into Western art. This brought new ways of expression to Western culture. That said, there were some unrealistic representations during the classical period, too, such as Daumier's caricatures and Arcimboldo's portraits[4] (see Images 25 and 26 in Fig. 1).

In contemporary society, artistic currents are increasingly being shared among different cultures. Comics, manga and digital animated characters (see Images 15 and 16 in Fig. 1) belong to a globalized society. They all involve anthropomorphic representations that use a very expressive facial code. The features of these representations are fairly exaggerated, both in the dynamic and static versions. Anthropomorphic figures have even reached the world of industry, now that humanoid robots are starting to be manufactured (Grimaud and Vidal 2012). These robots were initially designed to perform tasks that used to be carried out by humans, which is why they were given a human shape, and because they are liable to be used in a social context, many of them exhibit human expressions, mainly through faces (see Image 17 in Fig. 1). For instance, Baxter the robot uses facial expressions (via a screen) to communicate with its coworkers in an industrial environment (Fitzgerald 2013).

Expressiveness Through Faces

In the course of the present review of anthropomorphic figures in different cultures, we were struck by the dominance of faces. The face is the most expressive unit of the human body. It is the receptacle of expressions, and in the arts it is independent of physical constraints. It can provide improbable and varied expressions, and allow for distortions and unnatural twists, thus exploring all forms of facial expressiveness, as exemplified by masks in ethnographic art (Frobenius 1995; Levi-Strauss 1979) and Asian theatre (Lyons et al. 2000). The depiction of faces in sculptures and paintings in ethnographic, modern and contemporary arts is rarely governed by anatomical constraints. The expressiveness of these mimetic faces (i.e., realistic figures) and face-like representations (i.e., unrealistic figures) mainly arises from the configuration of their facial features. This configuration depicts an emotional state that can be visually conveyed to beholders. In face-like representations, the shapes of the facial features are simplified, but without losing their intensified expression: large circles for wide-open eyes expressing surprise and astonishment; small holes or dots for an insignificant or neutral attitude; skewed notches instead of eyebrows

[4]Assembled by brushstrokes from collections of fruit and vegetables, animals, and other objects. Even though these portraits were built from nonphysiognomic shapes, they are fully recognizable as faces.

Table 1 The description of different ethnographic figurative arts

Regions/period		Main cultures	Antrhropomorpic representations	Function
Prehistoric art[a]		Palaeolithic, Neolithic	Venus figurines (e.g. Lady of Brassempouy in Europe). Rock paintings (e.g. round heads and anthropomorphic groups in the Sahara)	Unknown
Ethnographic art	Mesoamerica[b]	Maya, Aztec, Olmec, Costa Rica, Teotihuacan,etc.	Holocaust painting scenes. Effigies of the gods. Death masks. Colossal heads. Statuettes and baby figurines	Idealization of dread and fear emotions
	West Indies[c]	Arawaks, Other Dominican people, etc.	Apotropaic amulets. Funeral urns (Zemi). Idol figurines. Dish ornamentations	Magic. Funerary shrine. Veneration. Decoration
	South America[d]	Mochica, Nazca, Chimu Quimbaya, Tairona, Tolima, Brezil, etc.	Facial figures sculpted in gold (e.g. offering knives), or decorating on jars, dishes and fabrics. Funeral urns	Adornment. Funerary shrine
	North America[e]	Haïda, Yakutat-Tlingit, Kodiak, Kwakiutl, Hopi, Zuni, etc.	Masks (e.g. transformation masks or kachina). Frontlets. Dolls (Kachina)	Spiritual worship. Fertility rites. Children's play and education
	Arctic lands[f]	Okvik, Ipiutak, Yup'ik, Inuit, Kodiak, etc.	Wooden masks. Stone and walrus tusk sculptures (e.g. tupilak)	Magical, spiritual, religious and worship contexts
	Oceania[g]	Baining, Kanak, New Ireland, Vanuatu, Hawaii, Australian aborigines, etc.	Figures on bowls (e.g. Hawaiian bowl with two figures). Hooks. Feather sculptures. Masks (e.g. kavat)	Adornment. Ceremonies and shamans' trance process. Effigies of the gods. Ancestor worship
	Africa[h]	Bambara, Grebo, Kplekple bla, Wee, Mbole, Ngindo, Venda, Akuaba, Nkonde, Kalunga, Mende, etc.	Masks. Statues and sculpture. Dolls. Reliquary figures. Statuettes and figurines	Religious rites. Worship ceremonies. Protection. Ancestor worship. Initiation ceremonies
	South East Asia[i]	Bahnar, Jarai, Borneo, Iban, Kayan, Mentawai, Ngada, Lio, etc.	Funerary sculptures. Ancestor figures	Abandoning the grave ceremony. Ancestor worship

[a]See Gauthier et al. (1996), Muzzolini (1989), Vialou (1996), Vialou (2006). [b]See Duverger (1999), Grube et al. (2000), Paz et al. (1992), Restellini et al. (2012). [c]See Geoffroy-Schneiter (2006), Paz et al. (1992). [d]See Cavatrunci et al. (2005), Galeries Nationales du Grand Palais (Paris), Réunion des Musées Nationaux (France), Museo del Oro (Bogot) (2000), Maurer and Hennen (2002), Paz et al. (1992). [e]See Feest (1994), Geoffroy-Schneiter (2006). [f]See Carpenter and Mooney (2008), Geoffroy-Schneiter (2006). [g]See Caruana (1994), Gnecchi-Ruscone (2011), Gunn and Peltier (2007), Hooper (2008), Kleinert and Neale (2000), Musée Territorial de Nouvelle-Calédonie (Nouméa) and Musée National des Arts d'Afrique et D'Océanie (Paris) (1990), Thomas (1995). [h]See Bacquart (2010), Falgayrettes-Leveau et al. (2005), Falgayrettes-Leveau and Stéphan (1993), Frobenius (1995), Hahner-Herzog et al. (2000). [i]See van Doanh (1991)

Table 2 The description of different figurative arts and artefacts in Western, Eastern and contemporary cultures

Regions/period		Main cultures/areas/trends	Anthropomorphic representations	Function
Eastern art	Far East[a]	China, Japan, Korea	Buddha and his disciples.Gods and daemons in paintings and sculptures (e.g. Nio of Nara). Ornamental plates. Figures of emperors and officials. Theatrical paintings and masks (e.g. kabuki painting, noh masks)	Religious purposes. Protection from evil spirits. Theatre. Political effigies. Ornament
	South Asia[b]	India, Pakistan, Nepal, Vietnam, Cambodge, etc.	Hindu god effigies. Buddha figures. Sculptures of monarchs	Religious purposes. Political effigies
	Middle East[c]	Ancient Egypt, Mesopotamia, Persia, etc.	Royal busts. Commemorative and funerary steles. Idols of the gods. Miniatures	Political effigies. Memory. Religious purposes. Mythology. Illustration
Western art	Ancient art[d]	Greek, Etruscan Roman.	Mythological scenes in painting and sculpture. funerary urns. Scenes on ceramics. Portraits. Emperor effigies	Mythology. Religious purposes. Memory. Political effigies
	Mediaeval and Classical art[e]	Western art trends from the Middle Ages to Impressionism.	Christian iconography. Biblical scenes in painting and sculpture (e.g. Michelangelo*'s David*). Portraits. Mythological subjects. Ideal figures. Epic and historical scenes (e.g. Delacroix). Genre views. Real figures. Arcimboldo. Caricature. Masks	Religious purposes. Ornament and secularuse. Commemoration. Support for monarchs and high society. Art. Jokes and criticism. Carnival
	Modern[f]	Western art trends since Expressionism	Nonrealistic portraits and genre art (e.g. Egon Schiele's *Male Nude*). Surrealist figures	Art. Avant-garde and renewal in art. Political purposes

(continued)

Table 2 (continued)

Regions/period	Main cultures/areas/trends	Anthropomorphic representations	Function
Global and technological productions[g]	International	Photography. Cinema. Cartoons. Animation. Manga. Comics. Assemblages. Robots (e.g. MIT's Nexi MDS robot)	Art. Communication. Entertainment. Social machine-human interaction

[a]See Comentale (2010), Elisseeff (2013), Fahr-Becker (2006), Kidder (1985), Murase (1996), Pacquement (2003), Shimizu (1997), Tsao and Rey (2013), Tsuji (1992). [b]See Béguin (1987, 2009), Chayet (1994), Fisher (1995), National Museum of India (New Delhi) (2007), Rawson (1955). [c]See Caubet and Bernus-Taylor (1991), Robin and Vogt (1997). [d]See Holtzmann (1995). [e]See Beauvais (2000), Beyer (2003), Cariel (2012), Ferino Pagden (2007), Grabar (1979), Guédron (2011), Heck (1996), Revelard and Kostadinova (1997), Wambrechies and Raymond (2011). [f]See Beyer (2003), Dube (1983), Moulin (1999). [g]See Denis (2011), Grimaud and Vidal (2012), Sigal (2007)

to convey anger; a half-moon serving as a mouth to signify joy or sadness, depending on its orientation, and so on. These contortions, described as a shift from human to inhuman by Lacoue-Labarthe (Lacoue-Labarthe et al. 2008), perfectly reflect human expressiveness. Twisting facial features in an expressive code places these images in the superstimulus category (Sperber and Hirschfeld 2004). These are stimuli with exaggerated forms, compared with natural stimuli. In this sense, even realistic figures belong to the superstimulus category, in that they highlight the natural expression either by exaggerating the expression itself or by using different types of illusion, such as contour and colour in painting. The frown on the forehead of Michelangelo's *David* is a great exaggeration of the natural frown, despite the sculpture's realistic aspect. We can assume that some superstimuli suggest a stronger expression when they arise from a shape economy process, as in the ethnographic arts. Mention can be made, for example, of Giacometti's astonishment that the creator of the Vanuatu sculptures had given them a gaze but no eyes (Charbonnier 2000). Superstimuli arise not only from an exaggeration of the shapes, whether simplified or not, but also from the technique of freezing the dynamics of the emotional expression. In a natural context, facial expressions are expressed across time, through the activity of the facial anatomy, and representing expressions in motionless images requires considerable effort to substitute these variations in time. The critical instants of the movement must be targeted, in order to properly summarize the whole emotion. Gombrich put it this way:

> "Art has to compensate for the loss of the time dimension by concentrating all required information into one arrested image" (Gombrich 1960).

Superstimuli enhance the activity of the sensory areas of the brain so that the onlooker's response is stronger than it would be to mere natural stimuli. This is what Ramachandran described as the "peak shift effect" (Ramachandran and Hirstein

1999). He considered this effect to be one of the principles of artistic experience. We would expect the peak shift effect to be particularly great for anthropomorphic representations featuring facial expressions, given that natural facial expressions already attract human attention. Expressive anthropomorphic figures should therefore play a special role among artworks. Understanding the expressiveness of these figures obviously leads us to investigate human attention mechanisms for natural faces and their representations. This can be addressed via face processing mechanisms in psychology and neuroscience, especially now that we are beginning to understand brain processes better. Fortunately, the perception and recognition of faces and their expressions have been extensively studied in the cognitive sciences, offering us an insight into the attentional and emotional reactions to facial expressions in art that constitute the aesthetic experience (see Sect. 2).

From Face Perception to Anthropomorphic Figure Reception

Face categorization is one of the first processes we master in infancy. Newborns are more attracted to faces and face-like objects than to other familiar objects (Bruyer 1983). Across societies, the attraction to faces (natural or not) may arise from this early stage of human life. Early models of face perception, exemplified by Bruce and Young's (Bruce and Young 1986) influential model, present face recognition as a series of stages that are accessed one after the other. This model posits that there are separate mechanisms for the recognition of facial identity and the recognition of facial expressions of emotion. In other words, certain component processes of face perception are functionally independent of each other, or more specifically, the processing of one type of social information from faces, such as age or ethnic group, is not influenced by the processing of a different type of social information, such as emotional expression. This descriptive model does not make any specific proposals about the neural location of these processes. The organization of neural systems for face perception is mediated by at least three main cortical regions in the human brain whose activity is greater for faces than for other, nonface objects. These face-selective regions are the fusiform face area (FFA), the occipital face area (OFA), and the posterior superior temporal sulcus (STS). Inspired by Bruce and Young's model, Haxby' more recent model of face processing (Haxby et al. 2000) situates the various components of face processing in specific neural regions. Moreover, electrophysiological studies have shown that the speed of face processing is highly specific. Faces trigger a characteristic brainwave: the N170.[5] The activity of this brainwave increases 170 ms after stimulus presentation if it is a face. If natural faces benefit from special processing, presumably their representations in art do, too. Some research has already shed light on this area. For example, Sagiv and Bentin (Sagiv and Bentin 2001) showed that realistic portraits, sketches and

[5]The N170 is a component of the event-related potential associated with face perception. It reflects the operation of a neural mechanism tuned to detect human faces (Bentin et al. 1996).

schematic faces increase the N170 just as much as natural faces. A difference between natural faces and schematic ones was only observed when the latter were displayed upside down.[6] Sagiv and Bentin's study yielded valuable information about the perception of some kinds of face representations. Various face-like objects have also been the subject of studies investigating perception mechanisms. The identification of faces in objects that do not represent faces but whose configurations resemble faces has been shown to be initiated very early on in face processing, and is not simply a late cognitive interpretation (Hadjikhani et al. 2009). The N170 component is markedly increased by the perception of face-like objects even if they are just everyday items with mere hints of a face (Churches et al. 2009). Face-like objects activate the brain areas in charge of face recognition. This means that our visual system is geared to rapidly interpreting stimuli as faces even if there are only minimal clues (Hadjikhani et al. 2009). Our predisposition to perceiving faces in such physiognomically poor objects suggests that all face representations in anthropomorphic figures are perceived of and recognized as belonging to a face category. For example experiments investigating the identification of Arcimboldo's characters (see Images 25 and 26 in Fig. 1) have shown that when these are displayed upright, they induce the same brain activation in adults as natural faces do (Jeffreys and Tukmachi 1992; Rossion and Jacques 2008).

This research on the perception of face-like objects has paved the way for addressing the issue of face representations in art. In the light of previous studies of face-like objects, we based our aesthetic-impact investigation on universal face processing, reasoning that this common process might mean that individuals' aesthetic relationship with anthropomorphic figures has an invariable property across different cultures.

According to the mind modularity hypothesis, faces are recognized by specific modules. From a functional point of view, the face recognition module is depicted as nested domains: an *actual domain* that includes both a *proper domain* and a *cultural domain* (Sperber and Hirschfeld 2004). Natural faces fall within the *proper domain*, meaning that they are the inputs to which the module is dedicated. By contrast, the artificial faces, including artistic representations that civilization has generated throughout the human evolution, belong to the *cultural domain*. Cultural faces fall therefore within the *actual domain*, which can be attested to by the enhancement of the N170 by artistic portraits, sketches and face-like objects. Some representations, however, such as faces wearing make-up (artistic make-up), can create ambiguity (Sperber and Hirschfeld 2004). These are first and foremost natural faces, with the make-up being applied later to exaggerate their expressions. Mention can be made of the faces of Maori people that are made-up or tattooed for the Haka dance. For Sperber and Hirschfeld (2004), if cultural artefacts featuring faces are so successful, it is because they rely on and exploit a natural disposition. They describe them as superstimuli, for unlike natural faces, they often exaggerate the important features.

[6]This test, called the inverted effect, is used to probe observers' face perception expertise.

This is especially relevant when the artefacts depict facial expressions that convey an emotion.

Facial expressions are processed partly by early perceptual processes, partly by processes at a higher conceptual level (Adolphs 2002). Thus, when it comes to recognizing an emotion in a facial expression, primary emotion categories are formed by perceptual mechanisms relying solely on the geometric properties of the stimulus. These are then refined by associated knowledge. This means that our past experience of the world enables us to guess the intention of the person expressing the emotion - in other words, the actions that the person is likely to perform (e.g., an expression of fear may trigger a scream or an escape) (Adolphs 2002). The associated knowledge (that referred to conceptual level) of facial expression processing mainly concerns the words used to identify the emotion and knowledge of the events that elicit the emotion, which differ between cultures. However, despite these differences in cultural knowledge that Ekman refers to, facial expressions are universal for evolutionary reasons. Ekman himself puts forward two arguments in favour of this (Ekman 1999): (1) The connection that can be established between one particular facial expression and one specific emotion; and (2) the transmission of important information about the person is producing the expression. Some facial expressions and emotions may be universally perceived, such as the facial expressions of threat that were studied in Aronoff's experiments (Aronoff et al. 1988). Several masks from 16 different cultures were compared with drawings made by American students. The facial features making up the threatening expression were found in both the students' drawings and the different masks. Whether emotional facial expressions are universal or not, their cultural relevance is universally acknowledged, and their impact is similarly cross-cultural, in terms of cognitive and perceptual mechanisms. Only their meaning and their interpretation, which come later, are reliant on the cultural context. The geometric perception of facial expressions and their associated knowledge may operate similarly for anthropomorphic representations. If so, the aesthetic relationship, insofar as it is a sensory one, is universally achieved at the perceptual stage, and involves the cultural background in the later conceptual stage.

The perception and recognition of facial expressions also take place via the simulation mechanism. This mechanism does not involve representations of someone else. Rather, it involves representations of ourselves simulating the other (Adolphs 2002). In other words, the purpose of this mechanism is to reproduce, in the body of the observer, the experience of the person producing the facial expressions—in short, an embodiment of these expressions. Simulation is therefore a kind of imitation, where the motor representations underlying the observed expression are guessed at and then reproduced (Adolphs 2002). The simulation mechanism places the observer in a situation of actively interpreting the perceived scene in terms of motor reactions, which rely on muscular configurations in natural bodies. There is plenty of evidence in favour of this imitation activity, or more precisely this mimicry (Künecke et al. 2014; Likowski et al. 2012; McIntosh 2006; Sato et al. 2008). For instance, Dimberg showed that individuals have similar muscle reactions to the facial expressions they observe (Dimberg 1982; Dimberg

1990; Dimberg et al. 2011). We can assume that motor representations are easy to detect when facial expressions are natural. As detection probably relies on the configuration of physiognomic features, we can surmise that mimetic faces trigger the simulation mechanism in the same way that natural stimuli do. This may explain the empathy felt as part of the aesthetic experience of artistic images, as illustrated by Freedberg and Gallese (2007). Simulation may even occur when representations are devoid of physiognomic clues, as face-like objects also trigger an increase in N170, and must therefore be perceived of as natural faces. Simply recognizing a facial expression may make it easier to estimate the corresponding motor representation. Empathy may therefore be extended to nonrealistic figures in the aesthetic experience.

The aforementioned studies tell us a great deal about some types of anthropomorphic figure processing. They were not, however, conducted with a view to answering aesthetic or artistic questions. On the contrary, they focused on unravelling perceptual and cognitive mechanisms in the human brain. But what about investigations into anthropomorphic figures in the humanities?

Facial Expressions in Artistic, Historical and Ethnographic Investigations

In art, facial expressions have been depicted using a variety of techniques (painting, sculpture, animation, etc.), in different ages and societies (ethnographic, Eastern, Western, etc.) and for a range of purposes (adornment, magical-religious rites, art, etc.). Art historians and ethnographers do not distinguish mimetic faces and face-like representations from other forms of representation. They do not examine them as a specific facet of figuration, let alone from an aesthetic point of view. Nonetheless, there have been some notable exceptions, where ethnologists and art theorists have focused on facial expressions in artistic figures, starting with Le Brun, Guédron, Lévi-Strauss and Gombrich. Each of these eminent scholars conducted their investigations from a different perspective. As part of a didactic project, Le Brun undertook a detailed study of the expressions of passions that he claimed were universal (Le Brun 1994). His main idea was to establish a match between movements of the soul and configurations of the facial muscles, based on the idea that the configuration of the expression (i.e., a visible pattern) ensures the externalization of the soul's passions (i.e., part of the invisible realm). For his part, Guédron conducted a historical scrutiny, investigating facial expressions in Western art from a social point of view (Guédron 2011). Based on an adaptation of an existing theory, Lévi-Strauss reflected on the masks of the Kwakiutl ethnic group (Levi-Strauss 1979). He adopted the myth analysis method to examine these masks, which revealed a correlation between the social and religious functions of the masks and their visual appearance. Gombrich, meanwhile, carried out a representation analysis of the shape-economy mechanisms behind caricature (Gombrich 1960). This kind of representation primarily involves simplified impressions of physiognomy. The success of this figurative style in terms of its aesthetic reception led

Gombrich to promote the mechanisms of caricature as a mode of representation. This brief description of the way that facial expressions in art have been studied shows that art theorists, historians and ethnologists did not aim either to explain the nature or relevance of these images, or to highlight the figures' aesthetic relation to or impact on beholders. Instead, the main focus of these studies was on figures as cultural creations.

To investigate the aesthetic and social relevance of anthropomorphic figures through space and time, we undertook an interdisciplinary reflection (see Fig. 2) on the aesthetic experience, the social agency, and the cognitive mechanisms of face processing. This exploration was based on cognitive approaches that appeared to constitute a good departure point for conducting cross-cultural research.

Interdisciplinary Reflection on the Impact of Anthropomorphic Representations

We think that the substantial impact that anthropomorphic figures have on individuals, as shown above, stems from a profound aesthetic experience. This is why we talk about an *aesthetic* impact. We believe that this aesthetic impact is a long-term repercussion of perceiving the artwork. It is expressed both in the aesthetic relationship that is experienced for a defined duration (i.e., artwork observation time) and in social and cultural interactions that may mark individuals for an entire generation. This point led us to explore the social agency through anthropological theories that take the social dimension of art reception into account. One of these theories in particular, which reflects one facet of this issue, is described hereafter. Moreover, based on our review of the psychological literature, we can surmise that the aesthetic experience, which is key to understanding the social relevance mentioned in Section "The Expressiveness of Anthropomorphic Representations and Their Reception", is governed by a set of common cognitive mechanisms. We can assume that this is true whether the figuration is artistic or not, and regardless of where it comes from.

The aesthetic impact of artworks on beholders can be understood in a variety of ways, depending on what we mean by the word *aesthetic*. Here, we viewed the aesthetic relationship as a form of attention paid to the world, relying on Schaeffer's conception of the aesthetic experience (Schaeffer 2015). It means not just an appreciation of beauty, but also and above all, an attentional and emotional reaction experienced by beholders, both cognitive and affective. Our case study was based on the premise that the aesthetic experience provides the elements needed to understand the aesthetic impact. The latter can be regarded as a set of attitudes adopted at various stages in the aesthetic relationship (i.e., perception, recognition, attention, feeling, judgement, etc.). It is also the ultimate repercussion of the entire aesthetic experience, which expresses itself in the social sphere, namely attitudes towards the figure's social relevance and the meaning it conveys (e.g., the fear we are supposed to feel in the presence of idols of the gods). In this case, the aesthetic relationship experienced by beholders should be sufficiently relevant to affect the way the artwork is initially received by society, as we can observe throughout history. We can only understand the impact of anthropomorphic figures if we understand the aesthetic experience they elicit. This amounts to saying that the impact of anthropomorphic figures on their beholders may be expressed in the latter's attentional and emotional behaviour when they observe these figures. Furthermore, the aesthetic impact of anthropomorphic figures on individuals' life in society suggests that considering the social dimension of artwork reception can enhance our comprehension. This aspect calls on anthropological theories of art.

One of these theories was developed by Gell (1998), who considered artworks to be just one technology among others (Bloch 1999). He saw them as *indexes*, just like any other visible and physical *thing*—indexes in the sense of *natural signs* (according to Peirce's semiotics) indicating the causes of their existence (Gell 1998). Similarly, we consider all figures concerned by an aesthetic relationship to be cultural objects in the broadest sense. This allows us to investigate different kinds of figuration in all their diversity.[7] Thus, we can study artworks, ethnographic objects[8] and even robots at the same time. One consequence of this view on the nature of artworks is that aesthetics is dismissed as a mere beauty judgement. In his theory, Gell (1998) rejected aesthetics entirely and focused solely on the cognitive relationship between artworks and beholders. We obviously do not share his conception,[9] especially when new theories on the aesthetic experience, such as Schaeffer's, also talk about the cognitive relationship. In his anthropological theory of art (Gell 1998), Gell claimed that what characterizes the artistic relationship is a specific cognitive relationship aroused by the *index*, which he called the *abduction of agency*.[10] This means that the beholder attributes social agency to the artistic object and makes an inference about its intentions,[11] based on this index. According to Gell, agency is a property attributed to those objects or persons who "cause events to happen in their vicinity" through acts of mind or will or intentions (Gell 1998). He therefore argued that artistic objects are treated as person-like, with intentions and acting socially. Their power of fascination is due to the agency they convey through their status as indexes. According to his theory, our relationship with artworks is a social one, based on social agency that represents a cognitive

[7]This is the aim of all anthropological theories.

[8]Especially when some objects regarded as artistic in Western eyes are not in their original environment.

[9]Where aesthetics referred solely to beauty judgement.

[10]*Abduction of agency*, in the sense of the anthropological theory of art (Gell 1998), is the inference of the intentions or capabilities of an object viewed as another person.

[11]Here, the word *intention* was used in its strict sense by Gell, that is, the desire to act, to achieve a goal. The notions of *agency* and *intentionality* were used by Gell in the sense of *implicit theory of mind* or *folk psychology* - terms usually used by philosophers, psychologists and cognitive scientists (Bloch 1999). In this chapter, we keep to these meanings when using the word *intention*.

means for humans to live fully in society—that is, it reflects how humans understand each other.

The cognitive perspectives of Gell's agency of art (Gell 1998) and Schaeffer's aesthetic experience (Schaeffer 2015) allow us to adopt a cross-cultural, interdisciplinary approach to art and its social and perceptual/cognitive relationships. They form a sound anthropological and philosophical basis for our investigations. In the light of these theories, we suggest that the aesthetic impact of anthropomorphic figures is represented by the social relationship, as reflected by the abduction of agency. We therefore believe that the social relationship with artworks, which is subtended by cognitive mechanisms, is related to the aesthetic experience (through its cognitive and affective forms). To illustrate this point, we can assume that the emotional dimension of the aesthetic experience allows for a higher understanding and more intense feeling of the anthropomorphic figure's emotional expression. This understanding and feeling may render the abduction of agency more effective. The emotions inherent to facial expressions could thus explain the agency of anthropomorphic figuration. The emotionality of an anthropomorphic representation, mediated by its facial expression, may lead beholders to infer even unconsciously an intention from the object's countenance. In other words, the emotions conveyed by such figures provide clues to human intentions. This may be why faces are generally used in figuration in the animist identification mode.[12] In this mode, figuration is largely expressed via hints of humanness. Animism is woven around the idea that all beings share the same interiority (spiritual), and are distinguished only by their bodies (materiality or physicality). Anthropology supports the idea that humans' attributes are represented by theriomorphic[13] figures in order to highlight the identical nature of their interiorities (Descola 2006). The depiction of human features in animist representations seems to be the best means of indicating the oneness of spiritual anteriority, as the resulting images have greater cognitive coherence (according to Descola) (Descola 2006). We hypothesised that human attributes are mainly used in figuration for their aesthetic impact, assuming that figuration is processed by the face recognition module. This is especially true when the processing is common to different cultures and elicits embodied reactions and emotions (see Section "From Face Perception to Anthropomorphic Figure Reception") that we call *embodied aesthetic reception*. As we explain in Section "From Face Perception to Anthropomorphic Figure Reception", even if this processing is culturally based at the associated knowledge stage, it is universal at the initial unconscious stage of perception, when primary emotion categories rely solely on the geometric properties of the stimuli. In other words, when human clues are recognized in a given anthropomorphic figure. We suggest that this stage is one of the underlying crosscultural foundations of the aesthetic relationship between beholder

[12]A mode of identification is a cognitive mode that humans use implicitly to experience the world (Descola 2006): how a group of persons, whether or not they are geographically and culturally connected, interpret, construe and conceptualize the world, and how they make sense of it.

[13]Having the form of animals.

and facial expression representation. The argument in favour of embodied aesthetic reception is based on the assumption that both mimetic faces and face-like representations trigger the simulation mechanism in the beholder. One reason why this may be so is due to these two facts: the simulation mechanism occurs when onlookers observe natural faces, and some artistic figures are perceived of as belonging to face categories. Thus the aesthetic reception becomes characterized by an embodied perception when artworks are anthropomorphic figures. If we consider the aesthetic reception to be embodied, the aesthetic relationship and impact may be substantial, for they are experienced bodily. In this case, the aesthetic impact of such figures influences the beholder much more deeply than we might imagine. The aesthetic reception of facial expressions—and may be bodily expressions—can henceforth be thought of as an embodied impact that brings the beholder into a far closer relationship with the anthropomorphic representation. We can assume that the more exaggerated the expression, the more significant the embodiment and the greater the aesthetic impact. Given the universality of the facial expression process, the expressiveness of anthropomorphic figures through space and time is presumably determined by the intensity of the aesthetic experience arising from the embodied impact.

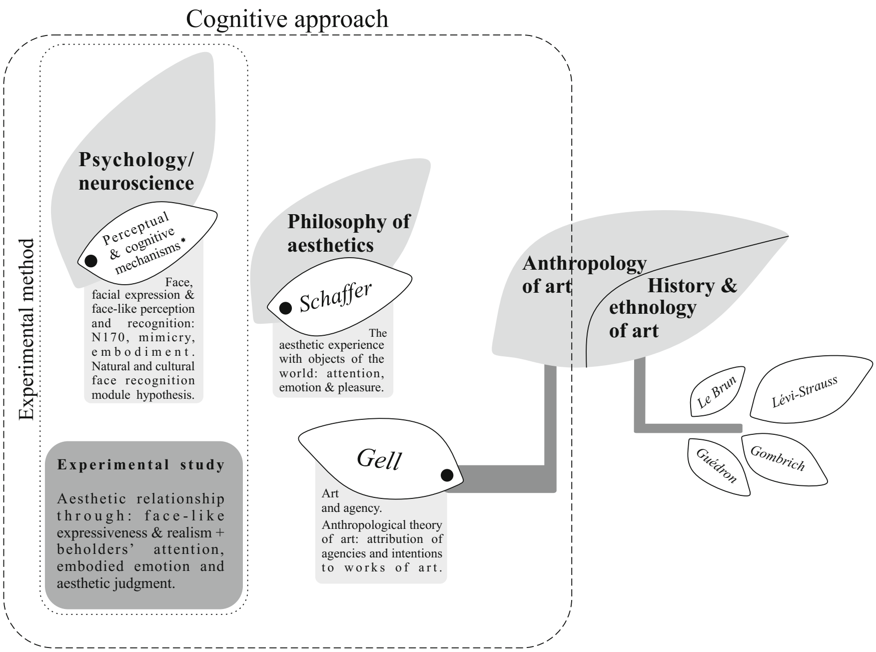

Fig. 2 The emergence of our contribution to knowledge about the aesthetic perception of facial expressions in art representations from a disciplinary network. *See Dimberg, Adolphs, Ekman, Sagiv & Bentin, Bruce & Young, Hadjikani, Ramachandran, etc

Our conceptual reflection helped to bring together different disciplinary fields in the quest to unravel the links between aesthetic relationship, social agency and cognitive models of facial perception and recognition. In order to shed some scientific light on our suggestions, we carried out an experimental study that took account of all these dimensions, which are usually regarded as independent, to provide fresh insight into the impact of anthropomorphic figures on social interactions.

Insights from an Experimental Pilot Study

Here, we describe and discuss an experimental pilot study that was intended to support our conceptual reflections (see Fig. 2). It was informed by the model of the aesthetic experience developed by Schaeffer in the light of cognitive results in psychology and neuroscience. We based our hypotheses on recent scientific results on facial expression processing.

Materials and Methods

The experiment was designed to examine how beholders react to anthropomorphic representations with facial expressions and how they emotionally embody the images they view. We reasoned that these behaviours might tell us about the aesthetic impact of figures in terms of aesthetic experience. The latter was understood from the Schaefferian point of view, whereby there are three components of the aesthetic experience: attention, emotion and pleasure (Schaeffer 2015). These components are transformed when an individual has an aesthetic experience, and therefore constitute objective measures of that experience.[14] More important, based on previous psychological results, Schaeffer stresses that attention is influenced by emotion, while emotion is biased by attention.

Unlike some cross-cultural studies that had a multicultural sample of participants, our experiment used multicultural material (stimuli) but a mostly Western-culture sample of participants (predominantly from France). The study was designed using Qualtrics software and administered via the Internet, while the data were analysed on MATLAB. We ask participants to assess a set of anthropomorphic images with facial expressions seen from the front. The material comprised 211 mimetic faces and face-like representations randomly selected from different styles, periods and cultures. These figures included images of natural faces

[14]We focused on the first two points here: attention and emotion. The third point has since been tackled in a study that is still ongoing and will not be mentioned here. However, we used a third criterion: aesthetic value, in this experiment, alongside attention and emotion to address the aesthetic experience issue.

($n = 10$), ethnographic art ($n = 103$), Western classical and modern art ($n = 54$), Eastern art and manga ($n = 28$), computer graphics ($n = 4$), and humanoid robots ($n = 12$). Each participant ($N = 386$) was shown 10 images that had been randomly selected from the database, and had to rate each of these images on six criteria, on a graduated scale ranging from 0 to 10: (1) degree of realism; (2) nature of the expression; (3) intensity of the expression; (4) intensity of the attention paid to the image; (5) intensity of the shared emotion; and (6) aesthetic value. The realism degree described how much the picture anatomically resembled a real face (facial structure). The nature of the expression described the configuration of facial features during the facial expression. The intensity of the expression referred to the force of expression communicated by the image. These three criteria assessed the image as an external object. The other three criteria assessed the viewer's subjective state. They provide a means not only of classifying the images according to their aesthetic value and their ability to attract attention and enhance emotions, but also of collecting information about aspects of the beholder's aesthetic experience. Intensity of attention and intensity of shared emotion are both strongly involved in the aesthetic experience, as is the beholder's aesthetic judgement. The emotional component probed the embodied side, meaning that we asked participants to evaluate the intensity of their shared emotion, and not their emotion in general. In other words, participants had to say how far the emotion they felt corresponded to the emotion displayed by the facial expression on the screen. This reflected the emotional impact of the figure in terms of emotional resonance. For simplicity's sake, we use the word *emotion* hereafter instead of the expression *shared emotion*.

Results

Figure 3 shows the correlations between the scores on the aesthetic response dimensions (attention, emotion, and aesthetic judgement). Pairwise correlations showed that attention and emotion were highly positively correlated ($r = 0.70$). Positive correlations were also observed between attention and aesthetic value ($r = 0.52$), and between emotion and aesthetic value ($r = 0.50$). Findings showed that the expressiveness of the images was highly correlated with both attention ($r_1 = 0.63$) and emotion ($r_2 = 0.50$). Given that attention, emotion and aesthetic

Fig. 3 Correlation coefficient between the three variables: attention, shared emotion and aesthetic judgement

Variables	Attention	Shared emotion	Aesthetic judgement
Attention	1	0.70	0.52
Shared emotion	0.70	1	0.50
Aesthetic judgement	0.52	0.50	1

judgement were interconnected, we can assume that emotion (embodied emotion) is involved in the aesthetic experience when participants view anthropomorphic figures. Results also showed that the expressiveness of these figures may influence the aesthetic relationship through attention and emotion.

Discussion

The data analysis yielded two major results. The first concerned participants' reactions to the aesthetic criteria and the relationship between them, reflecting a portion of the aesthetic experience and highlighting the involvement of shared emotion in the aesthetic experience when attention and aesthetic value ratings were high. The second concerned the expressiveness of the images and its impact on the aesthetic reaction. We were also able to consider some of the anthropological implications of the aesthetic impact.

Results for the three dimensions of the aesthetic experience (attention, emotion, and aesthetic judgement) showed that they are interconnected. The correlation between attention and emotion means that the greater the intensity of emotional reactions, the greater the intensity of attentional reactions, and vice versa. This does not mean that there is a causal link between the two, but it does illustrate how similarly the images trigger attention and shared emotion. The images that arouse the most intense attention also arouse the most intense emotion. This result supports previous findings on the mutual influence between attention and emotion (Schaeffer 2015). Most captivating figures impact the beholder emotionally in a way that can be related to emotional contagion. Emotional contagion, that is, the transfer of emotion from one individual to another, moves from figure to beholder in this case. This can be described as a projection of the emotion expressed by the figure (issuer) to the receiver (beholder). Via the contagion process, the emotional impact becomes part of the aesthetic impact, as emotion is a dimension of the aesthetic experience. This study demonstrates the relevance of embodiment into the aesthetic relationship between beholders and facial expression representations. Participants who rated their shared emotion intensity highly probably really felt the emotion expressed by the image. They may have reproduced the expressions they observed on their own faces via a mimicry process such as the one described by Dimberg et al. (2011) for natural faces. Therefore, we can also hypothesise that there is a relationship between attention and mimicry. If this is the case, given that embodied (shared) emotion is correlated with aesthetic judgement, the aesthetic experience of facial expression representations (and possibly anthropomorphic representations in general) may be characterized by a mimicry process. This can be investigated in electromyography experiments, where mimicry is measured by facial electrodes during perception of the images. This mimicry process, related to emotional empathy (Sonnby-Borgström 2002), may account for the special status granted to anthropomorphic figures throughout history.

Furthermore, the correlations between attention and aesthetic value, and between emotion and aesthetic value suggest that conscious aesthetic judgements reflect attentional involvement and felt emotion, reinforcing Schaeffer's idea of the aesthetic experience. However, we did note one interesting exception, as the aesthetic value of the images from non-Western art was assessed differently from attention and emotion. Whereas attention and emotion were enhanced by the intensity of the expression, the aesthetic judgement remained quite stable. This suggests that beholders produce undifferentiated aesthetic judgements when they are culturally distant from the image context. This conscious aesthetic judgement presumably relies more on cultural background than on universal perceptual and cognitive mechanisms.

The degree of realism and the nature of the expression informed us about the degree of face-likeness from structural and configural points of view. None of the correlations between these two variables and attention, emotion, and aesthetic value were significant. There was no effect of face likeness on aesthetic reaction. This may be because face likeness is less important to the aesthetic experience than expressiveness (see paragraph below). In other words, face-like representations (e.g., in distorted figures, see Images 8–17 and 24–31 in Fig. 1) are aesthetically perceived of in the same way as mimetic faces (see Images 1–7 and 18–23 in Fig. 1).

The correlations between image expressiveness and attention or emotion indicate that the attention paid to facial expression representations is modulated by their expressive intensity. Similarly, embodied emotion is determined by the expressive intensity of the image. Here, we hypothesize that expressiveness is the image property that affects both emotional embodiment and attention, as it exists independently of the beholder,[15] being conveyed by the stimulus. Furthermore, expressiveness exerts its influence regardless of the cultural source of the visual representation. Cross-culturally, therefore, the aesthetic impact of anthropomorphic representations with facial expressions may be deeply modulated by mimetic-face and face-like expressiveness.

If we were to extend our reflection to mimetic faces and face-like representations in general,[16] we might say that whatever the functional purpose of a mimetic-face or face-like representation, wherever it comes from, and whenever it was created, its expressive intensity appears to be a powerful cue, attracting beholders' attention and allowing them to be emotionally involved. We might even speculate that intense expressions elicit the interest of beholders and facilitate their adhesion to the ideas conveyed by the images (i.e., the ideas noticed on the inferred images intentions that are the intentions of the persons who created or instituted those images). This could reflect the social dimension of the aesthetic impact of anthropomorphic figures. As argued in Section "Interdisciplinary Reflection on the

[15]Even though expressiveness was assessed by the participants themselves, it was independent of their aesthetic reaction, as the assessment relied solely on the structure and aspect of the image.

[16]Which is only reasonable, as both the images and the participants were randomly selected.

Impact of Anthropomorphic Representations", the aesthetic impact is considered here to exceed the aesthetic experience and to continue through time, expressing itself in social interactions. This anthropological hypothesis is based on Gell's theory of agency in art (Gell 1998). Taking this theory one step further, we suggest that intensity of expression enhances beholders' social receptivity. In other words, the will and the intention that beholders assign to the figures may be more significant when the clues in the image are conveyed with considerable expressive intensity. Gell (1998) argued that agency may explain the power of fascination exerted by artistic images (Gell 1998). However, the intensity of expression presumably reflects the power of persuasion or, put less forcefully, inspiration. In other words, expressiveness may constitute the image's potential to incite and inspire beholders to act in accordance with its social purpose. Echoing Gell, we can say that the stronger the expression, the more effectively the image's social agency is abducted. This is because expressiveness places the viewer in a strong attentional and emotional state—a state experienced in the form of an embodied reaction. For instance, in a magical-religious context, we would expect figures to play an active role in society. The success of a figure can be measured in terms of its impact on the beholder. We can assume that this impact prompts the beholder to react in accordance with the intentions conveyed by the figure. Above all, however, this impact stems from the aesthetic experience. To sum up, the aesthetic impact of facial expression representations, mediated by expressiveness, alongside inferred agency, is probably the key to the social impact of this kind of figure: a social impact that actually arises from an aesthetic experience which, in turn, takes place though embodied perception.

To conclude, this experimental pilot study paved the way to achieving a more scientific understanding of the aesthetic relation between beholders and anthropomorphic representations featuring facial expressions.

Conclusion and Future Perspectives

In the visual arts, many cultures have used anthropomorphic figuration, and more especially facial representations. The different degrees of resemblance allow us to classify these figures as either mimetic faces (high realism) or face-like representations (low realism). In this chapter, we addressed the aesthetic impact of facial expressions in anthropomorphic representations from several different points of view. Attempting to conduct a cross-cultural and cross-disciplinary investigation, we revisited the anthropological and cognitive approaches through the work of Schaeffer (aesthetic experience), Gell (anthropology of art) and several other scientists, including Ekman, Dimberg and Adolphs (perception and cognitive mechanisms). We applied this interdisciplinary approach in a conceptual reflection and an experimental study. The latter proved to be significant and revealed that expressiveness constitute a common property that modulates the aesthetic reaction crossculturally. It also allowed us to establish correlations between attention, emotion and aesthetic judgement, and to compare our results with previous anthropological findings. Our experiment was, however, purely exploratory, and deeper investigations may provide more extensive results. In this experiment, we exposed Western participants to multicultural stimuli, but recruiting a multicultural sample of participants would ensure fully cross-cultural results. Investigating emotional responses through a large online survey, for instance, would allow for the assessment of a multicultural sample of participants in addition to the cultural diversity of the stimuli. Furthermore, actual embodiment and emotional involvement could be investigated by measuring participants' facial reactions (i.e., mimicry) to face-like objects and mimetic faces. This test could involve the use of electromyography or a thermographic camera. Likewise, we could develop other experiments such as exploring the N170 response to facial expressions in art representations. This would tell us whether mimetic faces and face-like objects in visual art are similarly perceived as natural faces. We could also use virtual reality to minimize experimental bias, by creating a more ecological context. This would yield more natural responses. Additional results on the perception of mimetic faces and face-like objects in art would further deepen our anthropological understanding of aesthetic and artistic relationships with figuration throughout history.

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How Art and Neuroscience Fell for Each Other

Marine Vernet

Abstract This chapter will provide a brief tour of what neuroscience can learn from art, of what neuroscience can tell us about our relationship with art, and, on the way, a glimpse of what art and neuroscience can teach us about our humanity. The first part will remind us that, because humans are produced by evolution, neuroscience and art are deeply interlaced. The second part will focus on the effects of art observation on our brain activity. Lastly, the third part will emphasize how our mind-body interacts with artworks.

Did We, Humans, Evolve for Art?

Art, without a doubt, is one of humanity's greatest achievements. It could even be what distinguishes us, humans, within the animal reign. However, this should not deny the role of biology, neither in the way art is created, nor in the way it is received. Miller (2000), also cited in Pinker (2002), observing the charming and sophisticated nests built by male birds of certain species, writes:

> If you could interview a male Satin Bowerbird for Artforum magazine, he might say something like "I find this implacable urge for self-expression, for playing with color and form for their own sake, quite inexplicable. I cannot remember when I first developed this raging thirst to present richly saturated color-fields within a monumental yet minimalist stage-set, but I feel connected to something beyond myself when I indulge these passions. When I see a beautiful orchid high in a tree, I simply must have it for my own. When I see a single shell out of place in my creation, I must put it right. Birds-of-paradise may grow lovely feathers, but there is no aesthetic mind at work there, only a body's brute instinct. It is a happy coincidence that females sometimes come to my gallery openings and appreciate my work, but it would be an insult to suggest that I create in order to procreate. We live in a

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> post-Freudian, post-modernist era in which crude sexual meta-narratives are no longer credible as explanations of our artistic impulses".
>
> Fortunately, bowerbirds cannot talk, so we are free to use sexual selection to explain their work, without them begging to differ.

By placing a caricature of an artist's speech into the Bowerbird's beak, Miller favors an interpretation that gives a large role to sexual selection in the production of art. This is not the only interpretation based on evolution theories. In general, such interpretations try to find what would be attractive to us as a species. For instance, a list of universal principles of art has been proposed by Ramachandran (2005). Among them, "Peak shift" was inspired by Tingbergen's experiments. As soon as a herring-gull chick hatches, it starts pecking at the red spot on the long yellow beak of its mother to beg for food. Based on this observation, Tingbergen showed that the chicks displayed a strong preference for long yellow sticks with three red stripes, actually larger than for a real beak, as if the sticks were "super-beak". Ramachandran proposes than human artists, through trial, error, and intuition, similarly discover the "figural primitives of our perceptual grammar" and exaggerate them in their artworks. For instance, we may find Picasso's paintings appealing because our brains' face-recognition system (which evolved to find faces attractive) becomes "hyperactivated" by the simultaneous presentation of different views of the same face.

This chapter will not defend any one theory about the purpose of art. Rather, neuroscientific studies will be surveyed to bring forth insight on the neurophysiological mechanisms by which art moves us (both in terms of physical and of emotional movements).

Does Our Brain Enjoy Art?

Neuroaesthetics is a recent field of research, where most studies are mainly directed towards characterizing the cortical and subcortical activations associated with viewing artworks, intrinsically beautiful objects, or objects we personally find beautiful (to what extent art and beauty do overlap is often beyond most neuroaesthetics studies).

Unsurprisingly, the neuroimaging results on art perception show great heterogeneity. Indeed, there is huge variability on types of artworks and as many ways to formulate a scientific question to answer the fundamental question: "how do we perceive art?" Nevertheless, some brain areas have been repeatedly coupled with art perception. Studies with functional magnetic resonance (fMRI),[1]

[1]Functional magnetic resonance imaging (fMRI) is a neuroimaging technique that supposedly measures brain activity by detecting changes associated with oxygenated and deoxygenated blood flow.

electroencephalography (EEG)[2], and transcranial magnetic stimulation (TMS)[3] revealed that areas that have been previously associated to the reward system (e.g., orbitofrontal cortex), to emotional processing (e.g., amygdala, insula) or areas related to high-level cognitive processes (e.g., prefrontal cortex), are activated during in aesthetics experience (Brown et al. 2011; Di Dio and Gallese 2009; Di Dio et al. 2007; Ishizu and Zeki 2011). Interestingly, in line with theories of embodied cognition, several studies revealed that artworks also impact parietal and sensorimotor systems.

Based on our largely shared taste for beauty, some studies focused on intrinsic, objective, characteristics of artworks that make us admire them, and on exploring how those characteristics impact neural activity. Di Dio et al. (2007) invited participants in an fMRI scanner to observe, as if they were in a museum, images of classical (e.g., Doryphoros by Polykleitos) and Renaissance sculptures, as well as versions of these sculptures with modified proportions. When no explicit behavioral response was requested (participants were invited to make an aesthetic judgment later, outside the scanner) a greater activation was shown for the original than for distorted sculptures in the insula: the activation perhaps reflected the pleasure evoked from the original sculptures' perfect proportions. Is the insula playing the role of an art-detector? In another study, however, different areas were shown to be important. Lutz et al. (2013) examined the difference between perceiving human bodies in artworks (from ancient renaissance artists as Peter Paul Rubens to contemporary ones as Ernst Ludwig Kirchner) and in non-artistic media. Compared to non-artistic photographs, artistic paintings evoked more activity in the right parietal cortex and the bilateral extrastriate cortex, stressing upon an enhanced processing of visuo-spatial information for artistic stimuli. These two studies also showed that the original works were more appreciated than their modified versions, or than the non-artistic media. The above-mentioned activations could thus facilitate the development of a positive aesthetic judgment.

Another approach emphasized subjective appreciation of art, and focused on individual preference and its neurophysiological correlates. A meta-analysis of 93 neuroimaging studies asking participants to make explicit aesthetic judgments revealed the importance of the right anterior insular cortex for perceiving beauty in four different perceptual modalities (Brown et al. 2011). Instead of working as an art-detector, could the insula serve to perceive beauty? According to another study, however, this role might be rather subtended by the orbitofrontal cortex. Ishizu and Zeki (2011), selecting artworks from both western and oriental cultures, explored the common substrate of beauty perception in visual (painting) and auditory (music) modalities. The results supported their theory, which relates the phenomenological

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[2]Electroencephalography (EEG) is neuroimaging technique that records electrical activity of the brain. When focusing on the spectral content of recorded signals, EEG typically evaluates neural oscillations or “brain waves”.

[3]Transcranial magnetic stimulation (TMS) is a noninvasive neuroimaging technique used to stimulate small regions of the brain. Reversibly disturbing the ongoing neural activity, it is useful to evaluate the causal involvement of specific brain areas.

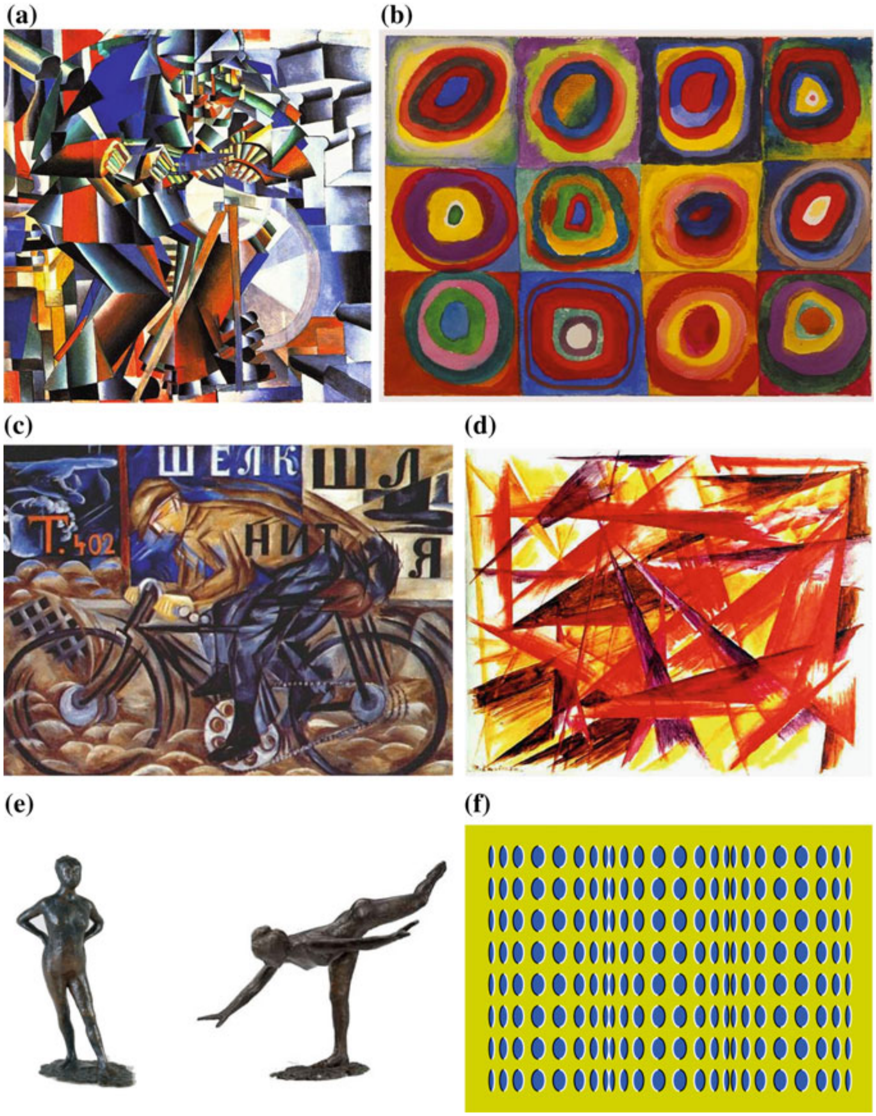

Fig. 1 Example of stimuli used in neuroaesthetics experiments. Brain areas encoding movement perception were more activated when expert observers viewed artworks with implied motion such as 'The Knife Grinder' by Kazimir Malevich (**a**) than artworks with little implied motion such as 'Color study—Squares with concentric rings' by Wassily Kandinsky (**b**) (Kim and Blake 2007). Applying TMS on brain areas encoding movement perception decreased the sense of movement that naïve observers had in front of paintings, but also their appreciation of abstract artworks such as 'Red Rayonism' by Mikhail Larionov (**d**), but not of representational artworks such as 'The Cyclist' by Natalia Goncharova (**c**) (Cattaneo et al. 2015). Greater body sways were observed when participants observed pictures of Edgar Degas' sculptures of a dancing ballerina (e.g., 'Grande arabesque, troisième temps') than of a static ballerina (e.g., 'Danseuse au repos, mains sur les hanches, jambe gauche en avant') (**e**) (Nather et al. 2010). Motion illusion was increased when observers spontaneously explored 'Rollers' by Akiyoshi Kitaoka (**f**, artwork reprinted with permission, (Kitaoka 2004)) with eye movements than when they fixated the center of the artworks (Kapoula et al. 2015)

experience of beauty to the activation of the orbitofrontal cortex. In other words, objects that are commonly considered beautiful might have universal properties, but the extent of their appreciation by an individual depends primarily on the activity within the orbitofrontal cortex. Nevertheless, confounding factors might have artificially increased the orbitofrontal cortex' role in beauty perception. Activity within this brain area seems to be also influenced by the "status" of the artistic object: when participants believed that an artwork originates from a museum, the median orbitofrontal cortex showed larger activation than when they believed it has been generated by a computer (Kirk et al. 2009).

In any case, viewing artworks obviously engages multiple brain networks. Calvo-Merino et al. (2010) identified two potential pathways for the aesthetic treatment of static ballet postures images. The first path goes through the extratriate body area, believed to house local representation of body parts, whereas the second one goes through the ventral premotor cortex, believed to process configural representation of complete body posture. Using TMS to disturb the balance between these two areas modulates sensitivity to aesthetic ballet postures images. However, our perception of art is not only determined by the intrinsic features of artworks. Context, emotional state, individual interest, background knowledge, familiarity with the works, etc., have strong influences. Cupchik et al. (2009) invited participants to approach social (nude, group portrait) and non-social (still-life, landscape) figurative soft-edge or hard-edge paintings either in an objective and detached way, in search of narrative information or, alternatively, to get personally involved and to focus on emotions and composition. Some brain areas revealed style-dependent activation; e.g., the upper left parietal lobe, which was more activated for soft-edge than for hard-edge paintings, may facilitate the visual-spatial exploration of more challenging visual stimuli. Other brain areas revealed context-dependent activation; e.g., the left prefrontal lateral cortex, which increased its activity when artworks were approached with an aesthetic angle, may reflect higher personal introspection.

Finally, appreciating artworks may be related to feeling whatever the artists try to convey. For instance, does motion depiction induce greater activation in the brain areas specialized in movement detection (MT+, MT/V5)? Are such activations related to the appreciation of the artwork? Kim and Blake (2007) demonstrated with fMRI that such areas were more activated for abstract paintings with implied motion (e.g. Marcel Duchamp, 'Nude Descending a Staircase No. 2') than for abstract paintings with little motion impression (Fig. 1b). This was found only in observers with prior experience to those kinds of paintings. Yet, in another study, these areas seemed to be important in art-naïve participants: applying TMS on them decreased the sense of movement they had in front of the paintings, but also decreased their appreciation of abstract (but not representational) artworks (Fig. 1c–d) (Cattaneo et al., 2015). Thus, the appreciation of abstract artworks could be related to feeling what is both there and not there: in the last example, movement in a static painting.

Does Our Mind/Body Play with Artwork?

As mentioned earlier, many artists consciously or intuitively discovered how our brain works. We perceive and experience what they intended us to see and feel. Artists rely for instance on their explicit or implicit knowledge of our visual system in order for them to play with our perception. Indeed, whereas certain physics laws are unconsciously integrated in our brains, allowing us to unambiguously understand the world, some physical transgressions can be ignored with impunity. A shadow, for example, must be darker than its immediate surroundings; if not, it will not be properly interpreted. On the contrary, it can take various fanciful colors or shapes without shocking us, like in a painting from Fra Carnevale (Cavanagh 2005). We can be just as impressed with the artists' virtuosity in reproducing the real world as surprised by their ability to take liberty. Sometimes, neuroscience later formally demonstrates (or still has to) the laws of our perceptual systems that artists empirically illustrate.

Through centuries, artists learned to master the depiction of space and then, to go beyond the reproduction of reality. To enjoy a full 3D perception, our brain combines binocular disparity cues (the slight offset between the two images received by the eyes), size cues (the fact that farther objects appear smaller), perspective cues (e.g., the fact that parallel lines get closer when going farther), as well as a priori knowledge (e.g., a face is convex, not concave; close objects are usually in the lower-visual field). Even if not all are present at the same time, these clues help us to quickly navigate depth. An artful transgression of any of these laws will create fascinating artifacts. Such transgression can even create powerful illusions. If you look straight ahead to the sculpture House 1 by Roy Lichtenstein, you simply see a house. Turn around the house and you will quickly realize that it is not convex, like a real house, but instead concave. In addition, this "house" is quirky—there is not a single right angle! The edge wall that seemed pointed towards you is actually farther than the sidewalls. You were misled by the larger size of this edge and your prior general knowledge about houses. These spatial cues are so strong that when you return to your original position, you cannot prevent yourself from seeing, once again, an almost normal house even though you may be more sensitive to small inconsistencies, e.g., to how the house reposes on the ground.

Such illusions suggest that our perceptual system uses cognitive shortcuts to quickly, and often correctly, perceive the world. The most plausible interpretation is imposed on us and can never be entirely overthrown. At the opposite extreme, when the sum of available evidence is ambiguous and several interpretations are equally plausible, a phenomenon of multistability arises. Only one interpretation is imposed on us at a time, but our brain ends up questioning it and another interpretation takes over, and so on. Many artists created multistable arworks (e.g., MC Escher, Sandro Del-Prete, Jos De Mey). Because the physical world and the content of our percepts often do not match, illusion and multistable artworks are providing a unique source of inspiration for neuroscientists exploring not only our visual system, but also our perceptual consciousness. Of course, listing all the types of inspiration we could get from art would be endless. Illusions and other visual phenomena might as well trigger, simultaneously, a real-world sensation and a supernatural sensation (see e.g., the painted murals by José Clemente Orozco in Guadalajara, Mexico).

Besides these fascinating aspects, how could these artistic treatments participate in our aesthetic experience? One hypothesis is that, our experience of art is embodied: through our spatio-motor system, our body will truly interact with artworks. Let us first go back to our visual system. Visual information does not come to us: we have to actively look for it, and bring the objects of interest at the center of our retina. The phenomenological experience of looking for information in real life is entirely different from the experience of being still and receiving information, like in most non-motor visual perception experiments (Wurtz 2008; Wurtz et al. 2011). Moreover, there is a permanent and complex interaction between the *physical* world, the *movements* made to explore it and the *perception* of it. In the case of depth, for instance, physical cues might participate in both the percept elaboration and the eye movements preparation (Ziegler and Hess 1997). Additionally, efferent copies of motor signals contribute to percept elaboration (Priot et al. 2012). Conversely, in the presence of an illusory percept, eye movements are sometimes triggered according to the physical stimulus (Wismeijer et al. 2008) and sometimes according to the illusory percept (Sheliga and Miles 2003).

The way our eyes explore artworks might contribute to how we interpret them. For example, the sensation of motion when viewing mathematically-generated Op Art seems to emerge from an unstable eye motor behavior made of many small saccades (Zanker et al. 2003; Zanker and Walker 2004). The perception of space in Renaissance artworks from Piero della Francesca, containing strong depicted perspective, seems to come from two motor aspects: first, an active exploration and repeated fixations over areas of the paintings that are important for spatial composition, even when no figurative elements are depicted; second, gaze instability in depth, i.e., small vergence movements, even if the painting is 2D (Kapoula et al. 2009).

This instability in depth is not limited to the eye movement behavior. Abstract paintings from Maria Helena Vieira da Silva containing depth elements cause greater postural instability than modified versions of these paintings, which eliminate those depth cues (Kapoula et al. 2011). Representation of movements and instability also induce mild postural instability in observers. Nather et al. (2010) showed significantly greater body sways when participants observed a picture of a Degas' sculpture of a dancing ballerina than of a static ballerina, demonstrating that images of body movement internally generate unconscious body oscillations (Fig. 1e). A complex interaction between artworks, eye movements, and postural stability was demonstrated in two studies. One used reproductions of Op Art artworks from Riley and from Kitaoka (Fig. 1f) (Kapoula et al. 2015), and another one was conducted in a museum in front of the monumental Richard Serra's Promenade sculpture (Kapoula et al. 2014). These experiments illustrate how artworks, excelling in representing depth, movement and instability, are able to physically impact us.

Furthermore, we would be particularly sensitive to artistic stimuli inducing some kind of motor resonance. Obviously, dance is particularly suited to induce such physiological response. For example, some portions of the occipito-temporal and parietal areas of the network dedicated to the observation of actions would be especially active when we evaluate movements as both pleasing and difficult to reproduce (Cross et al. 2011). Similarly, bilateral sensorimotor cortex would be particularly activated when observing movements that are on average highly appreciated (Calvo-Merino et al. 2008). However, real movements are not the only ones able to activate the parietal and sensorimotor network. In paintings, not only figurative content but also visible traces of the creative artists' gesture can cause space and movement sensations, that add to the aesthetic experience. For example, an EEG study revealed that observing artworks by Lucio Fontana made of cuts on canvas evoked modifications of brain oscillations similar to those observed during motor preparation. Modified version of these works containing drawn lines instead of the cuts did not evoke such modification (Umilta et al. 2012). Thus, the EEG allows us to demonstrate a true motor preparation while observing some artworks. Entering in resonance with the creative gesture: is there a more beautiful way to appreciate art?

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Part III
Understanding and Enhancing Art Experiences

Spectating Myriam Gourfink's Dances; Transdisciplinary Explorations

Coline Joufflineau and Asaf Bachrach

Abstract This article presents a singular research process immersed in Myriam Gourfink's choreographic research, at the crossroads of cognitive science, aesthetics and practice. This research is part of Labodanse, a transdisciplinarity research project in dance, cognitive neuroscience and new technologies.

Introduction

The co-presence of bodies inherent to the intersubjective context of performances is an invitation to investigate how the singular "presence" of the dancers (Louppe and Gardner 2004, p. 153), underpinned by their attention to the present moment, may inform the presence of the audience (Citton 2014, Chap. 4). The latest studies in cognitive neuroscience, carried out in ecological context (Konvalinka et al. 2011; Jola and Grosbras 2013), demonstrate how the co-presence of the bodies (of the performer and the spectator) in real-time plays a key role in processes underlying the spectators' subjective experience. Konvalinka and colleagues have found physiological synchronization between performers and spectators while Jola and Grosbras found increase in motor-neural activation for spectators when attending a live performance at the theater compared to observing a video recording of the same dance. In addition, from an embodied and situated perspective of art reception, and based on recent research in humanities, the spectator's attention plays a key role in the aesthetic experience (Schaeffer 2015, Chaps. I & II), and in the experience of art, across all artistic categories (Massin 2013, pp. 37–43). Yet within the sensing device constituted by the Western

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stage, the spectator's attention is differently solicited by different choreographies. (Perrin 2012) and so the study of the attentional and intersubjective mechanisms playing part in live spectating needs to incorporate the features of the specific artistic work explored and the context of its presentation.

Over the last 20 years, Myriam Gourfink, a French choreographer, has been developing a movement style characterized by an extreme continuous slowness, whose quality is induced by a contemplative technique, Energy yoga. This form of yoga-meditation consists in a genuine exercise of interoceptive focus and moment to moment attention to internal sensations (Gourfink 2013). During live renditions of her choreographies, the audience reaction may vary greatly. Some spectators feel bored and find time to go by slowly, while others relate a sensation of time flying by linked to a strong somatosensory experience: the dance induces in them an augmented attention to body sensations, which lasts beyond the performance itself (Fontaine 2004, pp. 129–142; Gioffredi 2008). Bringing together theoretical, experimental and practice-based perspectives, we developed a specific research paradigm to explore some of the physiological and cognitive processes at play during the observation of these performances.

We will first (Sect. 7.1.1) provide a phenomenological perspective onto the spectators' experience, outlining both common and singular traits of these subjective experiences. Later (Sect. 7.1.2), in a dialogue between aesthetics and cognitive neuroscience, we will discuss the study of dance perception and reception by emphasizing the interactions of the visual sense and of kinesthesia in the dancer-spectator relationship. In Sect. 7.2 we will present our research credo as it gradually took shape, at the crossroads of cognitive sciences, of the choreographer's practice, and of aesthetics. We will illustrate our position (III) by describing specific aspects of our research protocol including a quantification of subjective tempo "change", through a production task carried out by spectators before and after they observed a live performance (based on McAuley et al. 2006). In order to assess to what extent these changes coincide with the subjective experience of the spectators, we built a semi-directed questionnaire, in which one section addresses the spectator's attention during the performance. For the performance time itself, we developed a real time task, allowing the spectator to point, on a screen specifically elaborated for the purpose, where their attention was located at any given moment. The task was coupled with online measures of their physiological responses. We will end with some of the many questions this research perspective brings to the foreground.

Experiencing Myriam Gourfink's Dance Work

"Hypnotic" (Vernay 2003), "fascinating" (Mayen 2004), "unique", "a torture" (Frétard 2003) the audience reactions to Myriam Gourfink's dance pieces vary greatly. Some even leave early. Each of Gourfink's dance pieces is singular owing to the score, the materials at work, the presence of technology, the modes and places of performance, the costumes, the music by Kasper T. Toeplitz, etc. Yet with a regular observation of live rendition of her works, and a careful reading and analysis of all writings pertaining to her choreographic work, it is possible to sketch out a few descriptive "invariants" and recurring components in the experience of her dance pieces from 1998 to 2015.

First of all, the pieces are characterized by an extreme slowness, and an intense scarcity of movement. "Whether alone or shared, in a solo, a trio or a group piece, the dance unfolds gradually in a continuous *tempo*, as if the bodies encountered no obstacle to their regular evolution" (Piettre 2011, p. 107). Throughout this dance, unfolding "millimeter by millimeter", "the dancers exhibit highly unusual motor skills" (Gioffredi 2008, p. 169). By playing on micro changes in support, the pace of the movement is always far below the speed of 'standard' dance movement or that of daily movements such as walking. Sometimes the dancers are almost immobile, or their movement is imperceptible for the spectator's eye, to the point that they can generate a blindness to change: the spectator is surprised to find out that the configuration of the bodies in space has changed without having perceived the movement itself.

This slow movement in continuous flow consists neither in slowing down, nor in reproducing a slower movement. As the choreographer stated, it is the consequence of a specific body awareness technique, Energy Yoga. According to her, two components of Energy yoga induce the slowness: the breathing "it is the exploration of breathing which induces the slowdown" (Gourfink et al. 2009, p. 126), and the exploration through body-oriented attention: "we do not decide to start from a slow tempo to execute the movements (…), it's quite the opposite: the slowness is induced by the work on body exploration and by the consciousness of tiny movements" (Gourfink et al. 2009, p. 126). Energy yoga is a Tibetan technique, of which Myriam develops specifically certain elements for each dance piece. It combines work on breathing, focus, postures, micro movements and mental imagery. The breathing in Energy yoga is extremely stretched: "The breathing is done most times through the nostrils, often in a very fine way and without any sound." One learns "to dissociate the right and the left nostrils" (Goufink 2013, p. 1). Breathing movements are always done in synchrony with the slow and minimal movement of a specific segment of the body. Three types of attention and interoceptive focus are trained (Clerc 1976, 1979, 1982; Laffez 2000). First, a global and floating attention: a continuous observation of the production of sensations; second an internal focus on a specific body part; third an extreme focus on a micro point. "The attention, supported by the breathing, is applied to points, surfaces, volumes, lines, spirals, within the body's space or in the external space, it travels by connecting one space to the other, creating geometrical figures in motion" (Goufink 2013, p. 1).

While dancing, performers reenact these elements, and they always spend at least three hours practicing Energy yoga before going on stage. Yet Gioffredi (2008, p. 3) notes that "as the spectators are not informed on how these preparations go, their attention is not turned to the consequences of these constraints on the body and the movement of the dancers, they only perceive the effects of it". One of the questions we wanted to address as part of the project was whether first hand experience with the Energy Yoga practice changes how a spectator apprehends Gourfink's dances.

Contrary to numerous other choreographic styles, the spectator's attention is never captivated by new elements, ruptures, events or rhythmical variations. The dancers do not play with theatrical expressions, they never "put on faces" or look directly at the audience: "each dancer is absorbed in her task" (Fontaine 2004, p. 135). As a result of this extreme slowness and focus of the dancers, the spectators' visual attention varies, from moments of hyper-focalization to moments of panoramic opening. As G. Fontaine writes, "the slowness makes it possible to multiply moments and extend what would be too short to be perceived" (Fontaine 2004, p. 143), "what is hardly visible gains a great amplitude" (p. 135) there is a "removal of any spectacular device in the benefit of a sharpened gaze" (p. 136) thanks to which "one is surprised to become a watchman looking out for an almost-nothing" (Frétard 2003). In addition, not only the spectators' visual attention becomes sharpened: their kinesthetic sensations are awakened and amplified[1] (Gioffredi 2008, p. 3): "Indeed the rhythm, the points of support and moments of rest in *Rare* (2002)'s liquid dance are slowly unnerving for the spectators; they trigger new sensations, buried for too long out of a lack of attention" (Tappoiet 2002). The spectators' attention travels "from the most intimate corners of their bodies, revealed by the dance, to the performers' uninterrupted movements" (Gioffredi 2011, p. 172). A game of propagation and contamination of these body states settles (Gioffredi 2011, p. 172), driven by the dancers' breathing (Frétard 2003).

The spectators experience their bodies in a new way (Gioffredi 2008, p. 3), moved in their spatiotemporal references (Gioffredi 2011, p. 170); they come out of the experience feeling disoriented (Piettre 2011, p. 108), "Since our awareness of the duration is abolished or strongly disturbed, since now time sets its own beat outside of any rationality, there is no more obstacle in taking one's time, precisely, in rooting in the present moment, in the here and now" (Piettre 2011, p. 110).

Depending on the relationship that they engage with the piece, the audience may potentially feel largely bored, or have similar experiences as in meditation. Whether Zen meditation: focused on one's own breathing and interoceptive sensations, or mindfulness meditation: an awareness, moment to moment, of one's own perceptive experience: movements perceived on stage and internal movements, as well as one's sensations, emotions and thoughts. Or it could be an experience close to hypnosis, daydream, or even trance[2] (Piettre 2011, p. 108). Whether they

[1]"Le spectateur fait alors une expérience qui ne se limite pas à sa dimension visuelle, des sensations kinesthésiques sont éveillées, il devient sensible au micro mouvements ou à la qualité de présence des danseuses." ("The spectator's experience is not limited to its visual dimension; kinesthetic dimensions are awaken, the spectator becomes sensitive to micro-movements or to the quality of presence of the dancers.") (Gioffredi 2008, p. 3).

[2]"les chorégraphies de Myriam Gourfink forment un *continuum* qui modifie le degré de conscience et l'enferme dans une espèce de transe. L'étymologie du mot transe (de l'ancien français "transir": "passer par delà", "mourir") rapproche cet état second d'une petite mort." ("Myriam Gourfink's choreographies form a *continumm*, which modifies the degree of consciousness and encloses it in a kind of transe. The etymology of the word transe (from old French "transir": "to go beyond", "to die") brings this altered state closer to a 'little death'" (Piettre 2011, p. 108).

experience boredom or full engagement, often the spectators' experience is paired with a loss of spatiotemporal references: some find the time long, others didn't see it pass.

How can we approach experimentally, as close as possible, the subtlety and complexity of these experiences, while distorting as little as possible the choreographic proposal and the aesthetic experience itself? How can we find passageways between the subtle dimensions observed by first person introspection by dance researchers, and already existing experimental techniques in psychology? What tools can we develop to study the experience of spectators in real time, both in the first and third person? Especially, how can we explore the changes in temporal perception and the travelling attention between the spectators' own bodies and the dancers' bodies? Finally, as spectators are transformed by the experience of these performances, how can we quantify the changes induced by the reception of the dance piece based on the relationship the spectator engaged with it?

Dance Perception and Reception: Dialogue Between Cognitive Sciences and Aesthetics

For a long time, the reception and perception of art belonged to aesthetics and the philosophy of art; then it was gradually approached from sociological, anthropological, psychoanalytical and psychological perspectives, and, more recently by neurosciences under the title of "neuroaesthetics". In the last ten years, dance, its perception, and its reception have become a subject of investigation in cognitive neurosciences (Bläsing et al. 2012; Cross and Ticini 2011; Cross and Anastassia 2014).

In a dialogue between aesthetics and cognitive neuroscience, we will first recall a few key aspects related to the experience of art more generally, and then discuss some cognitive neuroscience studies on the perception and reception of dance in particular. We will highlight their contributions and limits, and especially how they contributed to the elaboration of the principles of our research credo (described in the following section).

The reception and perception of art is first of all a relational experience (Dewey 1934), in which the body takes fully and actively a part (Scarinzi 2015; Hume and Bouveresse 2000). Sensitive and conceptual characteristics of the object also inform the relationship (for the effect of stylistic characteristics cf. for instance Lengger et al. 2007, for the conceptual dimension cf. Minissale 2012), as well as the spectator's own sensitivity. Sociology brought to the foreground how much cultural and sociological factors and exposure to art inform the reception of an art piece (Bourdieu 1984), and aesthetics theories emphasize how much the reception involves acquired knowledge (Hume and Bouveresse 2000; Chateau 2010, Chap. VII). Recent neuroscientific studies also highlighted the importance of individual factors, such as the ability to apprehend novelty, surprise, ambiguity, absurdity, and lack of understanding (Goldberg et al. 2012).

As an experience, the perception and reception of an artistic proposal unfolds in time; it has a duration. Massin (2013), shows that, whether the work experienced is classical or contemporary, whether it's a so-called static work (visual arts: painting, sculpture, installation art), or a work developed in time (music, theatre, performance, cinema, literature), the experience of it "is built gradually", it "also includes gradations", and is characterized by "a dynamic process". A few studies demonstrated the variations in the time dedicated to the relationship with a "static" art piece depending on the context: in a lab setting or in ecological context (Brieber et al. 2014). With regards to works carrying their own development in time, more and more studies in cognitive neuroscience pay specific attention to the gradual and dynamic dimension of the spectator's experience, especially in the reception of music, and more specifically with the question of the emotional response to music (cf. chapter by Zenter and Eerola in Juslin and Sloboda 2010).

This progressive and dynamic process is potentially transformative, it is a moment (Jullien 2001) taken in the time course of experiences that make up our lives. The experience changes us, moves us, our sensations, our perceptions and our conceptions all at once (Pelowski and Fuminori 2011; Girons 2008), sometimes radically renewing them. In that sense, and although few studies engaged in it, it can be enriching to look at specific cognitive or other states before and after the exposure to a work, as demonstrated in the experiment carried by Kapoula et al. (2014). The authors measured the body sway of 23 visitors before and after visiting Richard Serra's "Promenade" sculpture exhibition in the Grand Palais in Paris. They found that the experience of walking through that exhibition improved postural control and judgement of the subjective visual vertical.

In the last 15 years, dance, its perception and reception have become a subject of inquiry in cognitive neuroscience (Blasing et al. 2012; Cross and Ticini 2011; Cross et al. 2014). The gap mentioned above between lab and "in vivo" settings is especially relevant in the case of dance. Indeed, the co-presence of the bodies of the dancers and of the spectators in a common time-space singles out performing arts among all artistic proposals. Phenomenology and dance theory insist on the "intensity of the dialogue between the body of the viewer and the body of the dancer" (Louppe and Gardner 2004, p. 12): "in contemporary dance, where body to body relational activities are constantly intensified, the body of the dancer touches the body of any spectator, even unknowingly (…). These bodily contagions spread on a very fine, almost imperceptible level."(Louppe and Gardner 2004, p. 174). Jola and Grosbras (2013) demonstrated how crucial studies in situ are, by showing how the motor cortex of novice dance spectators was significantly more active during (passive) observation of a live rendition of a dance piece in a theatre compared to the observation, in a lab, of a filmed version of the same piece.

In addition, the body has a very specific status in dance, since it is all at once the tool, the medium, and the matter presented. "On stage, the body also becomes an image" (Bernard 2001): its status is different from the musician's body for instance. The dancer's quality of presence is also a fundamental dimension of dance as an art form (Louppe and Gardner 2004, p. 153); it changes depending on the direction, the object and the quality of attention of the dancer at a given moment. From this point of view, several studies in cognitive neuroscience miss the necessarily intersubjective dimension between the subjects-spectators and the dancers in real time, and reduce the spectator's experience to an intra-subjective one. Moreover, they often omit the transformative dimension of the experience of art, which in the case of dance is brought about by elements of attraction and reaction through the gaze, attention and kinesthesia: "the spectator's perceptions are interwoven around the dancer's body, as the construction of the body-self through the perception of the other's body" (Louppe and Gardner 2004, p. 72). Finally, many studies use very short video excerpts or even only still images of dance (e.g. Calvo-Merino et al. 2004; Cross and Ticini 2011) thus eliminating the temporal dimension of the experience.

According to Ginot (2012), former dancer and dance theorist, one can distinguish two broad models in dance theories: "to view is to understand", and "to view is to sense" (Ginot 2012, p. 222). This latter model is largely followed by cognitive neurosciences, where one of the major research subjects (going back to at least Calvo-Merino et al. 2004), relies on the theory of mirror neurons (Gallese et al. 1996; Buccino et al. 2001) and privileges the nonverbal dimension of the reception of dance by emphasizing the nature of the activity observable in somatosensory and motor areas of the brain during the practice or perception of dance (Cross and Ticini 2011; cf. also Cross et al. 2011; Jola and Grosbras 2013; Calvo-Merino 2015). The brain activations observed were implicitly or explicitly associated with indications of kinesthetic empathy, as developed by Foster (2011).

However, according to I. Ginot, one ought to go beyond these two models ("to view is to understand" and "to view is to sense"), by exploring "how certain dances (…) help to build, through the gaze, a specific kinesthesia" (Ginot 2012, p. 225). Bachrach et al. (2015a, b), using fMRI, have demonstrated the joint activation of theory of mind (cognitive empathy) and kinesthetic regions during the viewing of short contemporary dance choreographies. According to Ginot, following Godard (1995) "variations in empathy rely first on the nature of the danced gesture (…). Some dance qualities would bring about empathy more than others, and maybe also invite different kinds of sharing, more or less colored by affect. Of course these qualitative variations of dance are also combined with the spectators' own sensitivity, which will make them more or less receptive to some gestures than to others" (Ginot 2012, p. 225). The only way cognitive neurosciences can address the relationship between empathy, the nature of the danced gesture, and the spectator's own sensitivity consists in collecting first and third person data.

To this day, most studies collect either extremely rich first person data through post hoc interviews (Reason and Reynolds 2010), or by using real time subjective reports (Egermann et al. 2013), but the nature of qualitative data (open questions, interviews) make comparison across the experiences of the subjects-spectators very complex, and comparison with other types of data (physiological measures, physical dimensions of the performance) almost impossible.

Alternatively, studies collect very rich third-person data, but comparatively "poor" first-person data, with regards to the complexity of the subjects' experience.

In fMRI studies for instance, the first-person data collected often address exclusively two "intra-subjective" dimensions, whether live or post hoc: the enjoyment and/or what could be related to the "judgement of taste" in the history of aesthetics: subjects-spectators are required to assess stimuli in terms of "how much they like it" or "how much they find it beautiful" (Grosbras et al. 2012; Kirsch et al. 2013). For instance, Cross and Ticini (2011) correlated the brain activation (especially in the "mirror" network) with the subjective satisfaction related to specific dance movements. Calvo-Merino et al. (2010) used Repetitive Transcranial Magnetic Stimulation (rTMS) to disturb the judgement of taste on dance postures. As we discussed above, these dimensions capture very little if any of the subjective experience of observing a dance piece.

However, some studies did go beyond this dichotomy, such as the remarkable projects by Stevens (2006) and the *Watching Dance* project (watchingdance.org), which worked toward connecting the different layers at play in the spectators' experience by collecting online and post hoc data. The online data was acquired by developing an online response tool (Stevens et al. 2009; Schubert et al. 2013). Rather than asking the subjects-spectators to signal their emotional response or how pleasing they found the specific moment, Stevens and her colleagues asked them to assess their "engagement" during the choreography. "Engagement" was defined as feeling drawn in, connected to what is happening, and interested in what is going to happen (Schubert et al. 2013, p. 4). The authors quantified the inter-individual agreement of engagement data. To this day, there are few other means to explore the online response of the audience in dance. To acquire post hoc data, the authors elaborated an ART questionnaire composed of three sections using a combination of open-ended and closed questions to collect qualitative and quantitative data. This questionnaire was made in order to explore the relations between the cognitive interpretation of the dance, the affective reactions, the individual Differences (Impact of Experience), and the impact of information.

In the Labodanse project we built upon the work of Stevens and colleagues, elaborating online tasks and post hoc questionnaires targeting the specific experience of Myriam Gourfink's spectators. In addition, we wanted to relate these first person measures with (inter and intra subjective) physiological dynamics during the performance and the transformation of the spectators' cognitive state by the performance.

The Labodanse Project

Labodanse was a three-year project (2013–2015) financed by the Paris 8 Labex ARTS H2H, jointly initiated by Myriam Gourfink (a choreographer), Frederic Bevilacqua (a Human Machine Interaction specialist) and Asaf Bachrach (a Cognitive Neuroscientist), in collaboration with a number of researchers, artists, philosophers and engineers. The aim of the project was to construct an ecological lab to study the interaction between dancers and spectators in Myriam Gourfink's work, bringing together physiological, cognitive, affective and subjective dimensions of this interaction.

It is worth noting that following Calvo-Merino et al. (2004), most fMRI studies on dance observation have focused on the effect of expertise or training in a specific dance style or choreography (or dance more generally) on dance observation (Calvo-Merino et al. 2004; Kirsch et al. 2013). In order to converse with the existing literature, we chose to evaluate the effect of familiarity with Gourfink's choreographic language on different dimensions of spectating by including a training phase in the paradigm. However, given the specificity of Gourfink's approach, which is based on 'choreographing' internal actions and states, using Energy Yoga, rather than formally defined gestures, we opted to train half of the spectators in the somatic practice developed by Myriam Gourfink. We wanted to explore how embodied familiarity with the internal dynamics of the dancers, otherwise invisible to the audience, affects their reception of the ensuing dance.

After a year and a half of preparations and piloting we conducted a total of 7 days of recordings, over a period of 8 months. Each day was composed of a morning yoga training of half of the audience with Myriam Gourfink, followed by two performances by dancers of the company. The performance consisted of selected excerpts from Myriam's most recent pieces. Each performance was monitored and preceded and followed by a battery of evaluations to be discussed later in the chapter.

The Labodanse Credo

Through our experience in the project we identified a number of key operational principles, which we now consider as essential components of the Labodanse project and research process, and which may potentially inform future projects in the field of neuroaesthetics, especially in the domain of dance and performance. In this section we will briefly present these principles, their motivations and consequences. Later in the article we will illustrate these components with concrete examples taken from the project.

The Artist as Co-researcher

Some neuroscientists consider artists as "neuroscientists using their own tools": "Artists and neurobiologists have both studied the perceptual commonality that underlies visual aesthetics. […] This is why I believe that artists are, in a sense, neurologists who unknowingly study the brain with techniques unique to them" (Zéki 1999). Yet most times they remain at the threshold of the space they opened and rarely collaborate with artists to understand how and which specific technique enabled such and such discovery or transformation. Most studies subscribing to the general label of "neuroaesthetics", investigate (with cerebral imagery, electrophysiology or observable behavioral measures) the artistic process, in its production and/or reception. "Art", "dance" (Christensen and Calvo-Merino 2013) "the artist", "the creation process", "the spectator", "the experience of reception" are all objectivized and taken as subjects of study. In other cases, culturally and historically located Western aesthetic concepts such as "the beautiful" are taken as subjects of study (Zéki 2011).

In the perspective developed by Labodanse, rather than conceptualize neuroesthetics as the study of creation and/or artistic reception by neuroscientists, we think of it as the study of the "mind" combining the neuroscience *praxis* and techniques specific to the artists (Goldstein and Bloom 2011). In other words, we consider the artistic *praxis* as an alternative form of research. As such, "neuroesthetics" becomes a transdisciplinary enterprise in which artists, scientists, and aestheticians join hands to elaborate research protocols and address specific questions on the intra- and inter-subjective dynamics of the "mind".

In the same vein, if the artist is a researcher, in as much as two researchers have different research methodologies, tools and techniques, so do two different artists. Within the Labodanse project, we do not refer to "labels" such as art or dance generally, but to specific practices, conducted by singular artists, and offered in situated contexts of reception.

Humanities and Cognitive Sciences Moving Together

The above considerations lead us to this second point: if we are to consider the artist as a co-researcher, then we must take the time to understand her research method, the tools she uses, the experiences and ideas involved. This is why we believe that the (partial or immersive) involvement of the researchers in the artist's creative process is primordial, maybe even more so when the tool is the body.

Indeed, the "embodied" implication of researchers has recently came up in different research trends in philosophy[3]: "philosophical discourses which integrate the body rely on experience, which remains the only category of validation and legitimation of the theory. If the theory deviates from what is received and perceived in the first person, it loses its authenticity (…)." (Formis and Ando 2009, p. 19). This deliberate choice in philosophical research is in a nascent state in the field of cognitive neurosciences, where its advantages have been acknowledged when the first-person experience of subjects serves as a guide to analyze results, as

[3]It's largely the case in dance and performance studies, in the fields of pragmatic philosophy. Cf. *Thinking through the Body: Essays in Somaesthetics* (2012) by Richard Shusterman for instance, or in continental philosophy, from phenomenology to Bergson. Cf. for instance *Pensées du corps* by Basile Doganis (2012), Susan Leigh Foster's work: *Choreographing Empathy: Kinesthesia in Performance*. London: Routledge, 2011, or *Relationscapes: Movement, Art, Philosophy* by Erin Manning (2009), or *The Corporeal Turn: An Interdisciplinary Reader* by Sheets Johnstone (2009).

in the neurophenomenology initiated by Varela (see Petitot 1999). Yet up until now few scientists consider that their own subjective experience may be an equal source of scientific knowledge and a field of experimental research (for an exception Desbordes and Negi 2013).

In line with this stand, all Labodanse researchers took part in Energy yoga trainings conducted by the choreographer, and attended several performances of her dance pieces. In the perspective of an interactive research between humanities and cognitive sciences, the researchers' immersion in the embodied experience proved to be very rich, by constituting a common ground from where discussion was possible. Within the Labodanse project, rather than beginning with theories and studies conducted in each discipline (philosophical research, cognitive science literature), we started from direct somatic and artistic experiences, and later only confronted them with the existing literature, to develop hypotheses and protocols. Direct experiences of the artistic practice are now for us the ground for an effective, efficient and "productive" transdisciplinarity. Being involved in the embodied experience enabled us to avoid a standoff between humanities and experimental sciences, by providing a common and shared material, from which a dialogue may be initiated and nurtured with each and everyone's specific knowledge.

Qualitative and Quantitative Data: Articulating First and Third Person Perspectives

From the Labodanse vantage, there are so to speak four first persons. In preparation for the study we can identify three distinct '1st persons' who dialog to develop hypotheses and protocols. These are the choreographer's words based on her subjective experience; the phenomenologists and art theorists through the reading and analysis of their work; and the direct experience of the researchers immersed in the practice and bringing in the specific knowledge of their respective fields.

The fourth "first" person makes reference to the subjective reports of subjects-spectators, acquired to guide the analysis of third-person data. Using online and offline elicitation techniques we attempt to capture at least certain aspects of the spectator's experience (and mode of spectating). Research in aesthetics, in particular in the humanities, investigates the first person experience of the subject-spectator using most often post -hoc open questionnaires or interviews. While these tools can provide a rich insight into the experience of a specific subject, they make comparison across subjects very complex. Even more problematic for our neurophenomenological enterprise is the difficulty to relate post hoc qualitative data with online physiological data (third person perspective). In the Labodanse project we made an important attempt to develop tools for 1st person elicitation that can facilitate cross subject and cross perspective analyses.

"In Vivo" and "In Situ"

Standard experimental or statistical methods in science require multiple repetitions of 'the same' event. In addition, certain experimental setups such as MRI machines or MEG's magnetic shielded rooms are not easily amenable for live interaction (though see Metz and Lutz 2010; Jola and Grosbras 2013). Finally, theatres, dance studios and almost any other space outside the scientific laboratory contain distractful, incontrolable 'noise'. For these multiple reasons much of the scientific work on dance spectating has used video sequences or static images of the dance work presented to isolated subjects in a laboratory setting. From a subjective point of view, it is almost trivial to point out that a video rendition of a 'spectacle vivant' is not itself 'vivant' neither for the performer nor the spectator (We mention again Jola and Grosbras's 2013 paper discussed in the introduction). Another important dimension of dance spectating is the plurality of the audience, while most lab experimental settings test participants individually. The co presence of other spectators has a clear effect on our subjective experience of a dance piece (and art more generally). Golland et al. (2015, personal communication) found that viewing the same emotional movie produces stronger physiological reactions when viewed in the presence of a co spectator. In order to address these issues, all Labodanse experiments took place in either theatres or dance studios with a group of spectators observing a live rendition of (excerpts of) Gourfink's dance pieces.

A Sketch of the Different Components of the Project

Different quantification and evaluation methods were established to explore the spectators' experience in its physiological, cognitive, perceptive and subjective dimensions, while seeking to create tasks both intuitive for the subjects and significant with respect to the objectives of our study. We present here the different aspects of this process and the questions which appeared along the way.

In order to address the limits previously described and related to methodology in cognitive science, with regards to the fragmentation of the spectator's experience, we attempted to provide the spectators with an experience as close as possible to that of spectating a dance piece in 'the real world' and took into consideration the spectators state when they arrived, as they waited before attending the performance, during the performance, as well as just after the performance. We sought to explore different dimensions of the audience experience that emerges from our research process: attentional, perceptive and relational.

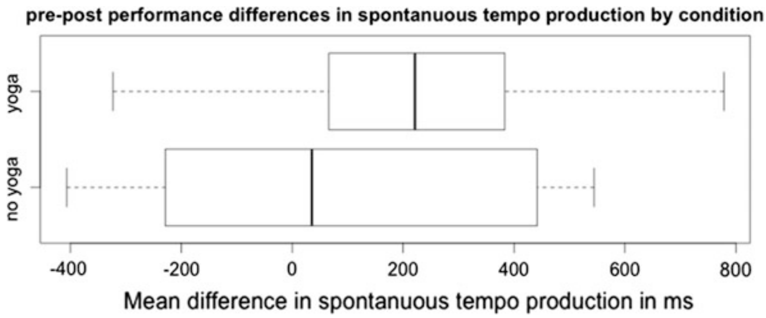

Fig. 1 Results of spontaneous tempo modulations

Quantifying the Transformative Impact of Spectating

As we alluded to above, we take the experience of dance (or art) spectating to have, potentially, transformative effect on the spectator that go beyond the experience itself. In the case of Myriam Gourfink's work, with its specific 'slowness', we hypothesized (cf. Bachrach et al. 2015a, b and Joufflineau et al. in preparation; for more details) that spectating will have effects on the temporal cognition of the spectators, bringing about changes in subjective time perception. In order to evaluate this hypothesis, we tested spectators just before and just after the performance using a number of different protocols from the cognitive literature on the topic. For example, we made use of a simple free tapping paradigm that provides an estimate of a subject's 'spontaneous tempo' (Macdougall 2005). We predicted that this tempo will be slowed down after the performance. Indeed, that is what we found. The tempo of free tapping after the performance was significantly slower than before the performance. Furthermore, we found out that the effect was significantly larger for spectators who did the yoga training in the morning before the performance, arguing for the role for expertise or familiarity in this cognitive change due to the performance (Fig. 1).

Another approach we have used to evaluate the transformative effect of dance spectating has been to use clinically validated self-report questionnaires regarding anxiety state[4] that were administered to the spectators twice (before and after the performance). Finally, we measured 'baseline' physiological measures (ECG, breathing) just before the performance to be able to compare these to similar measurements during a time interval after the performance.

[4]STAI, cf Stai Manual for the state-trait anxiety inventory ("Self evaluation questionnaire"), Spielberger et al. (1970).

Quantifying the Present: Subjective and Physiological Measures During Performance

The central, and arguably the most complicated, goal of the Labodanse project was to be able to investigate, in real time, the fine temporal dynamics of the subjective and physiological dimensions of a dance performance. Physiological synchronization or entrainment between performers and spectators has not been, to our knowledge, formally quantified in the context of dance. However, such synchronization has been demonstrated in other domains such as rituals (Konvalinka et al. 2011). It is tempting to relate physiological synchronization to the subjective notion of kinesthetic empathy. While this relationship between subjective empathy and physiological synchronization has been studied in the case of romantic couples for example (Chatel-Goldman et al. 2014), to our knowledge, this relationship has not been studied in the case of live performance.

As we have discussed above, the challenge of ecological study of a performance is its temporal extension. It is reasonable to expect that both intersubjective physiological synchronization and the subjective sense of kinesthetic empathy or involvement of a spectator would vary along the duration of a dance piece. Hence, a global measure of empathy or synchronization is not very informative if we want to assess their relationship over time. To address this concern we wanted to be able to relate temporally dense subjective report data with the timecourse of intersubjective synchronization.

In order to accomplish this, we have created a tablet-server based application that allowed us to acquire real time subjective ratings from spectators, temporally synchronizing these data across subjects and with each subject's physiological data.

Physiological Data

Electrocardiography (ECG) and Breathing timecourse were acquired using the Bioharness belt sensor (Zephyr Technologies) and was sent in realtime, wirelessly, to the tablet of the subject. Analysis of this data collected over a period of 8 months is still in progress. We report here one preliminary result from one recording session (comprising of 4 repetitions, with 4 different audience groups of four excerpts, two solos and two duets, danced by two dancers of the Myriam Gourfink Company). Using graph theoretic approach (Fallani et al. 2014), we quantified the degree of connectedness between spectators' and dancers' breathing rate. We found that the spectators who had a yoga training with the choreographer earlier that day were significantly more connected to the dancers compared to the spectators that did not have such training. We also found a significant correlation between an individual subject's breathing rate connectedness with the dancers and their reported attention to the dancers' breathing (as assessed by a post hoc questionnaire) (Fig. 2).

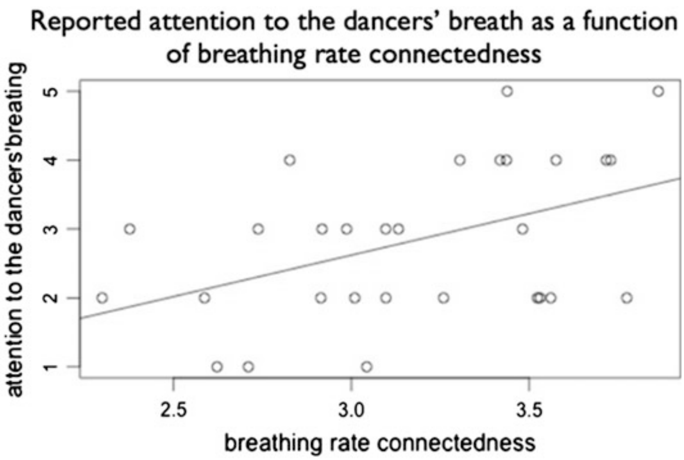

Fig. 2 Correlation between breathing synchronization and subjective report regarding attention to breath

Subjective Online Data Collection

Following Kate Stevens and her colleagues, we attempted to implement a procedure allowing the spectators to report non-verbally on the course of their experience during the performance. We chose to implement an online procedure, such as the one used by C. Stevens (Stevens et al. 2009; Schubert et al. 2013), but with two important differences: the participants were using their fingers rather than a stylet, the scale and sampling method were continuous rather than discrete. During the first recording we asked the audience to indicate the level of their 'engagement' (used by Stevens et al.). We described 'engagement' to the spectators as the intuitive sum of their level of focus during the piece, their level of interest, and the level of their physical/emotional arousal, energy, and enjoyment. An upward movement of their finger indicated an augmentation of their engagement, and downward, a diminution of it.

Because of errors in the application's architecture, we were not able to use the data. But we were not satisfied with the engagement task itself. Spectators and members of the team found the notion of engagement too vague, too global, too difficult, and too abstract to be able to continuously evaluate it in real time. Moreover we found it insufficiently specific compared to the choreography and the specificity of the movement, to inform us on the fine "structure" of the spectators' subjective experience.

For our second recording session, we decided to test three different tasks alternatively, to replace the notion of engagement. We induced three spectating attitudes by proposing three "objects" of observation: (i) the state felt by the spectator (the spectator observes him or herself), (ii) the spectator as observer of the dancers, and (iii) the spectator as observer of his or her relationship to dance(r). More precisely, we asked the participants-spectators to evaluate if their attention was rather directed toward themselves or toward the dance (internal or external attention) (i), to evaluate the intensity of the connection between two dancers during their duet (ii), and to evaluate the proximity they felt between themselves and the dancer (in a solo excerpt, iii).

In itself the task was similar to the engagement task, in the sense that the participants were asked to provide a continuous report by intuitively using the scale to evaluate each dimension to observe (the three dimensions were tested separately). Each task generated motor constraints and a restrictive framing of the attention. The participant-spectator had an obligation of temporal continuity in holding the finger on the tablet, and had to keep the finger moving in an upward-downward vertical axis, to indicate the modulations of the experiences. Most importantly, this task forced the participants to maintain a permanent meta-cognitive process while the experience is made of discontinuities.

Our own experience with the task, as well as the feedback of participants led us to re-evaluate not only the content of the task, but also its logic. During the third and fourth sessions we used new tasks, considerably different from our previous approach and from those existing in the literature. We tried to stay as close as possible to the spectators' experience (cf. phenomenological studies and dance watching theories), by using the tablet as a means to report their experience in the most direct and intuitive way. For instance, in one of these tasks we focused on the notion of attention, while opening spatiotemporal possibilities to indicate its variations, objects and distribution, thereby allowing temporal discontinuity and spatial dispersion.

To do so, the tablet given to participants contained a screen schematically picturing the mapping of the intersubjective space of the studio (their body by the side of the others spectators' bodies and of the dancers' bodies, Fig. 3).

The participants could freely indicate on the screen, by drawing with their fingers, "where" their attention was "located". By touching one specific icon, they could also indicate that their thoughts or attention have drifted somewhere else, away from the studio and the ongoing dance.

Contrary to the previous attempts, this new procedure allowed for a more free and spontaneous input. Importantly, the spectators could define the object of their attention (grouping or not different elements in the scene) and were not burdened by a continuous meta-cognitive task but instead invited to report when meta-cognitive awareness of their own attentional experience emerged spontaneously, a marked feature of spectating Gourfink's work (Gioffredi 2008, 2011).

The data from these online attentional tasks is now being analyzed quantitatively and also qualitatively in relation to the video of the performance. In a second stage we will use the results of these analyses to explore the physiological state of the spectators and their connectedness with the dancers and among themselves.

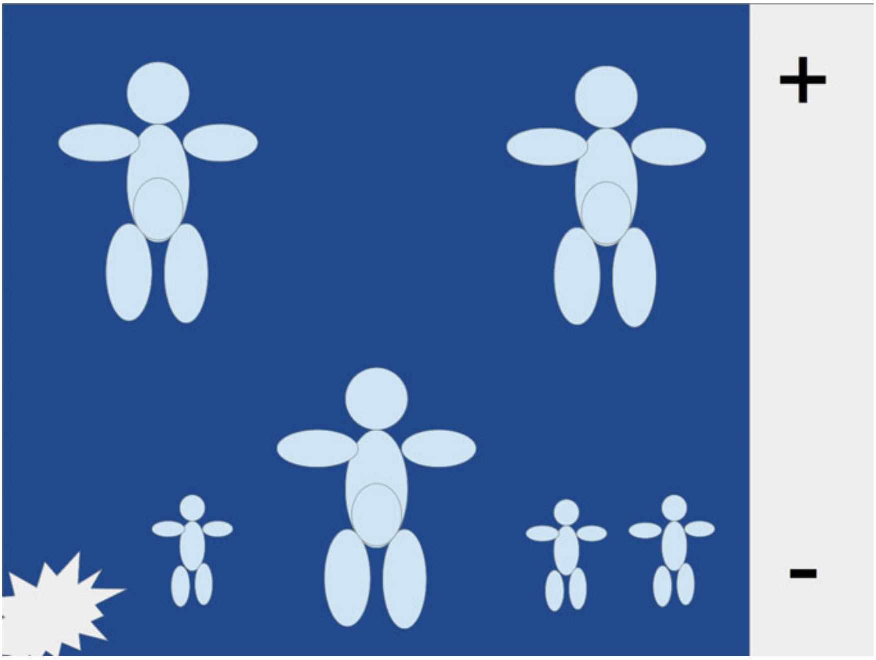

Fig. 3 Background image for the attention cartography task. Each participant had this image at the background of their tablet. This is a schematic representation of the context of the performance. The two characters that are above represent the dancers. The largest of those at the *bottom* of the image represents the viewer herself. The three smaller correspond to other viewers. The *blue surface* corresponds to the space of the studio. The *star* is a "button" allowing participants to indicate the times when her attention is elsewhere, outside of what is going on in the studio. The *plus* and *minus* were for another task not discussed here

Quantifying the Right After: Labodanse *Questionnaire*

The Labodanse questionnaire was elaborated to connect first-person experiences to measurements made before and after the performance and to physiological data acquired during the performance. It is made of 4 sections: (i) one section on attention (interoception) in everyday life (semi-directed questions from the FFMQ, Baer et al. 2008; Heeren et al. 2011) and empathy in the experience of art (semi-directed questions related to different art's experiences (cinema, literature) taken from the Interpersonal Reactivity Index (IRI) questionnaire, (Davis 1983); (ii) eighteen semi-directed questions on the experience during the performance; (iii) open questions on the experience of the performance and perception of time; (iv) and an open question on which body areas were felt most vividly during the performance.

Our aim with the semi-directed questions on the performance (ii) was to explore some correlations between (1) impressions felt after the performance (loss of spatiotemporal references, sensation of a slowdown of the body, sensation of having travelled versus having felt bored) and (2) modulations of the attention consciously noticed by the spectators. Especially, we were interested in the direction of the attention: interoceptive or exteroceptive; its mode: narrow-focused or distributed, and in the objects of the attention: the dancers' faces, the overall shape of the body, the breathing.

Asking spectators right after the performance for such precise indicators on their sensorial and meta-cognitive experience posits a challenge. As we might have all experienced after a show, the transition from an aesthetic experience to verbal interpretation is not always immediate. According to L. Louppe (p. 29), [the felt state after a performance is] "like the edge of a wave overloaded with accumulated impressions. Like the journey of a body arriving on the shore of its own speaking. The body would have to acknowledge, probably with awkwardness, the blindness of its words: speaking of dance is too jostled by the present of its experience". This difficult transition from the aesthetic experience to language is attested in responses to post hoc questionnaires in cognitive scientific studies. The authors of the ART questionnaire (Glass 2006a, b) noted that a great number of spectators were not able to articulate the specific sensorial experiences underpinning their interpretation of the dance. They suggest to explore these results in future research, proposing that a possible explanation might lie in the lack of clearer direction in the formulation of the questions.

By taking into account these remarks and in order to stay as close as possible to the spectators' possible experiences during live renditions of Myriam Gourfink's dance pieces, we took as starting point for the development of the questionnaire the semantic analysis of studies lead by phenomenologists and art theorists, making use of these terms and expressions to formulate more suggestive questions to the participants-spectators. In addition, the questionnaire was inspired by the mindfulness questionnaire (FFMQ), in which the formulation of questions takes the form of suggestions in which a one-to-five scale allows indicating one's relative agreement or disagreement with the proposition. Part of the questions address the bodily experience and internal attention to its kinesthetic and interoceptive aspects. For instance: "Several times, I felt my breathing during the performance." Or: "I stayed pretty immobile during the performance." Another section addressed external attention, both its mode (focused or distributed attention) and its objects. For instance: "I often paid attention to the dancers' breathing", or "Sometimes I was focused on a muscle or on the dancers' muscle tensions"). The third section addressed global impressions: "I lost the notion of objective time during the performance").

These semi-directed questions enabled us to correlate reported subjective experience with, among other things, changes in temporal perception after the performance and the extent of physiological synchronization with the dancers (as described above). In one study we found that spectators' agreement with the following three statements regarding their object of attention (one interoceptive, two exteroceptive): "Several times I felt my breath during the performance", "I often paid attention to the dancers' breathing", "Sometimes I was focused on a muscle or on the dancers' muscle tensions" to correlate with the extent of change in subjective time perception. In a second study we found significant correlations between the same three questions and dancer-spectator breathing rate synchronization during the performance (Bachrach et al. 2015a, b).

Open questions, in the second part of the questionnaire, aim at offering a space for a less constrained expression than with semi-directed questions. They encourage the emergence of new themes that can serve for future versions of the semi-directed questionnaires, and better understand the shades of sensitive experiences in their singularity and commonality among spectators.

Open Questions and Concluding Remarks

Dance spectating and the multiplicity of experiences it brings about are extremely rich and complex phenomena. Quite naturally we were able to address only a fraction of the multitude of potential questions these raise. Many avenues of research are still in development within our group or could be further investigated in future projects. Alteration in time perception ("timelessness", "extended now") has been associated (both in discussions of Gourfink's work (cf. Gourfink and Boisseau 2009) as well as in the study of meditation (Berkovich-Ohana et al. 2013) with an alteration in body boundary perception. We have begun studying the effect of Myriam's training and performances on related questions such as body image, body size and peripersonal space.

As for attention, we have reported an online measurement of spectators' attention, however we have also started to explore the effect of Gourfink's training on attentional capacities such as control and inhibition of non-relevant stimuli using standard cognitive paradigms. It would be also very interesting to study the online visual attentional behavior of spectators using eye-tracking technology.

In terms of spectator-performer interaction, we focused on real time monitoring of breathing synchronization for reasons specific to Myriam Gourfink's work, during the Energy yoga training and live performances. However, it would have been also very interesting to quantify other forms of synchronization or entrainment, looking for exemple at the spectators' postural or head sway and how it relates to the movement of the dancers.

Our protocol evaluated the effect of brief intervention (a 3 h training session with M. Gourfink) on the experience of spectating. It would be interesting to explore the effects of longer training regimes as they might bring about other changes in the implication of spectators in the performance. Along similar lines, we have quantified the transformative potential of spectating but on a very short time scale (comparing different outcome measures just before and just after the performance). It remains to be found out to what extent spectating (of Gourfink's work or more generally) has long lasting transformative effects. This would require retesting of spectators after longer time lapse (a week or a month). To begin to address this question we have made a first pilot study that consisted of qualitative interviews with a number of spectators ten days after the performance. The first results appear to be promising: "I feel like it opened something that stayed with me. In the perception of my own body." (A.M participant-spectator)[5] "It opens a number of doors that I had never seen before."[6] "I wondered if being the actor-spectator of this body moving so slowly didn't make me access an antique aquatic memory" (J.M participant-spectator)[7].

While we insisted on the specificity of the live performance with the co-presence of spectators and dancers we have focused primarily on the effects of performance on the spectators. But what about the effect of the audience on the performers (Moelants et al. 2012)? In current work with the choreographer Mélanie Perrier we explore the effect of the co-presence of spectators (and in particular their gaze) on the performer.

A major issue in any experimental intervention is that of the control condition. This issue presents a particular difficulty in the case of ecological, situated studies. In the case of our study one would have liked to include a control to the training with the choreographer before the performance as well as a control to the spectating event itself. Regarding the first question, we have chosen in our last testing session to include a relaxation session as control to the yoga training with Myriam. Another alternative could have been a meeting with Myriam or a dance scholar to discuss her work. Regarding the second question, the answer in our mind is much less obvious. What would a relevant control of the choreography be? Should we present another form of slowness, such as the slow-motion choreographies in some hip-hop technique? Or should it be a dance piece from another choreographer, introduced to the participants as a dance piece by Myriam Gourfink, as Creswell et al. 2016, did with mindfulness meditation? Or should spectators simply spend 45 min observing a blank wall? We believe that the question of appropriate controls would require a field-wide discussion and elaboration if ecological protocols are to become more common in the domain of neuro-aesthetics.

The working model for neuroaesthetics presented here consists in a transdisplinary approach to a very specific case study rather than a study of art sui-generis. The focus of Labodanse on the perception of time and the modulations of the spectators' attention resulted from the meeting between the specificity of the artistic practice of Myriam Gourfink and the theoretical interests of the academic partners. Our mode of investigation of the spectators' experiences was centered on staying as close as possible to the subtleness, the complexity and the specificity of these experiences. Had we worked with another choreographer, the questions we would

[5]"j'ai l'impression que ça a ouvert quelque chose qui est resté quoi. Dans la perception de mon propre corps." (A.M, participant-spectator).

[6]"ça m'ouvre pas mal de portes que je n'avais jamais vues".

[7]"je me suis demandé, si d'être l'acteur-spectateur de ce corps qui bouge tout doucement je me suis demandé si ça n'avait pas fait accéder à moi, si ça ne m'avait pas fait accéder à une mémoire aquatique ancienne" (J.M, participant-spectator).

have formulated and the tasks we have elaborated would have been different. Each question and each task emerged in the specific context of Myriam Gourfink's practice, and at the crossroads of phenomenology and the literature in cognitive neurosciences.

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Interactive Experiences Shape the Perception of an Artistic Performance: Evidence from Eye Movements and Physiological Measures

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Abstract The present study investigates the impact of different interventions on the gaze patterns and physiological reactions of observers during the perception of *Sediments*, an abstract dynamic art work performed by the artist *The Baltazars*. Thirty-four participants watched the performance before and after participating in one of three interventions: one involving direct manipulation of the visual effects of the show via a tactile interface, one involving verbal exchanges about the performance, and one unrelated to the performance. Eye movements and electrodermal activity were recorded during the two exposures to the show. Results showed that the two interventions focusing on the show impacted visual exploration and physiological responses, beyond the effect of repeated exposure. Participating in an activity related to the artistic performance increased visual exploration and emotional arousal. In addition, interventions changed visual exploration in different ways depending on their content. Verbal exchanges led to a *global visual exploration* of the artistic performance whereas manipulation of the visual effects of the show led to a more *local visual exploration* of the show. Together, findings demonstrate that interactive experiences can modify the subsequent perception of an artistic performance.

General Introduction

The project of the artist duo The Baltazars was well suited to this challenge (http://www.baltazars.org/). Aurélie and Pascal Baltazar have developed several pieces of artwork halfway between the visual and the performing arts. Their performances involve sculptures of matter in motion through the use of light, mist, smoke, wind

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and sound. This abstract artwork is designed to produce sensory experiences that suggest waiting, expectation, fragility, etc. In parallel, the artist duo has developed possibilities of interactive experience with their work through the construction of tactile interfaces, in collaboration with researchers in modern art. By Manipulating the tactile interface, individuals can create their own show of visual effects by modifying different parameters on the artistic device (e.g., color of the light, intensity of the wind). This opportunity of direct interaction with the art work was expected to change individuals' perception of the artistic performance and, perhaps, influence individual sensitivity to art and general well-being. Our common project with the Baltazars aimed to evaluate the impact of manipulating artistic visual effects using the tactile interface on the subsequent perception of their performance. From the literature in cognitive science, there were indeed strong reasons to believe that acting on a visual object will modify its perception.

Background

Growing behavioral and neurophysiological evidence supports the existence of a close relationship between perception and action (e.g., Aglioti et al. 2008; Bidet-Ildei et al. 2011; Casile and Giese 2006; Chao and Martin 2000; Kiefer et al. 2007; Olivier and de Mendoza, 2001; Rizzolatti and Craighero 2004; Tucker and Ellis 2001). In particular, visual perception is affected by individual previous motor experience. For instance, the visual recognition of gait patterns from point-light displays is improved after participants are trained to execute the same movements (Casile and Giese 2006). Similarly, basketball players better anticipate the success basket shots than basketball novices (Aglioti et al. 2008). Perceptual processing entails some form of simulation, in the own body of the observer, of the actions perceived or evoked by visual entities, and motor simulation efficiency depends on individual motor experience. Together, recent studies in cognitive science indicate that motor practice shapes visual perception.

Although interactions between perception and action processes have been importantly studied overall, they have only received little attention in the domain of artistic perception. The few studies investigating the role of action in artistic perception have mainly focused on the neural correlates of human body movement perception, such as the perception of dance movements (Calvo-Merino et al. 2006; Cross et al. 2011). Results from those studies suggest that greater neural simulation of the perceived movements produces better aesthetic evaluation of dance movements (Cross et al. 2011). Some neurophysiological data have also been collected during the perception of paintings (Battaglia et al. 2011). As for the perception of artistic movements, they suggest that the aesthetic quality of a piece of work is related to motor simulation intensity in the brain. These sparse findings are consistent with the hypothesis of an important role of action in artistic perception. Yet the consequences of the modulation of motor cortical network activity on the behavior of the observer during the perceptual experience remain largely unknown.

The rarity of research bearing on the relationships between action and art perception comes in part from the difficulty of elaborating methodologies and tools that are adapted for measuring artistic perception and aesthetic experience. A few results suggest, however, that some implicit behavioural and neurophysiological responses may inform about the cognitive and emotional processes at play during artistic perception. Note that most findings in this line concern static art work such as paintings, which leaves the challenge of measuring behavioural and neurophysiological changes during performing art perception completely open.

Several research teams have investigated eye movement patterns during visual exploration of art work (Hristova and Grinberg 2011; Kapoula et al. 2009; Locher 2006; Massaro et al. 2012; Quiroga and Pedreira 2011; Tatler et al. 2007; Vogt and Magnussen 2007; Wallraven et al. 2007). Although the identification of regularities in the gaze behaviour of the observers that may be generalized across different pieces of work remains delicate, those studies identified several factors that may modify gaze strategies. These factors include the presence of title information (Hristova and Grinberg 2011; Kapoula et al. 2009), the task and instructions provided to the observer (Massaro et al. 2012; Wallraven et al. 2007); the prior presentation of a modified version of the art work (Quiroga and Pedreira 2011), and expertise (Kapoula and Lestocart 2006; Pihko et al. 2011; Vogt and Magnussen 2007). The effects of expertise and repeated exposure on gaze strategies are particularly interesting. Observers tend to make fewer but longer fixations, associated with saccades of smaller amplitude, on the second exposure to the painting. In contrast, art experts tend to make shorter fixations and saccades of greater amplitude than novices, who focus their gaze on the main elements of the paintings. In other words, the visual exploration of paintings seems to increase with expertise but to decrease with repeated exposure. Moreover, in the study by Pihko et al. (2011), the gaze patterns of novices became closer to those of experts after they received information about the painting (Pihko et al. 2011). Overall, previous findings indicate that the effects of expertise, repeated exposure, and artistic instructions on (static) art perception can be visible in the gaze pattern of the observer, in particular in the number and duration of fixations, as well as in the amplitude of saccades. Thus, measure of eye movements during visual exploration of art work may be a good candidate to assess the effect of past action experience on art perception.

Skin conductance or electrodermal activity (EDA) may also be an interesting indicator of emotional arousal during art perception. EDA is a typical measure of the activity of the autonomic nervous system that varies with individuals' emotional states. Recently, EDA has been related to aesthetic evaluation of art work in naturalistic environments such as museums (Tschacher et al. 2012). Moreover, EDA is sensitive enough to detect subtle changes in the aesthetic experience of the observers. Pihko et al. (2011) also reported increased EDA during painting perception after their participants received information about the paintings. These results suggest that EDA may be an interesting implicit measure to quantify the effect of action on art perception in naturalistic conditions.

Aim of the Study

The study was designed to assess the impact of short interventions that gave observers the opportunity to manipulate the visual effects of an artistic show on the eye movement patterns and neurophysiological reactions of the observers during the perception of this artistic show. In particular, the aim was to evaluate to what extent the influence of interventions based on direct manipulation differed from more classical interventions based on verbal exchanges about the show.

Methods

Participants

Thirty-four participants took part in the study. There were 18 females and 16 males (mean age = 24 years, age range = 18–66). Most participants were students or young professionals. Fourteen out of the thirty-four participants had some background or expertise in arts (e.g. student in cinema or history of art, artist).

Design

Participants were randomly divided into 3 groups of interventions that took place between the first and second exposure to the artistic show. Participants watched the show and participated in the intervention by small groups of 2–3. Interventions lasted 15 min.

In the "Manipulation" intervention, participants had the opportunity to directly manipulate different parameters of the visual effects presented in the show (density, movement and color of the mist) with the artists, using a tactile interface implemented on iPAD (Fig. 1).

In the "Verbal exchange" intervention, participants had the opportunity to discuss with the artists about the phenomena they observed and the sensations they felt during the show, about the concepts and imaginary world evoked by the show.

In the "Control" intervention, participants were presented with a recent research in cognitive science that was completely unrelated to the show and had the opportunity to exchange about the results of this research.

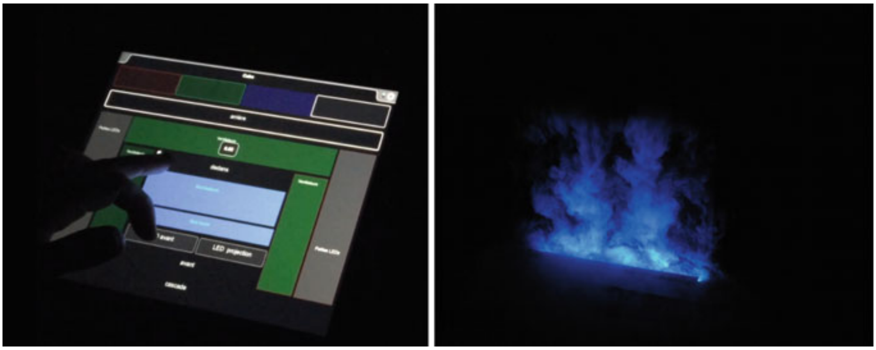

Fig. 1 Illustration of the tactile interface (*left*) and visual effects (*right*) associated to the art work *Sediments*

Procedure

The study took place in a large dark room on the research platform Equipex IrDive (Imaginarium, Tourcoing, France). Participants came to the platform on 2 occasions, one week apart. Each session lasted between 1 h and 1 h and a half. During the first session, participants first watched the artistic show *Sediments* performed by the Baltazars (18 min). Then, they were asked to fill out two questionnaires, the State-Trait Anxiety Inventory (STAI) and the Rosenberg Self-Esteem Scale, for a global assessment of their well-being. Finally, they took part in one of the three interventions: Manipulation, Verbal Exchange, or Control for 15 min. Participants came back for the second session one week later, still in small groups of 2–3. They watched the artistic show *Sediments* and filled out the questionnaires a second time. The procedure is summarized in Fig. 2.

Gaze and Neurophysiological Measurements

Eye movements and electrodermal activity were individually recorded in situ during the two exposures to the 18-min show with SMI eye-tracking glasses (30 Hz) and Affectiva Q sensor bracelets (32 Hz) (Fig. 3). Duration of fixations, number of fixations, and amplitude of saccades were averaged for each session of each participant over time bins of one minute. The level of electrodermal activity (EDA) throughout the show was also averaged over 1-min time bins, after subtracting an individual baseline level (electrodermal activity during the first 2 min).

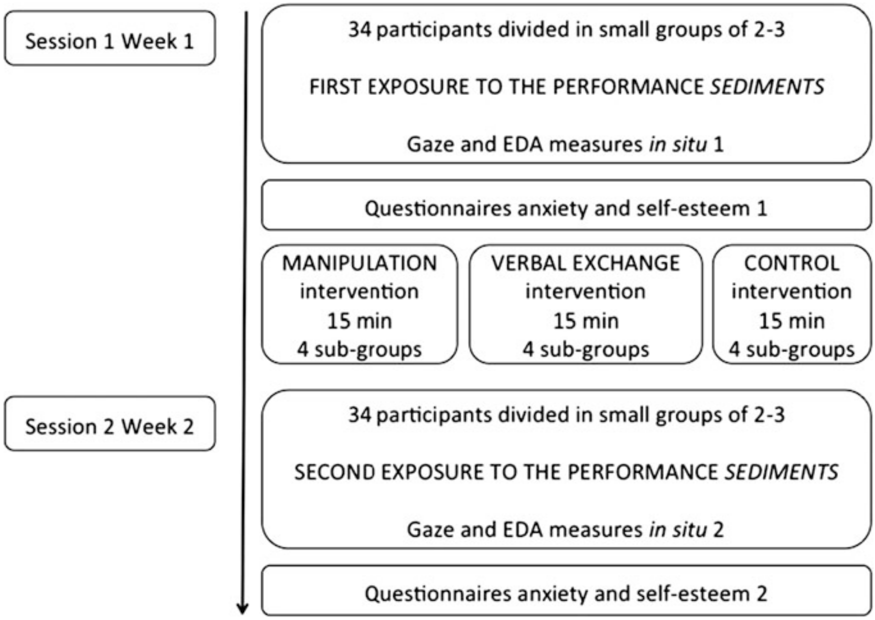

Fig. 2 Illustration of the experimental procedure used in the present study. Participants took part in one of 3 possible interventions between the two exposures to the show

Data Analysis

Gaze and EDA measures were analyzed as a function of Time, Session, and Intervention using multilevel mixed-effect models (lme4 package of R version 3.2.0). Change over time (between 1 and 18 min) was modeled with fourth-order polynomials with random effects of participants on all time terms. The fixed effects of Session (1, 2), Intervention (Manipulation, Verbal Exchange, and Control), and their interaction were added individually, and their effects on model fit were assessed using model comparisons. We were particularly interested in the Session × Intervention interaction model, reflecting how the changes between session 1 and 2 differed as a function of the type of intervention. Overall changes between session 1 and 2 would simply reflect the effect of repeated exposure to the show. Thus, our main goal was to test whether interventions would impact gaze patterns and EDA beyond the effect of simple repetition.

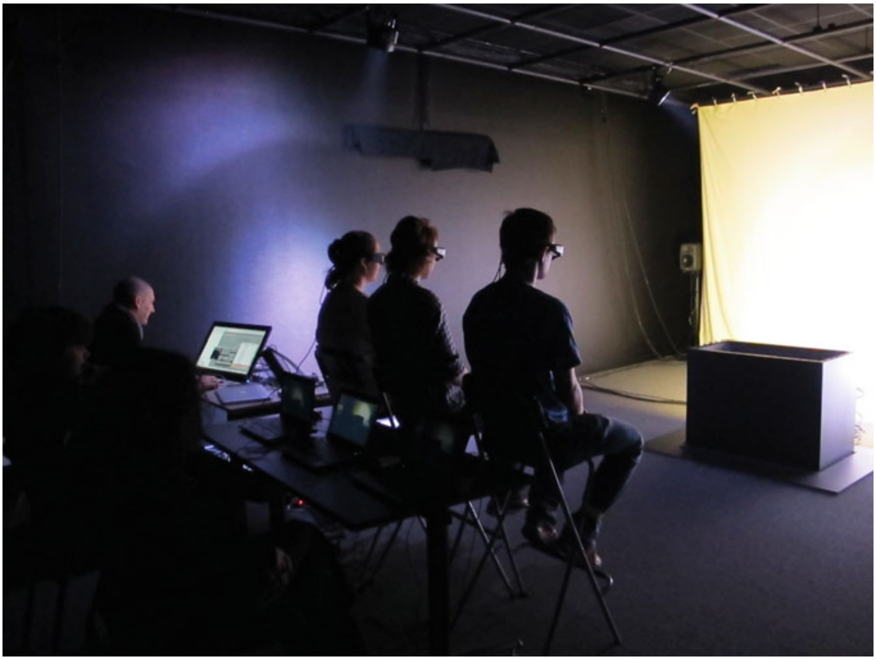

Fig. 3 Illustration of gaze and EDA recording in situ

Results

Gaze Data

Complete gaze data sets were available for 27 participants (10 in Control, 9 in Verbal Expression, and 8 in Manipulation intervention), after excluding missing data for technical reasons or absence of participants to the second session.

Duration of Fixations (Fig. 4)

Overall, mean fixation duration was not significantly different between session 1 and session 2 (estimate = −13 ms, t = −1.41, standard error (SE) = 10 ms, $p = 0.16$). However, interventions changed how fixation duration evolved from session 1 to session 2. Compared to the Control intervention, the two interventions focusing on the artistic performance led to a decrease in fixation duration between session 1 and session 2 (estimate Manipulation −85 ms, t = −3.63, SE = 23 ms, $p = 0.001$; estimate Verbal Exchange = −178 ms, t = −7.88, SE = 23 ms, $p = 0.001$). This pattern is highlighted in Fig. 4. In the control group, mean fixation

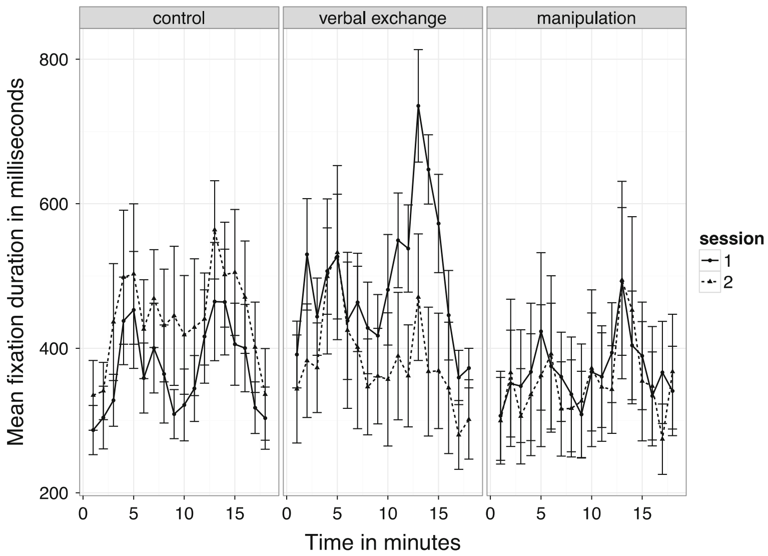

Fig. 4 Mean fixation duration as a function of time, session, and intervention

duration increased from session 1 to session 2 (estimate = +71 ms, t = 4.12, SE = 17 ms, p = 0.001).

Number of Fixations (Fig. 5)

Similarly, mean number of fixations was not significantly different between session 1 and session 2 overall (estimate = +3 fixations, t = 1.82, SE = 2 fixations, p = 0.06). Yet the difference varied importantly as a function of the type of intervention. Compared to the Control intervention, the two interventions focusing on the artistic performance led to an increase in the number of fixations between session 1 and session 2 (estimate Manipulation +22 fixations, t = 3.92, SE = 4 fixations, p = 0.001; estimate Verbal Exchange = +13 fixations, t = 3.11, SE = 4 fixations, p = 0.002). In the control group, mean number of fixations decreased from session 1 to session 2 (estimate = −7 fixations, t = −2.55, SE = 3 fixations, p = 0.01).

Amplitude of Saccades (Fig. 6)

Mean saccade amplitude was not significantly different between session 1 and session 2 overall (estimate = 0.06°, t = 0.65, SE = 0.09°, p = 0.51). However, there were again important differences between interventions. Compared to Control, Verbal Exchanges increased saccade amplitude (estimate = +1.28°, t = 5.80,

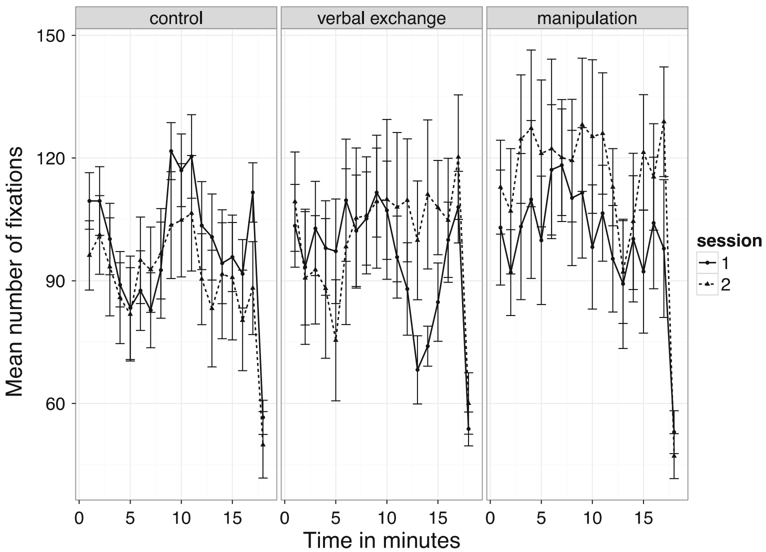

Fig. 5 Mean number of fixations as a function of time, session, and intervention

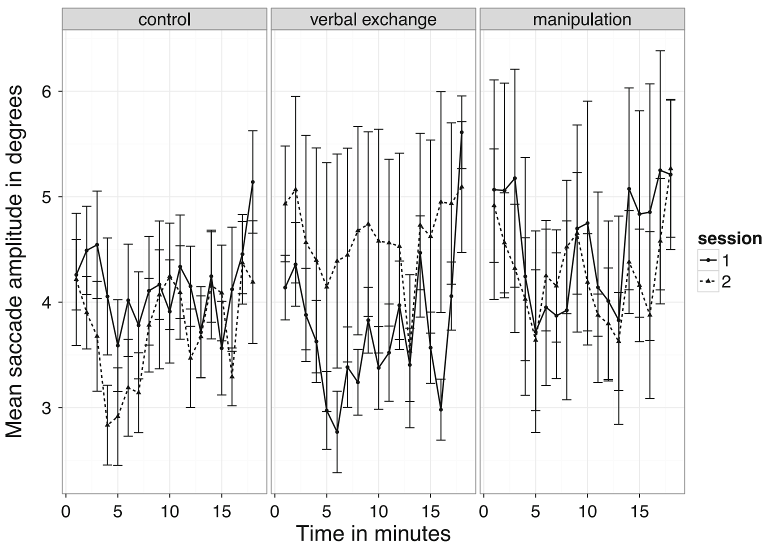

Fig. 6 Mean saccade amplitude as a function of time, session, and intervention

SE = 0.22°, p = 0.001). The effect of Manipulation on saccade amplitude did not differ significantly from Control (estimate = +0.14°, t = 0.59, SE = 0.23°, p = 0.56). In the control group, saccade amplitude decreased from session 1 to session 2 (estimate = −0.40°, t = −3.31, SE = 0.12°, p = 0.001).

EDA Data (Fig. 7)

Complete gaze data sets were available for 27 participants (9 in Control, 8 in Verbal Expression, and 10 in Manipulation intervention), after excluding missing data for technical reasons or absence of participants to the second session.

Whereas overall, EDA level increased from session 1 to session 2 (estimate = +0.21 μS, t = 4.94, SE = 0.07 μS, *p* = 0.001), it decreased in the control group (estimate = −0.39 μS, t = −9.21, SE = 0.04 μS, *p* = 0.001. Compared to the Control intervention, the two interventions focusing on the artistic performance led to an increase of EDA between session 1 and session 2 (estimate Manipulation = +0.67 μS, t = 7.04, SE = 0.09 μS, *p* = 0.001; estimate Verbal Exchange = +1.21 μS, t = 12.14, SE = 0.10 μS, *p* = 0.001).

Impact of the Level of Art Expertise

In each intervention group, some participants had a background in art whereas others did not. Since art expertise has been shown to influence gaze patterns and neurophysiological responses to art work, we ran complementary analyses that integrated this variable to our experimental design. Despite small sub-groups of experts and novices in each intervention (3–5 participants), and a certain heterogeneity in the groups of experts, we found that art expertise had a massive impact on the effects of interventions. For each gaze and EDA measure, the type of

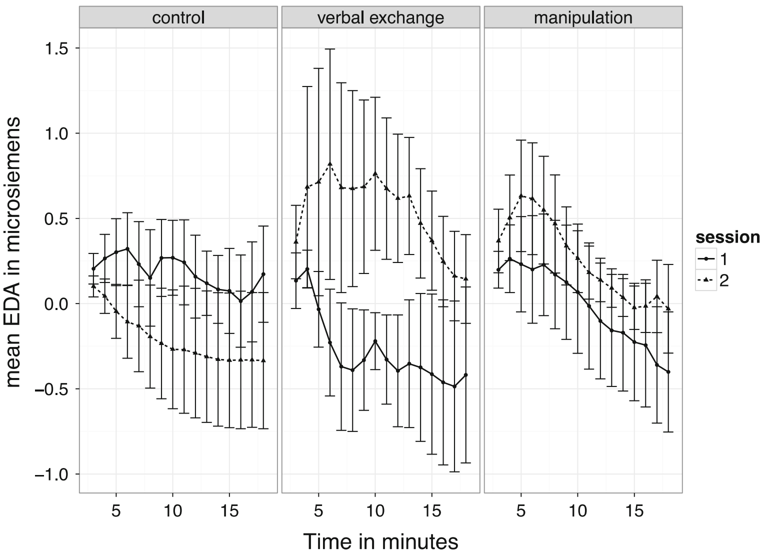

Fig. 7 Mean EDA as a function of time, session, and intervention

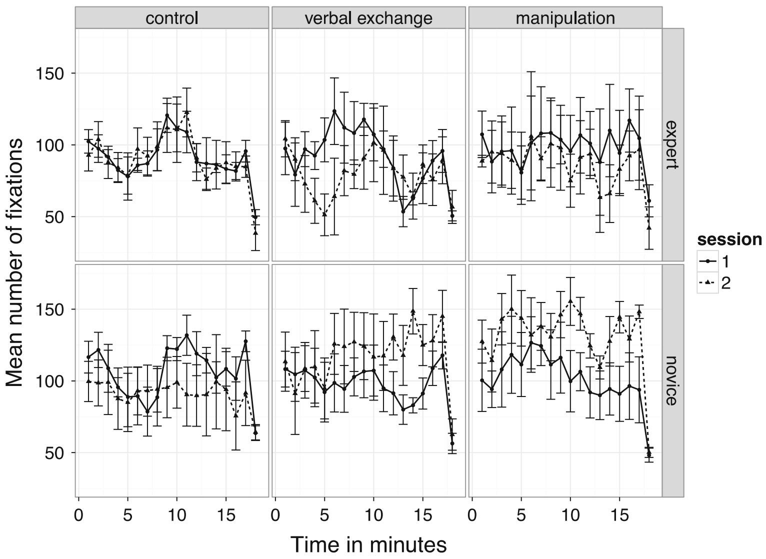

Fig. 8 Mean number of fixations as a function of time, session, intervention, and expertise

intervention had an important effect on the changes between session 1 and session 2 for art novices, while it had little impact for art experts. An illustration of the influence of art expertise on changes in the number of fixations is provided in Fig. 8.

Relation Between Changes in Fixation Duration, Fixation Number, Saccade Amplitude, and EDA

In the sample of 25 participants for whom we had both gaze and EDA data, we tested the correlations between the changes between session 1 and 2 on the different measures. Changes in fixation duration were negatively related to changes in fixation number: an increase in the number of fixations after participating in the intervention was associated with a decrease of fixation duration ($r = -0.73$, $p = 0.001$). Moreover, changes in EDA tended to be positively related to changes in saccade amplitude: an increase of saccade amplitude after participating in the intervention tended to be associated with an increase of EDA ($r = 0.35$, $p = 0.09$).

Questionnaires Assessing Anxiety and Self-esteem

Anxiety, as measured with STAI-B scores, diminished between session 1 and session 2 overall (estimate = −1.24 point; t = −2.60, SE = 0.48 point, $p = 0.01$). Yet there was no specific effect of the type of intervention on the importance of this reduction.

Summary of Findings

Simple repeated exposure to the show influenced eye movement patterns and electrodermal activity. In the control group, fixation duration increased from session 1 to session 2 while fixation number and saccade amplitude decreased. EDA also decreased from session 1 to session 2.

Interventions focusing on the show impacted eye movement patterns and electrodermal activity during the perception of the performance, beyond the effect of repeated exposure. Compared to Control, both Manipulation and Verbal Exchange interventions decreased fixation duration, but increased fixation number and EDA. Nonetheless, the two interventions showed a few specific effects on perception. Verbal Exchange influenced fixation duration and EDA more than Manipulation, and further increased saccade amplitude. In contrast, Manipulation increased fixation number more than Verbal Exchange. Moreover, the impact of interventions on eye movement patterns and electrodermal activity was sensitive to the level of art expertise of the viewers, and was emphasized in novices.

Discussion and Conclusion

The present study assessed the impact of different types of interventions on eye movement patterns and electrodermal activity measured in vivo during the perception of an abstract artistic performance, beyond the effect of repeated exposure. The effects of simple repeated exposure on the perception of the 18′ abstract artistic performance corroborates previous findings from studies on the perception of static art work such as paintings (Zoï Kapoula and Lestocart 2006; Pihko et al. 2011; Vogt and Magnussen 2007). Observers tend to make fewer but longer fixations, associated with saccades of smaller amplitude, on the second exposure to the show. Moreover, they experience less emotional arousal and less anxiety, as witnessed by EDA recordings and questionnaires. In other words, repeated exposure to the same piece of art work tend to reduce both visual exploration and emotional arousal, and it would be possible to generalize this effect to very different categories of art (e.g., concrete and abstract paintings, abstract visual art performances).

The comparison of the effect of different types of interventions on art perception revealed that interventions focusing on the show, regardless of their specific content, tend to invert the effect of repeated exposure. Participating in an activity related to the artistic performance increases visual exploration and emotional arousal. Interestingly, art novices seem to benefit from the interventions more than experts. All happens as if interventions provided some art expertise to the observers: interventions make novices' perception of art become closer to experts' perception of art. This finding is consistent with the observation of Pihko et al. (2011), who found that the gaze patterns of novices during painting exploration became closer to those of experts after they received information about the painting, and suggest, again, that the effect of interventions and expertise may be applied to a great variety of artistic fields.

In addition, interventions increase visual exploration in different ways depending on their content. Verbal exchanges lead to a *global visual exploration* of the artistic performance (shorter fixations and larger saccades, no important change in the number of fixations) whereas manipulation of the visual effects of the show leads to a more *local visual exploration* of the artistic performance (shorter but more numerous fixations, no important change in the amplitude of saccades). These differences reflect different ways of exploring a piece of art work, with a more global *versus* analytic approach, that will be elicited by focusing on language/imaginary *versus* action/visual effects when interacting about the show. Thus, manipulating the visual effects of an artistic performance via a tactile interface has a selective effect on the subsequent perception of the performance. An important remaining question concerns how visual effect manipulation is implemented on the tactile interface. In the present study, there was an analogical correspondence between the interface and the technical parameters of the artistic device responsible for the visual effects. The design of the interface, oriented towards a somehow analytical understanding of the visual effects (a single action is associated to a single effect), may account for the patterns of local visual exploration observed after the Manipulation intervention. One possibility is that a more global conception of the interface, where a single action pilots a set of visual effects that covary, may lead to a global visual exploration of the show. This hypothesis should be tested in future research.

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Variations in Visual Exploration and Physiological Reactions During Art Perception When Children Visit the Museum with a Mobile Electronic Guide

Laurent Sparrow

Abstract The present study focuses on painting perception during the visit of a museum and aims at evaluating how a portable technological interface may improve young children's perceptual experience in the museum. A tablet-based educational platform targeting young public have been designed for a museum (Museo+, *Palais des Beaux Arts de Lille*) in accordance with *Design for All* recommendations. Physiological (electrodermal activity) and eye tracking data from 2 subjects were collected during a museum visit mediated by the mobile device Museo+. Results showed that children behave differently but each one has manifested some interest for the visit. Moreover, our methodology allowed us to obtain objective data concerning the usability of the application and detect which in-game events triggered arousal and engagement.

General Introduction

The purpose museums is to acquire, preserve, communicate and exhibit the pieces and contents of their collections and it is also certain that they have become part of the actual educational process and for all kinds of public. Technology has enabled museums to explore new ways to provide visitors with richer experiences, and many museums have employed audio tours with customized mobile devices. Different electronic guides with sign language videos and audio descriptions are beginning to be introduced in museums with the aim of allowing disabled visitors to explore them in a more independent and adaptable way. But as museums explore

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these new technologies it is important to consider the affordances of the specific technologies. A museum visit which is supported and mediated by mobile technologies can improve the visitors' motivation by stimulating their imagination and their engagement, allowing better learning because knowledge is constructed through interaction with objects and people. But it becomes increasingly important to ask if we are fulfilling the needs of all children and if these new technologies grant everyone access to culture. The aim of this study was to test the usability of a mobile device to provide a better experience for all kinds of young public, disabled or not, with a new methodology based on wearable technologies.

Background

With recent advances in wearable biosensing technologies it is now feasible to monitor not only outwardly observable behavior, but also inward physiological states of people during naturalistic situations like a visit in the museum. Neurosciences research has shown that there are a number of physiological correlates, such as skin conductance, by which the experience of a spectator may be embodied (Höfel and Jacobsen 2007). The autonomous nervous system (ANS) regulates fundamental functions of the body independently of volitional control. This system has two branches: the sympathetic branch mobilizes energy in stressful situations, whereas the parasympathetic system conserves and restores our resources in the absence of environmental pressure. Electrodermal activity (EDA) is a sensitive index of sympathetic nervous system activity witch refers to the variation of the electrical properties of the skin in response to sweat secretion. The sympathetic nervous system stimulates increased metabolic output to deal with external challenges. Changes in EDA provide a sensitive and convenient measure of assessing alterations in sympathetic arousal associated with emotion, cognition, and attention (Boucsein 2012). One can distinguish between tonic and phasic EDA. Whereas tonic refers to long-term skin conductance level indicating vigilance, sustained attention, phasic EDA reflects an event-related skin conductance response.

The existence of wearable gaze tracking glasses has also created the possibility to measure gaze behavior under naturalistic conditions. Eye movements provide an unobtrusive and real-time behavioral index of ongoing visual and cognitive processing. Eye movement research indicates that people can switch between two attentional states, local and global attention (Liechty et al. 2003). The focus of the local attentional state is on specific aspects and details of a scene and on examining its content with greater visual detail. The focus of the global attentional state is on exploring the informative and perceptually salient areas of the environment. In local visual attention, stimuli are explored in detail by extracting information from specific and adjacent locations, and it is characterized by shorter saccades. In global visual attention, stimuli are explored to identify locations to extract information, and possibly to integrate the information from various locations in the stimulus. It is characterized by longer saccades.

Several educational games and the technology supporting them (Museo+ PBA Lille), have been designed for the *Palais des Beaux Arts* (Lille) by a society (Signes de Sens), who is specialized in the conception of educational products in accordance with *Design for All* recommendations. These good practices aim to ensure that anyone, regardless of age, gender, capacities or cultural background can participate in social, economic, cultural and leisure activities with equal opportunities. Museo+ PBA Lille is an application designed for tablets around a specific educational scenario where the users, children aged 6–15, are challenged to act a role and carefully complete designed pedagogical tasks. The activities proposed by the software are taking place in several stages. At first, participants must seek an artwork in the museum, with the help of a map presented on the tablet. Then, once they have found the artwork, the application presents an historical fact about it and then offers fun activities regarding this artwork.

Aim of the Study

The present study focused on the impact of new technology on visitors' experience. By collecting physiological and eye tracking data from 2 subjects who participated in a museum visit, we investigated whether this data would allow us to recognize whether participants felt good or were stressed by the device and which in-game events triggered arousal and engagement.

Methods

Participants

The first participant was a 15-year-old boy who was diagnosed with a severe form of autism with, in addition, a social anxiety disorder (an excessive and unreasonable fear of social situations). The second participant was a 14-year-old boy with no particular developmental disorder.

Technical Setup

A SensoMotoric Instruments (SMI) ETG eye tracking system was used to measure gaze behavior under naturalistic conditions. The SMI-ETG is a lightweight (76 g) pair of glasses with a mounted binocular system that uses dark pupil tracking to measure the point of gaze with a spatial resolution of 0.1° and temporal resolution of 30 Hz, with a built-in high-definition scene camera.

Physiological data was collected using the Affectiva Q Sensor which measures skin temperature and skin conductance (i.e. electrodermal activity) at a sampling rate of 32 Hz. It also has a built-in accelerometer that outputs three-dimensional relative displacements of the sensor. The Q-sensor was worn on the inside surface of the wrist of the non-dominant arm. The equipment took about 15 min to set up and 2 min to dismantle.

Procedure

Upon arrival, participants were fitted with the Q-sensor wristband. After that, in a quiet room of the museum, instructions were given by the experimenter. Then, participants were fitted with the SMI-ETG system and a calibration was made. After a 5 min habituation period, Museo+ PBA was given to the participant and he was free to use it as he wanted.

The application begins with a short video explaining the scenario of the game: a passionate of art, who collects posters of artworks, prepares at home her next visit to the *Palais des Beaux Arts* (*"Palace of Fine Arts"*, Lille, France). But a little mischievous character, "Mange-Tout" (*"Eat All"*), has disorganized her files. She needs the children's help to put them in order. After this short presentation, 3 training games are proposed to verify if the participant knows how to use the tablet, in particular, to verify whether the gestures "tap" and "press and hold" are executable. Then a map showing the locations of the seven artworks is presented (one pottery, two antique portraits, two sculptures and two paintings of the twentieth century). The participants visits the museum and when they find the artwork, they taps on the icon "I found it!. Then the explanations occur and the games begin. To go further, participants must see all the videos and complete the different tasks. The visit lasts between 45 min and 1 h depending on the pace of children. The application contains 30 min of video and 10 interactive games. All videos are dubbed in French Sign Language (LSF), with a voice-over and subtitling.

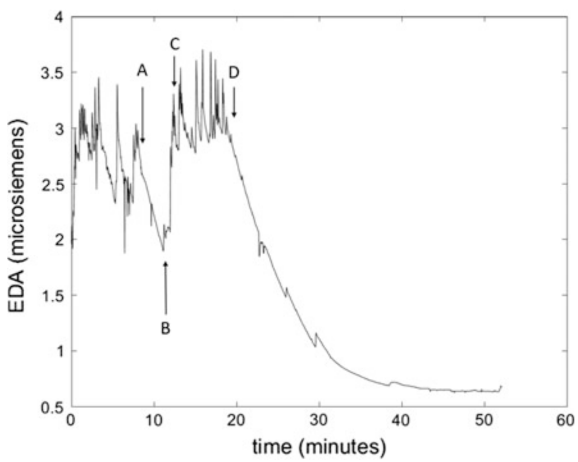

Fig. 1 Skin conductance level (microsiemens) for P1. Arousal increased upon arrival. Activation dropped when instructions were given in a quiet room (*A*) and was stable after the participant was fitted with the SM1 ETG and calibrated (*B*). Skin conductance increased when the participant started to use the Museo+ PBA application (*C*). The participant started to visit the museum when the skin conductance level decreased (*D*)

Results

P1 was diagnosed with a social anxiety disorder and a guided tour in a museum may be very painful for him. Effectively, as we can see in Fig. 1, arousal escalates upon arrival in the museum.

Instructions were then given to the participant in a quiet room of the museum and, at this moment, the level of activation dropped, even after the participant was fitted with the SMI-ETG system (Fig. 1). When the participant started to use the Museo+ PBA application, the skin conductance level increased again with a burst of high frequency peaks indicating a high stress level. At the same time, the participant experienced difficulties to use the application and he was not able to complete all of the training exercises without help. Theories on the relationship between stress arousal and performance share the view that a certain level of stress arousal is favorable for optimal performance, while a too low or too high level can have adverse effects (Driskell and Salas 2013). Perception, attention, memory, decision making, problem solving and response execution are stages of information processing that can be degraded by a high stress level, and it seems to be the case here. But the scenario proposed by the application and the interactions between the characters (a passionate of art and a mischievous personage) were able to capture the attention of P1. The skin conductance level progressively decreased which permitted to P1 to obtain his first success in one of the games. After this stress period, the participant was able to profit from the guided tour.

As we can see in Fig. 2, as soon as tonic and phasic EDA activation dropped a local pattern of eye movements occurred, with smaller saccades and longer fixation times. In local visual attention, a scene is explored in detail by extracting information from specific and adjacent locations. It has been suggested that higher-order (cognitive, semantic…) information is more likely to be extracted while subjects are in a local attention state, while the global covert attention state serves to redirect attention to perceptually salient or potentially informative regions of the environment (Liechty et al. 2003). P1 recordings showed us an increase in local attention

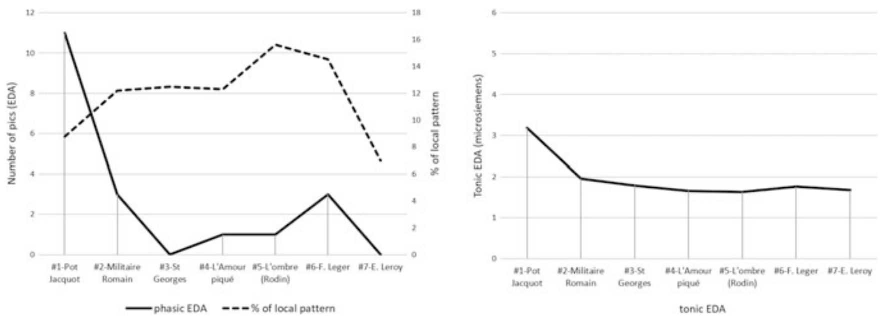

Fig. 2 Number of pics and % of local pattern of fixations (*left panel*) and tonic EDA (microsiemens) for the 7 artworks for participant #1

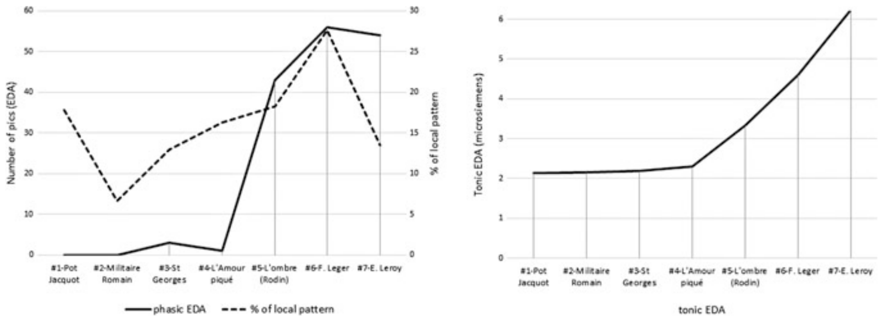

Fig. 3 Number of pics and % of local pattern of fixations (*left panel*) and tonic EDA (microsiemens) for the 7 artworks for participant #2

state for 2 artworks («*L'ombre*» from Rodin and «*Les deux femmes au vase bleu*» from F. Leger) accompanied by an increase of phasic EDA, mostly for the artwork of F. Leger.

For the second participant (P2) we observed an increase in local attention state for first artwork but which decreases rapidly. The tonic and phasic EDA activities were also very low. But at the time of the encounter with Rodin's sculpture, a significant increase was observed in phasic and tonic EDA activity accompanied by a significant increase of local attentional state (Fig. 3).

Discussion

In this study, we collected physiological and behavioral data including skin conductance which is considered as an arousal or a stress measure as well as gaze behavior data from 2 participants who participated at a museum visit supported and mediated by mobile technologies. We then investigated whether these data would allow us to recognize whether participants felt good or were stressed by the device and which in-game events triggered arousal and engagement.

The results of this study showed us that our methodology has allowed us to obtain objective data concerning the use of the application. For the first participant, the Muséo+ PBA permitted to control the stress and excitation level, which then allowed the child to enjoy his visit. The level of engagement remains relatively stable throughout the visit. The pattern of results was different for the second participant: the child's interest gradually increased to become important at the midpoint of the visit. Therefore, even if children behave differently, each one has manifested some interest for the visit. So, the use of a mobile device to provide a better experience for all kinds of young public, disabled or not, can be very promising.

Acknowledgments The results presented here were part of a larger, multi-faceted investigation of children's interactive and informal learning in museums undertaken by the Palais des Beaux-Arts (Lille, France), a three-year research project funded by *Conseil Régional du Nord-Pas-De-Calais*, and 3 laboratories (GERIICO, SCALab, Université de Lille and DeVisu, Université de Valenciennes et du Haineau-Cambrésis). This work was also funded by ANR-11-EQPX-0023.

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Part IV
Training and Teaching Through Art and Neuroscience

Steps Towards the Art of Placing Science in the Acting Practice. A Performance-Neuroscience Perspective

Daria Lippi, Corinne Jola, Victor Jacono and Gabriele Sofia

Abstract This chapter describes the 'Performer's cognition' workshop, a collaborative endeavour, thought and participated by artists, neuroscientists, and performing arts scholars. The main goal of the workshop was to stimulate actors' reflection on their practice by means of linking a number of exercises to current understandings and methodologies of cognitive neuroscience. Here, we aim at presenting this novel way in which cognitive neuroscience can inspire reflections on the training of the performer, starting from the experience of the workshop in relation to one of the exercises practiced, the '8 steps exercise'. We propose that the desired effects of continuous training may be achieved more efficiently when the underlying cognitive and neuronal processes have been explored. Also, we suggest that the relevance of continuous training will be more widely acknowledged through scientific explorations. This is of huge relevance, since actor training and in particular actors' motivational forces (or the lack thereof) to engage in training particularly as a form of continuous professional development, is still poorly understood. The closer look at actors' practice as discussed during the workshop and further examined here, will inevitably also impact on empirical research in the field of the actors' profession.

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Introduction

An actor on stage faces the challenge to capture an audience's attention and 'move' them performance by performance. While there is considerable discussion on how an actor can consistently succeed in this task, there is little consensus on the competences (or skills) required of actors. McVittie (2007), for instance, proposed that abstract competencies, such as maintaining a role or a character, establishing circles of attention, delivery of text, stage 'presence', and conveying the illusion of naturalism are vital. Since 'naturalism' is linked to a particular theatrical aesthetic, we propose the use of other terms, such as the facility to convey credibility and organicity (Ciancarelli and Ruggeri 2005). In either case, a better understanding of the requirements of an actor to perform a role convincingly and repeatedly through voice, gesture and movement is of great interest to the actor, the curious spectator, as well as directors and teachers. At present, however, the exact required capacities remain unknown. Our aim is therefore to shift the focus from the discussion of which skills are needed to how the relationship of actors and their daily practice can be modified, in order to enhance their experiences by means of a more reflective and inquisitive approach.

With the objective to inspire performers and evidently increase their motivation for and in-depth reflection on their daily practice, we conducted an international workshop that proposed an interwoven practice linking cognitive neuroscience and daily exercises. The name of the workshop was 'The Performer's Cognition' and it was held in August 2015. This chapter takes the experience of the workshop as a point of departure. The objective was to enhance the validity and contingency of deliberate training by incorporating a reflective stance from cognitive neuroscience. In other words, our approach is to employ knowledge from cognitive neuroscience to inspire reflection on the training of the performer—before, during, and after practice. This is a novel approach in the theatre profession whereas in dance, for example, cognitive neuroscience has infiltrated practice, performance, and spectatorship over the last decade (Bläsing et al. 2012; Jola 2010; Jola et al. 2011; Karpati et al. 2015). Based on these experiences, the participation of scientists in theatre practices such as ours, are over time also expected to feedback to the way science is conducted.

Clearly, a better grasp of the cognitive and neuronal processes underlying continuous actor training will increase our understanding of the latter's effects. Thus such a transdisciplinary practice is predicted to become more appreciated and eventually its effectiveness further enhanced. This is of huge relevance, since actor training as continuous professional development is still poorly understood. At this point in time, we focus however on the actor's enhanced reflection and awareness of the processes involved in the exercises. We agree that empirically validated scientific explanation of the processes involved in the exercises can be beneficial, in particular in the selection of specific exercise. However, as a first step, it is crucial to explore the phenomenal experiences when introducing neuroscience to the performing profession. There are several reasons for doing so. Overall, it is known that evidence-based knowledge is not a driving force in altering an individuals' behavior. For the field of actors' profession specifically, we know little about 'which exercises exist' and 'who practices them' and with 'which effect'. Hence, as a first step, a more general experiential approach can give insight into the pertinent elements of the practice. The current chapter thus takes the standpoint that a stimulated questioning of the practitioner itself can act as a catalyst for enhanced engagement with continuous practice.

Actors' Daily Practice: Some Empirical Background

A common starting point for many prospective experts in the performing arts or the sciences is attending some form of formal education in their chosen field. It does, however, not stop there. Successful actors and directors emphasize that natural talent alone does not produce great performances, and that thorough training as well as continuous professional practice are the cornerstones of good performance (Prior 2012). In other words, while it is almost impossible to pinpoint individual capacities or skills that are required of actors, we do know that daily practice can provide them. This is somewhat of a conundrum which may be one of the reasons as to why actors often do not engage in daily practice—as unfortunately, in our experience and as further outlined below; there is little engagement in the acting profession with daily practice. We argue that it is thus of primary importance to increase actors' desire to engage in daily practice even though we cannot identify specific requirements or an individual targeted exercise at this point in time.

Despite a large body of theoretical debates on developing the actor's performance abilities (e.g., Chekhov and Prey 1985), there is very little empirical evidence on how contemporary actors maintain or perfect their practice over time. Empirical data regarding the professional life of actors and their daily practice is sparse. To our knowledge, the French national survey on the practice of professional acting, initiated by the Ministry for Culture and Communication and conducted by the Arts Sociology Centre run by Pierre-Michel Menger only a decade ago, is the only available empirical source to date. The findings support the prevalent observation of experts in the acting sector: actors think they learn on the go, while their engagement in training is limited (Patureau 1999). The perception that it is feasible for actors to pick up the essentials tools in a rather unplanned manner persists even though most casually employed actors underwent a training specific to the actor's trade. In fact, 85 % of the actors participating in the survey had undergone at least one form of professionally-oriented drama training, such as private classes, municipal and regional academies/conservatoires, courses with the National Drama Centres, university drama studies or internationally highly acclaimed establishments. Notably, when asked about what they do when not employed—which is an essential feature of an actor's life—regular deliberate training is not named. Instead, an actor spends most of the time out of contract in search for new work. Hence, when actors report that the challenges of their profession require them to continually revise their professional skills and knowledge, one is left to wonder how they actually do that. Based on this report and everyday observations in the profession, we suggest that actors do not engage sufficiently in regular training. We therefore aim to foster continuous deliberate training in order to support actors in producing expert performances of high quality.

Notably, some state that only peripheral skills such as vocal projection or body flexibility can be trained through deliberate repetitive practice (e.g., Noice and Noice 2006). Nevertheless, it is important to acknowledge that any expert compared to a non-trained individual performance—whether in acting, music, or dance—is considered to be based on a qualitatively different representation and organisation of knowledge (Ericsson et al. 1993). Ericsson also proposed that on average 10,000 h of deliberate practice are necessary in order to become an expert or master in a given field. Notably, Ericsson describes the activity of practitioners aimed at achieving professionalism as 'deliberate practice', which includes frequent training as well as initial formation studies. Here, we focus on continuous training within the profession, excluding the stages of early formation.

The 'Performer's Cognition' Workshop

The dialogue and interaction between cognitive neuroscience and the performing arts has increased substantially over the last decade (e.g., Hagendoorn 2004; Blair 2008; Sofia 2009, 2013a; Bläsing et al. 2010; Calvo-Merino et al. 2008; Jola 2007; Kemp 2012; Shaughnessy 2013; Falletti et al. 2016). Cross-disciplinary enquiries led to numerous conferences and seminars worldwide. Nevertheless, the performer's learning and creative processes as core elements of performance practice were rarely investigated. In particular, most early studies on the brains of dancers focused on the effects of spectators' expertise when watching dance movements. Here, we describe the first international workshop, 'The Performer's Cognition', the focus of which was precisely that of creating an environment in which inputs from cognitive neuroscience may directly engage the performers' experiences in their practices (acting, dance, music, acrobatics).

To this end, the Fabrique Autonome des Acteurs (FAA),[1] in collaboration with the Sorbonne University Paris 1-CNRS, the University Paul Valéry of Montpellier and the independent performance group CoCoDanse, invited researchers, artists, performers and theoreticians to participate in a practical and theoretical workshop, held between 26 and 29 August 2015, at the picturesque locality of Bataville, the

[1]The Fabrique Autonome des Acteurs (FAA) is an association founded in 2014 to provide an autonomous workspace for artists pertaining to diverse performance disciplines. Its purpose is to promote continuous learning for performing arts professionals, basic research, and transdisciplinarity via concrete actions. Within its Laboratory, the FAA focuses on the dialogue between performer's practice and science, discovering privileged interlocutors among researchers linking theatre and neuroscience. Thus, the project entitled "The Performer's Cognition" presents an original interdisciplinary format, in which theoretical sessions are suggested, stimulated and addressed precisely by the performer's practice. Photographic and video archives of the workshop (included the 8 steps exercise described below) as well as information on the ongoing research can be found on the web site (www.fabriqueautonome.org).

former industrial complex, now converted in a space for artistic research at the very heart of the forest in the Pays de Étangs (France).[2]

The workshop welcomed 24 participants from 9 different countries: the United Kingdom, France, Italy, Spain, Rumania, Switzerland, Belgium, Poland and Malta. 15 of them were professional artists (7 in the field of dance and 5 in the field of theatre) and 9 researchers (from various disciplines including neuroscience, cognitive science, cognitive psychology, history of arts, economics, phenomenology and neurobiology of foreign languages). Each working day was organized in order to interweave practice (exercises led by the authors) and conferences,[3] with a space dedicated to open practical and theoretical sessions, some of which were proposed by the participants themselves. The workshop's objective was to explore the relationship between performance practices and neuroscientific research. The primary questions addressed during the workshop were: Can neuroscience contribute to your individual experience of performance practices? If yes, how? Further, could the systems of knowledge developed by the performer reciprocally contribute to neurocognitive disciplines? Notably, in a post-workshop questionnaire, artists reported to have engaged with these questions beyond the workshop. We recognize that research compared to artistic outcomes instigated by the workshop will require even more time to substantialize. We are positive that the influence on the researchers' methodologies will however become evident in the near future.

Actor Training Challenges

Actor training has always been a complex topic to discuss. In the present age of hybrid theatre aesthetics and poetics, the issue of continuous training has arguably become even more of a Gordian knot. In our workshop, as noted above, we placed training at the interface between pedagogy and research, and we looked at this interface as an ongoing cultivation of the art's primary instrument: the performative self.

By training, we refer to a deliberate practice of varied duration (e.g., between 20 min and several hours), consisting of procedures—or exercises—that put the actor to work on the foundations of his/her craft (e.g., Savarese and Brunetto 2004). We will further exemplify what we believe constitutes important structural elements

[2]Bataville is the name given to an industrial complex and workers' residence, built in the 1930s by Tomas Bata, founder of the namesake shoe brand. Located at the heart of Moselle, in Lorraine region, it is surrounded by forest trees and ponds. Its remarkable Bauhaus architecture earned it the recognition of Heritage of the twentieth century. The variety and the beauty of its working and living spaces, together with its feeling of quiet isolation, provide artists and researchers the opportunity to truly immerse themselves in their work, be it a seminar, a laboratory or a creative residency.

[3]The titles of the conference were: Gabriele Sofia: *Action in theatre and neuroscience.* Corinne Jola: *Experimenting with Sensory Experiences in the Lab/in the Studio; Empirical Evidences of Shared Kinaesthetic Experiences.* Victor Jacono: *Erasing and drawing lines*. Daria Lippi: *My theatre, advanced techniques explained to my neighbours*.

for such procedures with reference to a specific exercise, the '8 steps' (see below). Notably, this exercise was one of several training exercises practiced during the workshop. The '8 steps' has been chosen specifically as it trains an action hugely relevant as a basic tool for actors on stage: direction turns. According to Prior (2012), actors often struggle to correctly turn facing the audience, even after formal training. Further, the '8 steps' has important elements of collaboration and attention (see 5.1.3 for more details). Last but not least, it was one of the most liked exercises as evidenced in the post-workshop questionnaire.

In general, an acting exercise is built on one or more constraints (or limitations) similar to those used to find novel and/or creative solutions in dance improvisation (Torrents et al. 2015) as well as in sports training (Hristovski et al. 2006). The effects of constraints on creative solutions have also been explained for complex neurobiological systems (Hristovski et al. 2011). Yet, although physical constraints are present in the exercise described here, the focus during the workshop was on its social and attentional components. In this chapter we discuss primarily the attentional components.

As already indicated above, it is relevant to distinguish between initial training (i.e., formal education), continuous training or practice, and warming up exercises. Just like the athlete or the singer, the actor prepares his/her voice and body for the extra-daily effort required during rehearsals, performance or training. The difference between warming up and training is, therefore, subtle, yet relevant.[4] Training engages the performer completely and creatively, in a way that is comparable to the work on stage during a performance. The aim of training is not just to improve physical skills, but to explore a different logic in any given action, as well as to enhance sensory awareness and to provide a new way of organizing the body-mind system of the performer. Hence, training is not something that occurs before or in preparation for the theatre, but it constitutes a dimension that is integral to the work in the theatre. The essence of acting is, as some argue, not based on the training of peripheral skills but consists paradoxically of successive attempts to refrain from repeating yesterday's rendition, to create the events anew at each moment of every performance (Noice and Noice 1997). Contrary to the assumption that only peripheral skills can be trained, we argue that training supports the very attempt of refraining from repeating actions.

One of the many challenges for training are external constraints such as the time between one work commitment and another, as well as the need for an appropriate location and a group to train with. Such conditions are rare to find outside theatres. Notably, however, dancers face similar constraints yet engage in daily practice.

[4]Notably, there are considerable efforts in the field of dance to link 'warm-ups' and regular training with the creative process, such as 'pre-choreographic elements' (de Lahunta and Pascual-Bermudez 2013) or biological acting by Jan Fabre. Biological acting consists of several fixed exercises each performer who is participating in a working process with Jan Fabre has to go through. The idea that such exercises prepare for the creation is in line with research that proposed a new functionality of 'warm-ups': not to warm up the muscles but to activate representations of the desired actions (Ajemian et al. 2010). Hence, the idea of "warming-up" may be obsolete and should be discussed under the heading of mental preparation for performance.

Hence, with the right mind-set, these challenges can be overcome. Moreover, when actors venture into the so-called “physical theatre” or dance theatre, the demands on the performative apparatus become more apparent and performers are more likely to supplement rehearsals with “physical training”. Indeed, this is indicative of a culture that is, in fact, still deeply rooted in the body-mind dichotomy.

Hence, it is more likely that psychological constraints hinder the acknowledgement of the importance of deliberate training. While some may simply not think of training outside the rehearsal context to be of any importance, others struggle with the psychological pressures of the profession (e.g., loneliness). Moreover, even during rehearsals, many ensembles do not actively promote training. This may result from an implicit conception of the actor’s work as a performative exploration of everyday life issues and situations. Hence, some performers may believe that their consideration of everyday experience provides them with enough preparation for the roles they are to play (promoting the idea that psychological pressures are useful for the profession and not something the actor has to resolve). This conception could come from the fact that, unlike dancers or singers, the art of the actor does not necessarily imply showing an extraordinary action to the audience. We could even say that most actors do and say what every human being could do or say in everyday life. The difference simply is that the actor does it on stage, in front of an audience. It is indeed the presence of the spectators, and more precisely its effect on the actor, that tips ours scales in favor of the necessity for a demanding training for the actor.

Neuroscientific Reflections

One of the toughest prejudices considers the actor as someone who is very good at *imitating* reality. The actor is thought of as someone who “walks in the character’s shoes” so that she or he lives somehow through the situations experienced by the character she or he has to play. A spectator may thus be unaware that what they watch results from the creation of different dynamics that may sometimes be opposed to those ruling everyday life. Hence, the neuroscientist may also remain bound to a sort of “spectator ethnocentrism” (Barba 1995: 42), which leads him to consider an actor appearing perfectly natural on stage as someone who is perfectly “repeating” reality. This assumption ignores that such naturalness is just an *effect* made possible by the actor’s technique.

Such “spectator ethnocentrism” disregards an element that may be supposed to have precise physiological consequences: stage acting is not merely acting on a stage, but a kind of acting that is supposed to constantly keep, feed and rule the attention of the spectator. A practical example can maybe make this concept clearer: if an actor has to drink from a glass on stage, every motor act he is going to activate (“grabbing the glass”, “bringing the glass to his mouth”, “swallowing the water”, “put the glass again on the table”) will be aimed at performing the act of “drinking a glass of water”, but, although the action is factually the same and follows *the same* *series of motor acts* and is performed *in the same time*, it will be different, since the actor is here supposed to stimulate the spectator's attention. The actor's action is not only directed to an on-stage aim (drinking the glass of water) but also to the audience (stimulating the spectators' attention). The same action has at once two different aims. This gives rise to a "double intention" of the actor, or better to a *dilated intention* (Sofia 2013b) that broadens from the performed action out to the audience. We can reasonably suppose that such a "broadening" of the intention concerns a peculiar neuromotor dimension.

Further, unlike everyday life where every action gets reorganized according to the particular situation and the unexpected events, on stage, the actor knows the complete sequence of events that will take place during the performance, so that any possible contingency is minimized. However, the actor must be able to not anticipate the following actions and to render all the dynamics and ways of restructuring and reacting to the unexpected events as it occurs in the everyday behaviour. Although he knows exactly what is going to happen, the actor must recreate on stage such an *effect* that makes the spectator 'believe' that what is going on is 'really' unexpected and incidental, as it 'naturally' occurs in the everyday life. These two examples show the difference between everyday action and stage action, and allow us to remark that this difference is probably quite relevant. Considered in neurophysiological terms, it may concern the processes of action planning, postural control, decision making, body schema, etc.

Very recently, studies in cognitive neuroscience commenced to embrace a more complex perspective, one that calls for an inclusive methodological approach (Klein et al. 2010; Reason et al. 2016); renegotiating the sharp distinction between the body and the mind as present in the Cartesian mind-body dualism and the cognitive sciences at the time (Gallagher and Zahavi 2008). Current trends in cognitive neuroscience regard the body-mind more as a dynamic continuum emerging from processes connecting different levels of organization, from the neurobiological to the cultural level rather than placing the mind as the 'commander' instance (Jola, in press; Dijk et al. 2008; Kiverstein and Miller 2015).

Neuroscience contributes particularly to our understanding of processes of actors training by placing an emphasis on motor perception, motor prediction and execution. Research increasingly regards the nervous system as an instrument for action, rather than representation (Berthoz and Petit 2008). Such studies provide further evidence of the importance of training motor faculties as a way of enhancing the performative apparatus as a whole. For instance, training can lead to an enrichment of the individual's motor repertoire. Studies related to the mirror mechanism indicate that when a group of people train together, thus sharing their motor repertoire, they also enhance their creative potential, both individually and as a collective (Sinigaglia and Rizzolatti 2011). In this sense, cognitive neuroscience can contribute towards a deeper appreciation of why ongoing training, besides rehearsals, is important for creativity in performance. At the same time, the performing arts may contribute towards a more holistic approach in researching human cognition. The legacy of cognitive neuroscience is indeed abundant with reciprocal interaction and cooperation with performing arts cultures (see Jola 2010; Jola et al.

2012a, b; or Sofia 2014; for an overview). For example, Paul Ekman studied Stanislavski's techniques in order to highlight the links between emotional and facial expression (Ekman 1985). More recently, actors trained in Lecoq's technique joined the neuroscientific team of Julie Grèzes for a study on the mechanisms of emotional contagion (cf. Dezecache et al. 2013). Considering their expert ability to perform an emotional pattern with the whole body, one could argue that the emotional contagion evidenced by Grèzes and her team may not have been observed with non-trained actors. A similar observation of a study on watching dance showed that only in the experiment proper with professional performers were the predicted effects found, which were not evident in the pilot study with non-professionals (Jola et al. 2012a, b).

Notably, even interdisciplinary collaborations that may not lead to a direct empirical output are arguably still of fundamental epistemological value. One such example is the longstanding cooperation between the director and theatre scholar John Schranz and the neuroscientist Richard Muscat at the University of Malta. During their cooperation, Muscat started to look at the performer as a unique point of view on the human being and transferred that perspective to laboratory research which led to a deeper and more profound understanding of the limitations of neuroscientific research (Muscat and Schranz 2007). Moreover, the performing arts are contributing to the neuroscientific study of creative practices while giving further consideration to body and motor mechanisms. To this date, the role of the body is largely neglected in scientific research related to creative processes. This posits an evident contradiction to findings that highlight the impact of the body and the motor system on human cognitive functions (e.g., Spirduso et al. 2008). For this reason the study of the performer's cognition and creativity could lead neuroscientists towards an "embodied" methodology when considering creative practices, as proposed in some recent studies (Jola 2010; Sofia, in press).

The Exercise, The Science, and The Actor Scientist

The 8 Steps Exercise

We describe here one of the exercises proposed during the practice sessions part of the Laboratory. It's called the 8 steps (see Fig. 1).

The basic rules were transmitted to Daria Lippi by actor and director Arnaud Churin, who learned them from Jaques Brillant, himself an actor and aikido professor. The exercise was done by the entire group for at least one hour per day on the three days of the Laboratory.

Fig. 1 Participant of 'performer's cognition' workshop during the 8 steps exercise. Credits Andrea Messana ©FAA

Basic Rules

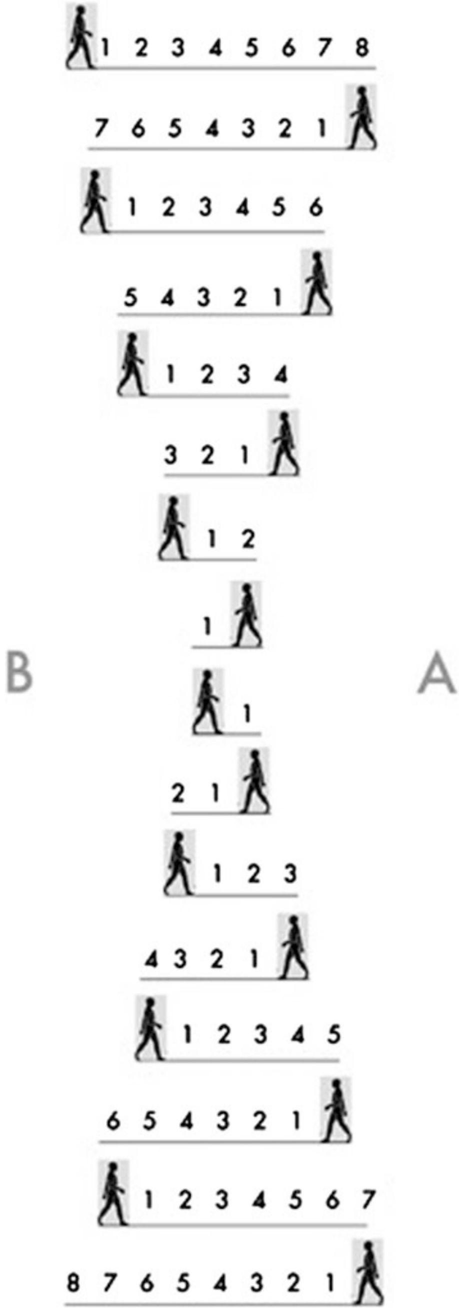
Let us call A any direction in the space, and the opposite direction on a straight line B. The task is to take 8 steps in the direction of A, then 7 steps in the direction of B, then 6 steps A, then 5 steps B, then 4 steps A, then 3 steps B, then 2 steps A, than 1 step B, then 1 step A, then 2 steps B, then 3 steps A, then 4 steps B, then 5 steps A, then 6 steps B, then 7 steps A, then 8 steps B.

At this point you scaled down from 8 to 1 and up from 1 to 8. You have performed the 8 steps once (Fig. 2).

Initial Constraints

1. This is a group exercise. If anyone misses a count or makes a mistake, the whole group should stop and start again from the beginning, without judgement.
2. To begin, the group stands facing direction A, as close as possible without touching, in a random formation.
3. To make the first step, the group makes a collective and non-verbal decision. There is no leader who gives the start.
4. The first step is always taken with the right foot.
5. You walk up and down, in a straight line, as on a rail.
6. The speed of the walk is up to the group's choice, but it has to be the same throughout the exercise. The moment you put your feet on the floor should be as regular as the rhythm of a metronome.
7. You should not make any noise.

Fig. 2 Indicating walking paths



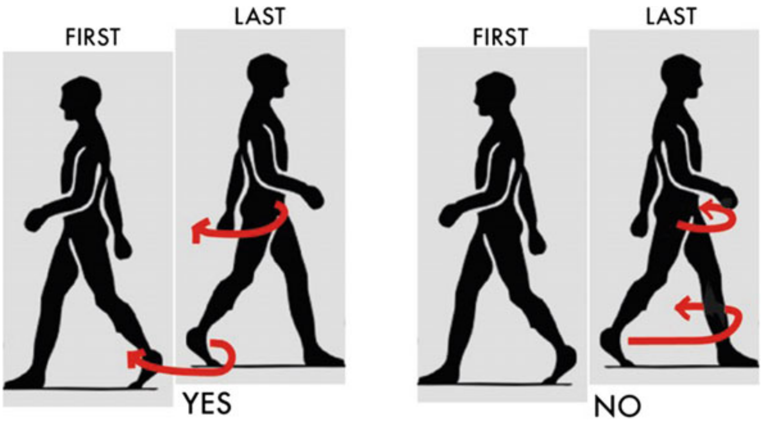


Fig. 3 Indicating direction turns

8. To turn towards the opposite direction you should use the most economic trajectory, which means that you always turn clockwise if your last step was done with the left foot, counter-clockwise if it was done with the right (Fig. 3).

Once the group achieves the exercise for the first time, it should practice enough to achieve it most of the times. At this point you can add further constraints, or sharpen the existing ones.

It is very important to notice that understanding the rules of an exercise (which is what you are presumably doing as a reader), is not the same thing as understanding the exercise. The word «understanding» itself is, in fact, inappropriate, because an exercise is meant to be done, not to be understood. This exercise in particular, at the beginning, plays upon this kind of misunderstanding: as we announce the rules, most of the participants think «Oh that's easy!». As a matter of fact, we are all very capable of counting down from eight to one and up from one to eight. Walking is also an action that we think we master without having to pay it any further attention, and turning back does not really preoccupy us either. Nevertheless, having led the 8 steps in many different contexts, and a considerable number of times, we can say that, depending on the number and the composition of the group, it can take up to 15 attempts or more to achieve the exercise for the first time, and much more practice to achieve it most of the times.

What Is a Good Exercise?

Based on this example, we would like to share some hypotheses on how a good exercise for the performer's training is constructed.

A good exercise requires a continuous work on attention. As practitioners execute the 8 steps exercise observing the basic rules, they are challenged to direct their attention to very different tasks: counting is an ongoing task, and, at the same time, they have to memorize the last count to be able to anticipate the next turn. The direction (clockwise or counterclockwise) of the turns also requires their attention, while not losing concentration on the counting. The regularity of the tempo is also a task requiring attention, as very often there is a tendency to accelerate as they aim towards the end of the exercise. Finally, practitioners have to attend to what the others practitioners are doing, because tempo is a shared, non-individual choice. Attention on the work of others is also necessary in order to stop immediately if an error occurs, no matter who makes it.

A good exercise allows the performer to (always) add constraints (increasing the difficulty horizontally). For instance one can ask practitioners to choose three points in space, each no bigger than a coin, hence to do the exercise looking exclusively at these three points, shifting eyes from one point to the other as they walk. Another example: one can choose a step, e.g. the fourth, and add a 45° turn on each fourth step in addition to the basic rules. These are only two examples and the list of additional constraints is virtually endless. It is interesting to notice that adding constraints is a process that very often causes «forgetting» the basic ones. Putting attention on something new brings one to lose the ease already gained.

A good exercise allows the performer to always sharpen the constraints (increasing the difficulty vertically). For instance, making no noise at all, especially in a group, is a very difficult task that requires a lot of practice, possibly some preparatory exercises as well. Walking in a straight line, especially after turning back, is also a demanding task. Turning back itself very often causes a tempo problem, for the action is longer than that of just taking a step, although it must be executed in the same duration. Raising the difficulty of the basic constraints requires as much attention as adding new constraints, and likewise provokes the forgetting of constraints previously introduced.

A good exercise cannot be mastered. This follows from the previous points made, but also derives from many years of experience. A good exercise is made in such a way that it can be practiced and developed for life. It offers the performer an inextinguishable «problem», which he cannot solve once and for all, and the work he does to solve it trains and enhances some of the skills he needs on stage.

It is important to note that insights from neuroscientific inputs during the workshop had an interesting effect on the participants who already knew the 8 steps exercise. In fact, their reflections made the exercise more challenging. A further level of awareness was activated: what attention was focusing on. This additional, reflective challenge resulted in an increasing interest in the exercise and motivation to practice it regularly.

Neuroscientific Foundations

In our neuroscientific injections for reflection during "The Performer's Cognition" workshop, we presented current scientific research findings and methodologies related to motor action, expert performance and spectatorship, as well as attention. The aim was to provide participants with the basic knowledge on the elements involved in the exercises and to trigger their own investigative enquiry. Since the content of this week's workshop is too vast for a single book chapter, here, the focus of the neuroscientific link to the exercise is twofold: first, how continuous deliberate training may affect performance and spectatorship, and second, why a seemingly simple group exercise like the 8 steps is in fact a challenge.

Mirror Neuron Mechanism

A number of studies showed that expertise in action execution not only changes the way we perform actions, but also the way in which our brain 'fires' when watching those actions (Rizzolatti and Sinigaglia 2008). This understanding is relevant since the actor does not shut down the two-way path of seeing and doing. In many cases, a stage action involves the coordination with other actors. Hence it is important to acknowledge that the actor, an expert in action execution, also perceives actions. Even in a solo, the performer may for example perceive actions from audiences as well as his/her own actions in his/her peripheral vision as well as his/her imaginary projections.

The research on the link between expert action execution and action observation is related to the so-called mirror neuron mechanism. In fact, since the coincidental finding of mirror neurons, the performing arts have stepped into the limelight of cognitive neuroscience. The seminal study by Calvo-Merino et al. (2005) showed that the strength and pattern of brain activity evoked during passive action observation is dependent on whether one is expert in the movements observed or not. The finding of increased brain activity in the mirror neuron network when observing familiar actions has been replicated and refined numerous times (Bläsing et al. 2012), showing evidence that practicing a novel movement (or exercise task) modifies the neurobiological responses not only in execution, but also in passive observation. Therefore, the performer and the spectator resonate in the same action. Notably, in regards to the 8-step exercise, the performer resonates in the same action with the co-performers. Further research is required to specifically study evidence of this co-action.

Importantly, it has only recently become possible to study neuronal activity of moving participants by means of novel wireless measurement tools. Moreover, although proposed over decades, the relevance of novel methods that allow studying the mirror neuron system in experiments with enhanced ecological validity has been more widely acknowledged only lately (see Christensen and Jola 2015). The findings of these studies indicate functional specificity of particular areas of the mirror neuron system. For instance, activity in the inferior frontal brain area, activated during passive action observation and action execution, is sensitive to the coherence of a movement sequence—with enhanced activity for more coherent movement sequences (Bachrach et al. 2015). Notably, this finding corresponds to the earlier study on coherent linguistic phrases (Pallier et al. 2011), indicating that the inferior frontal area is responsive to structures in different modes (i.e., language, movement, music). This area could be of great relevance for actors, since movement and language both play an important role in their stage performances. However, only few studies looked at the mirror neuron system in actors, and how practice changes actors' neurobiological functions is yet undetermined. One of those studies explored differences in embodied language between actors and non-actors (Sofia et al. 2016). Embodied language (Gallese and Lakoff 2005) relates to the assumption that sensorimotor areas and thus the affiliated mirror neuron system are involved in language processing and comprehension. Preliminary results indicated that actors and non-actors showed a tendency to different embodied language mechanisms; yet, some of the results were assigned to differences in *attention*. However, this research is still in progress.

Clearly, dance lends itself well to study the mirror neuron network since an expert performance is often easily distinguishable from the execution of a novice. In relation to actors, expert mirror neuron network activity can be expected to be more subtle. As explained earlier, particularly in naturalistic theatre, most of the time an actor performs actions that anybody could do. What is of greater relevance is whether the actor can make the audience believe that it is 'real' (i.e., done for the first time). There is yet no study that compared expert actors' mirror neuron network with that of novices.

Yet, it is interesting to note that research showed the relevance of the potential of make-believe in real-life situations: action observation is enhanced when novices watch gestural actions live compared to on video or other digitized mediated environments (Jola and Grosbras 2013; Järveläinen et al. 2001). It could be argued that it is the co-presence of the performer and spectator (see Jola and Reason 2016) or elements linked to social motivation. The latter is of further relevance for the 8 steps exercise chosen here.

In this exercise, the neurobiological functions involved are very distinct to, for example, dance actions. One may say that it entails 'just' walking. Yet, walking is a very complex activity if one were to describe the biomechanics of it.

Performative Body Schema

Another means of explaining the challenges of the exercise is through the framework of a performative body schema. Shaun Gallagher defined body-schema as:

> A non-conscious system of processes that constantly regulate posture and movement – a system of motor-sensory capacities that function below the threshold of awareness, and without the necessity of perceptual monitoring" (Gallagher 2005: 234).

As we noted above, when we practice the 8 steps exercise we experience that our conscious attention is not expandable to more than a certain number of tasks. A more common illustration of such an attention mechanism can be noticed when we learn to drive a car. We are incapable of paying attention at the same time to placing the foot on the clutch and the hand on gear lever, we stall. When we learn how to drive, only experience, the hours spent driving, allows us to free our attention enough to be able to admire the landscape, speak to the passenger or sing at the top of our voice, all while driving. Some tasks have been integrated to another level that is pre-conscious. To put it differently, through practice we have created a body-schema that is adapted to driving. We posit that the same process takes places in the execution of such an exercise as the 8-steps. As in music, actor training entails constraints whereby continuous practice in time allows the modelling of an extra-daily body-schema. The difference lies in the fact that, compared to learning how to drive or learning a musical instrument, in this case there is no object or instrument that the body-schema needs to adapt to.

Some interdisciplinary research on this subject proposed the notion of 'Performative body schema' (Sofia 2013a) in order to indicate how theatre training develops a different body schema used by the performer during his relationship with the spectator.

The studies concerning the notion of *body schema* teach us that our body-mind system is a widespread mechanism that cannot therefore be traced back to a "purely central mechanism" supposed to combine information concerning the outer environment with information concerning the position of our body in space, our posture, and our possibility of interacting. Furthermore, the *body schema* also regulates the pre-reflective organization of the whole body towards a precise goal. It is, therefore, absolutely related to the intentional dimension of action, as Dorothée Legrand highlighted in her studies with these words: «To have an intention is not only to have a reason to act, but also to have a body oriented toward a goal» (Legrand 2010: 166). In everyday life the whole body reorganizes itself according to any intentional event. For the actor, the important point is that such an organization or combination of egocentric and allocentric information, is not a conscious process:

> If the behavior monitored through the body schema does not necessitate conscious control, it is not reducible to a mere reflex either. Such behavior can indeed be precisely modulated according to the conscious intentions entertained by the agent rationally and consciously. For instance, if a subject holds out his or her hand to reach a glass of water to drink, the subject's hand forms a grip adapted in size to this goal automatically and in an anticipated way (Legrand 2010: 167).

The body schema operates so that several body mechanisms cooperate at a pre-conscious level in preparing the concatenation of action. This means that on stage, where the actor already knows the concatenation of actions, his body schema may naturally anticipate the following actions even if they are supposed to be a reaction to an incidental event. For example, if during stage action somebody is supposed to suddenly knock at the door, the actor must be able to reproduce his own reaction so that this event can appear as "unforeseen", although this same event has been repeated several times by the actor during rehearsals. This moment is very difficult because, unless the actor controls his whole body, some parts of it—such as the legs, which are not "directly involved" in the action—may unconsciously move in advance towards the door. This would normally happen in order to make the action following the unforeseen event easier—go to the door and open it—but in this case the 'surprising' event would appear to be merely pretended. These anticipating mechanisms are, therefore, not related only to action, but involve the whole body of the actor, who is usually completely exposed on stage. This is why the actor needs to control his body schema at a higher level of consciousness, and to this end he elaborates special psychophysical strategies which consist of exercises that the actor does during his training.

As we have already seen, the pre-reflective status of the body schema's activation prevents the actor from willingly inhibiting it, so that he has rather to construct a 'performative body schema', that is different to the usual one, since it is controlled differently and more carefully. The processes of constructing such a 'performative body schema' take different forms, depending on the performative tradition. Most of them are based on two basic moments, i.e. the fragmentation of everyday neuromotor routines, and the reconstruction of other routines at a different level of control.

In the 8 steps exercise, these two moments are quite clear. Walking is actually one of our most frequent routines and we usually can do that without a particularly explicit cognitive effort. But the simple task of counting our steps, scaling down from 8 to 1 and up from 1 to 8, make this task challenging as we are obliged to put an explicit attention on each step. We said that the body schema works below the threshold of our consciousness, so if we put explicit attention on some actions that are generally regulated by the body schema, we are fragmenting our daily routine. That is why the practice of this exercise is so hard at the beginning. And that is why the work on two parallel tasks, which are normally easy when taken alone (walking and counting), seems really complicated in practice. Once the exercise has been practiced more times, our attention can add some other task: this is the reconstruction moment. Once the new body schema is created, the subject can add some new constraint in order to continue this process of fragmentation and reconstruction at a deeper level. That is why, as we said, a good exercise allows you to continue sharpening its constraints further. The 8 steps exercise works precisely on this process of fragmentation and reconstruction. Indeed, it is no wonder that so many actor training exercises are based on applying constraints to the simple action of walking.

Going to a deeper level of detail means also learning to engage the entire body in every action. This is because an actor is required not only to reproduce a suitable intention, but also to have an unusual control of his whole body during performance. For instance, Meyerhold considered this aspect as the basis of the whole system of biomechanics: «Biomechanics is entirely based on this fact: if the tip of the nose is engaged, the whole body is also engaged» (Meyerhold 2009: 100).

The conscious awareness produced in action fragmentation is necessary to the actor not only to inhibit undesired anticipating movements, but also to reconstruct the fluency an action requires to appear effectively spontaneous. The conscious control of any motor act is not enough. The actor must reach a new pre-reflective control, which, unlike everyday pre-reflective control, has to allow his intention to broaden out to the spectator, so that the actor can play with him, surprise him, listen to his breath, feel his level of attention. In so doing, he can make every performance a unique experience, an authentic complex relationship instead of a mere automatic repetition of a series of acts. This is the aim of constructing a 'performative body schema'. Just as the everyday body schema is continuously modified and cannot be reached by a conscious effort, so the artificial body schema can be constructed only *through experience*, i.e. only by unceasingly and physically experiencing a lot of unusual situations that develop several thought-action dynamics through the actor's body-mind:

> Exercises are small labyrinths that the actors' body-minds can trace and retrace in order to incorporate a paradoxical way of thinking, thereby distancing themselves from their own daily behaviour and entering the domain of the stage's extra-daily behaviour.
>
> Exercises are like amulets, which the actor carries around, not to show them off, but to draw from them certain qualities of energy out of which a second nervous system slowly develops. An exercise is made up of memory, body-memory. An exercise becomes memory, which acts through the entire body (Barba 1997: 128).

In our opinion, when Barba says «An exercise becomes memory, which acts through the entire body», he is tracing an alternative way of describing the process of embodying the artificial body schema, which operates *as* body, or body-memory.

In this sense, the Western actor's work is not very different to that of the Eastern actor. Both work on constructing a 'performative body schema' able to assure that the whole body *coherently* moves towards a goal. We notice again that the effectiveness of an action on the spectator does not depend on its level of *likelihood* but on how coherently the body organizes itself in aiming at a goal. An action is felt as intentional and therefore believable, if the actor takes care of the details of the action as well as of the coherence of the involved collateral movements.[5] For instance, Indian performative practices develop ways of acting on stage that are distant to usual acting and they nevertheless maintain the "naturalness" of action, as if it were quite a natural way of interacting with space. Considering how long and complex an Indian actor's training is, we realize that such an effect of naturalness results from a long and careful work of fragmentation, new composition and organization of the performer's body.

Similarly, in order to be effective, even the most "naturalistic" theatre practices do not require the actor merely to evoke a precise intention or to identify with a

[5]In this regard the philosopher Pierre Livet has remarked in a recent contribution that the collateral movements are essential for identifying the intention: «Adjustments like collateral movements, or like updatings of the position of the body and its limbs relative to the environment, are required both from the observer's and the agent's perspective in order to feel the movements as intentional» (Livet 2010: 189).

particular condition. They rather require him to demolish and to work, to dig, to split and reconstruct the deep motor mechanism ruling any action.

The Actor Scientist

The above mentioned studies highlight an important fact: a great part of cognitive processes occur below the threshold of consciousness. The body schematic process is one such clear example. Yet, consideration of such a mechanism can affect the very way we relate to the organization of the body in performance. Indeed, especially for the theatre practitioner, cognitive neuroscience reveals a level of organization that is not experienced by that very same body engaged in a deliberate, repetitive practice such as actor training.

On the other hand, actors may get caught up in repetition, thus forgetting that training also entails a deliberate practice. In other words, a training that does not merely serve as apprenticeship or warming up requires the actor to develop a scientific aptitude: the ability to make precise distinctions and connections, to predict, to simulate and model aspects of performance, to measure, to experiment and produce further questions from the forthcoming results. In particular, such a scientific disposition allows the actor to use training exercises as models through which to address specific aspects of their performative organisation. For instance, in the 8 steps exercise we could focus particularly on the problem of attention. Further levels, i.e. added constraints, would allow us to work on imagination or visualization (exploring different qualities of the terrain upon which one is walking), or even on inhibition (how does one interrupt a perfectly memorized motor routine in the moment that a particular response or improvisation is required), and so on. Of course, such topics are of interest also to neuroscientists, only they are more used to addressing these questions from a pathological or everyday (spectator) perspective. Training as a research-based practice could perhaps furnish a different point of view from which to address such important topics to cognitive studies.

Training by way of ongoing professional development entails a research dimension, which is, precisely how actor training developed in western theatre. At the turn of the twentieth century, influential figures such as Stanislavski, Meyerhold and Copeau regarded training as performative research. The so-called “director-pedagogues” of that time were concerned especially with the actor’s creative development, therefore with the actor’s learning processes. In line with their work we have chosen to relate cognitive neuroscience specifically to actor training, rather than to theatre poetics (how theatre is made) and aesthetics (how theatre is presented). Their research on the performative self inevitably led to investigating the organization of human cognition in performance: what can we learn about human action, emotion, imagination, perception, attention, and so on, that we may then learn how to consciously organize performance in the creative encounter with the spectator? It is for this reason that actor training pioneers also related to the psychophysiological studies of their time. Their investigations addressed very precise questions related to very precise problems raised by the practitioners themselves. Hence, Meyerhold’s insistence: «Training! Training! Training! But if it’s the kind of training which exercises only the body and not the mind, then no thank you! I have no use for actors who know how to move but cannot think.» (Law 1979). These were the first steps towards placing science in the acting practice (Jacono 2014).

Conclusion/Outlook

In the present chapter we addressed the question of actor training and how the exchange with cognitive neuroscience could help better understand and appreciate the importance of deliberate continuous training in the acting profession. We distinguished actor training as an ongoing, deliberate, repetitive practice, as opposed to primary apprenticeship and warming up routines. In spite of the fact that actors acknowledged the importance of continuous artistic development, we noted that only few actually engage in training. We also noted various cultural and economic reasons why actors still refrained from such deliberate, repetitive practice, however, concluded that the predominant challenges are psychological and lie in the attitudes specific to the acting profession.

We presented the first edition of the 'Performer's cognition' international workshop organized by the Fabrique Autonome des Acteurs as an example of the context in which such an exchange between neuroscience and the theatre performer's practice can take place. To further illustrate the interdisciplinary encounter here, we focused on a particular exercise, the 8 steps exercise, which served as one of the practical and theoretical focal points during the workshop. It is important to note how the dialogue with neuroscience spurred us to identify essential characteristics of a training exercise: the continuous work on attention, the possibility to both add and sharpen constraints, and the impossibility of fully mastering the exercise once and for all. Such distinctions then allowed us to look at the 8 steps exercise in the light of studies on particular neurocognitive mechanisms, namely the mirror neuron system and the body schematic process. Research on the mirror mechanism provided insights into the difference between expert and novice performance. It also shed light on the effects of training in terms of shared motor repertoires that enhanced creative collaboration. Studies addressing the body schematic process, a pre-conscious mechanism coordinating the interaction between self and environment, pointed at two distinct phases in training: fragmentation and reconstruction. These served to modulate such a mechanism into a performative body schema.

Placing science in the acting practice meant gaining access to levels of organization that remain beyond the direct experience of the performer when not equipped with the instruments or terminology of neuroscience. It thus meant looking at the body in performance from a new perspective. One of the feedback responses that we collected sums up the body, mind, artistry and emotion connection very well, and reflects the feeling of many participants after the workshop: Leaving Bataville … "I felt physically tired and sore, emotionally stable, artistically reinvigorated, mentally stretched. I felt richer (and still feel like it), and surrounded by people with an energy that carried (and still carries) me." The particular focus on training, however, also highlighted the importance for the actor to use such a deliberate practice in order to consciously address particular aspects of his profession with a scientific approach. Such a scientific predisposition is still lacking, as is training, among acting professionals. Many participants emphasized that the workshop was enriching because they met people who asked and engaged in similar questions, and were open to new forms of practice. One participant reported that she started a specific training practice in her community during the workshop. It was also mentioned how inspiring the workshop was for their present and future research and practice, and how experiencing practical exercises from a cognitive viewpoint clarified the incorporation of science for training. Notably, some participants had already engaged in this field before the workshop and have since created performances further linking neuroscience and dance or theatre performances. The link between neuroscience and practice was however novel for most. Hence, combining cognitive neuroscience and actor training showed starting points for some and an expanding inspiration field for others. It clearly provides important research opportunities for a community that operates in the exchange between theatre performance and neuroscience.

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Art, Mathematics, Pedagogy

Claude Paul Bruter

Abstract One of the major activities of the mind is to represent. This activity establishes links between mathematics and art: only a few are briefly discussed in this chapter. They justify the presence of artistic works for cultural and educational purposes, addressed to all audiences. We present a few examples taken from the activities of a European vocation institution dedicated to these purposes.

Artworks and Mathematics as Representations

Ravel (1989) used to claim not making any difference between the poet, the painter, the architect and the composer. He had grasped the universals of thought structure and thought functioning.

Valéry (1973) was probably following this line of thinking when he expressed in his *Cahiers*: "Fortunately, I have established in 1892 the mathematical thinking as the standard for measuring the values of the mind on the one hand and, on the other hand, construction or specific experience … I have since then only valued and esteemed an "artist" of any kind when his demands and (genuine) *freedom* were similar to the one of a geometer or a builder (e.g., of machines)".

Similarly, Cartan (2004), one of the fathers of the Bourbaki family, for the moment called in France the "Pope of Mathematics" declared: "In the speech I gave on February 1st, 1977 when receiving the Gold Medal of CNRS—The National Institute for Scientific Research in France—I argued that mathematics were more relevant to art than to philosophy". Was he not implicitly expressing how the steps of thinking, whether applied to mathematics, to art or even to other fields, are all part of the same unit?

This belief is based on a simple observation: the primary activity within our sensorial and nervous system leads to the representation of our environment, which is essential to ensure our spatio-temporal stability. Any representation, and ultimately any mental representation, can be externalized when creating artifacts imitating and symbolizing the environment.

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But all representations are necessarily incomplete. A song with sorrowful or enchanting verses will convey the intense emotional and mental activity of a poet, but not his face features. No perfume rises from the melodious sound of a flute. The lips of a sculpted head are forever still. Painters and engravers will never make us hear the faint whispering of the breeze through leaves and foliage.

All these representations are highly symbolic. Whereas it is rising or falling, the sun painted by Monet isn't the true sun. It rather symbolizes the presence of the sun and the effects of such presence on human senses in a specific context (see Figs. 1 and 2). Moreover, such artworks illustrate another characteristic of symbols: they are universal and spatio-temporally independent: artworks can be (theoretically) admired by the entire mankind; across space and time, many men and women will indeed be exposed to them.

Finally, the drawing of the sun is characterized by the perfect form, the so-called disc of mathematicians. In Monet's painting, obeying mathematical and perspective rules, a specific and major place was given to this disc.

In this specific aspect, the painter (who is primarily a draughtsman), composing his art, meets the geometer, the mathematician. Indeed, the latter also represents and symbolizes, and for this he primarily uses drawing.

What are indeed numbers and letters, used by the geometer, the mathematician, if not originally drawings? Across years, centuries and millennia, the form and semantic attached to such drawings have evolved, drifting away from concrete and immediate reality, gradually becoming symbolic elements.

Fig. 1 Monet, Soleil couchant sur la Seine, effet d'hiver, 1880

Fig. 2 Monet, Impression soleil levant, 1872–1873

The drawing "1" shows primarily the presence of an object. The "1" means that this object exists, with a huge potential of being embodied. However, each form of embodiment is secondary compared to the presence of the object. Its existence and presence are its deepest characteristics.

A representation is a portmanteau word, which agglomerates several components, including a source, such as a budding artist or an adult artist, and a support, such as the paper, canvas, computer screen or the material and intellectual tools allowing the representation to be created.

The transformation, which is everything made by the artist to create his artwork, which is a word that includes the act of performing the transformation, is represented by the mathematician by a single drawing, often that of the letter f. If C indicates the child or A the adult, the mathematician will note f(C) or f(A) their representation, their image on the canvas, that is to say the f-transform of C or of A.

The work of mathematicians seems to be similar to the one of other artists, except that their efforts are focused on the analysis and the study of the data arising from our environments. Such data are forms in a frozen state, characterized by their appearance and structure. However, these forms are not necessarily stationary objects: they can take the forms of moving objects, of becoming objects.

A simple glance at the four paintings illustrating this chapter (Figs. 1, 2, 3 and 4) is enough to reveal what they have in common: an axis of symmetry. The axis is horizontal in the two first paintings; vertical in the other two, and in all cases it structures the painting.

Fig. 3 R. Mazoyer, The young Artist, 2006. Artwork reprinted with permission

Fig. 4 R. Mazoyer, the serious Artist, 2006. Artwork reprinted with permission

Symmetry is the manifestation of the balance of forces, which confers stability to an object or an artwork. Symmetry became a field of study in the late 19th century, following the lead of physicists, such as Pierre Curie. Understanding, recognizing its importance, and even its simple presence, took time.

The mere act of existing implies a balance between internal forces, and therefore the presence of symmetries. Thus, it is not surprising that the discovery and classification of "elementary" particles have been largely relying on group theory, in which symmetry is a constitutive element.

These brief comments on four paintings and on the links between the thinking across different fields could belong to a larger study on the links between mathematics and arts. Some of these links are described for example in the Catalog 2013 (Bruter 2013) of the works from the ESMA funds, or in presentations made last year to high school students in Saverne and Etampes.[1]

Artworks Serving Pedagogy

It appears that genuine artworks get important media coverage and have the power to attract large audience. This fact has been exploited by talented politicians. I shall quote for example these lines from the Ernst Kitzinger's very interesting book "Early Medieval Art" (Kitzinger 1983):

> It was not, indeed, Charlemagne object to make artists appreciate and reproduce the outside word for its own sake. In fact, he and his contemporaries condemned art as a means of reproducing things which are obvious to the senses. They believed, however, in its usefulness in conjuring up the things of the past, and making them alive. Charlemagne had a very clear vision of the part that such realistic art could play in his work of political and cultural reconstruction. If art succeeded in giving physical reality to things which otherwise could only be grasped intellectually it could be turned into a powerful instrument of education.

This specific approach has been followed across the centuries. Given that mathematics is impregnating all forms of art, appealing to the content of artworks for helping mathematicians to convey their message to a general audience became obvious. Recently, the ARPAM Association (Association pour la Réalisation du Parc d'Activités Mathématiques), and later on the European Society for Mathematics and Arts (ESMA, http://www.math-art.eu), consisting of artists and mostly of academics, were established for this primary purpose. A brief presentation of the society and of its activities can be found in the recently published Bulletin 517 available online (http://www.apmep.fr/IMG/pdf/Multimedia_no_517_Final.pdf) of the French Association of the National Education Mathematics Teachers (APMEP).

[1]Bruter C.P.: Deux universels dans la décoration, premiére partie http://www.math-art.eu/Documents/pdfs/Etampes/etampes. Look also at: http://www.math-art.eu/Documents/pdfs/Florence_Conference_2016.pdf.

ESMA also organizes international seminars in Europe. The first one took place in Paris in 2010 [proceedings published by Springer (Bruter 2012)], the second one in Cagliari in 2013 [proceedings published by Cassini (Bruter 2015)] and the third one took place in Ljubljana in September 2016. The themes of these seminars were:

– *Theme* 1: Mathematical tools and software for the creation of artistic scientific visualizations;
– *Theme* 2: Analysis of artistic works from the mathematical point of view;
– *Theme* 3: Pedagogical uses of scientific artworks.

One can be delighted to observe, in various disciplines, the increasing presence of educational experiences based on artistic tools. For example, the next International Congress on the Mathematics Teaching (Hamburg, on 2016) will hold a session entirely dedicated to mathematics pedagogy based on artistic works. Various realizations will be presented and ESMA will be present (Bruter 2016).

As kindly and pertinently suggested by one reviewer, I shall here give an example of the use of artworks for introducing basic knowledge on mathematical objects. We will first discover the notion of knot illustrated by two mathematical objects and later on, see in which theories knots may appear. Finally, this example will also illustrate how our mind work and along the way, evokes some familiar concepts about reality and perception. Please go to http://www.math-art.eu/Documents/pdfs/bonneAnnee/Bonne_Année.pdf and reach slide 51 where you will see this image (Fig. 5).

Such golden ring is named a trefoil. When made with a line (to not call it a rope), you can recognize a kind of knot as the ones used by sailors. At the end of the 18th century, mathematicians started developing a vast theory called the knot theory. A knot is a curve in our usual space, like a wire with both its ends glued together. A circle is a trivial knot. A trefoil is not trivial, yet still very simple and elegant.

Another theory for which knots might be useful is the dynamical systems theory, which studies the trajectories of moving objects like, for example, airplanes. On the

Fig. 5 Jos Leys. "Anosov" trefoil. Artwork reprinted with permission

next slide 52, you will find a link to an animation: http://www.josleys.com/gfx/DanseNDT_01.mov.

This animation will first display a point, i.e., a circle of null radius named a singularity. This point suddenly becomes a tiny circle, which progressively gets larger: you are attending to a general phenomenon called blowing up. Then, the circle will start to rotate in space around its diameter. A shadow seems to be created by a source of light, let us say, for instance, by the sun. Note how when the circle is perpendicular to the screen plan, the shadow appears as a segment, i.e., a straight line! Imagine you did not see the transformation, and you just look at this line: could you imagine that what you see is not just a segment, but instead the shadow of a circle? Now, let us introduce the notion of deformation of a mathematical object. The circle is transformed into a triangle, which is another kind of closed curve, but with three singularities. Observe the triangle as it rotates around its horizontal edge. Again, when perpendicular to the screen plan, the shadow appears as the same segment than earlier: what you see is not the reality! Remember Plato's allegory of the cave!

At the end of the animation, the circle is back. Actually, two circles are appearing. These trivial knots are in symmetric positions. They are cut, deformed and their ends are glued together: they are now two symmetric trefoils. And look again: two people are dancing, and their respective trajectories follow exactly the trefoils. These trefoils are symmetric, with respect to a mirror that would be located in between them, and they cannot be stacked together: they are different! Like for many biological molecules, there are two versions of the trefoil, perfectly symmetric yet different: surprising, is it not?

We predict that, in a few years, when these experiences and realizations will have multiplied and the analyses of such situations will be more advanced, the implementation of artworks in pedagogic set-up will become more widespread and better coordinated. However, one difficulty contributing to slow down such implementation could arise from insufficient training of the teachers committed to this educational way.

The various contents of conferences, lectures, lessons, and practical exercises will give birth to reflections and probably to original work, both in the field of mathematics per se and in the field of artistic creation. Note how the alliance between mathematics and art were fruitful in the past, during the golden age of Renaissance with the introduction of perspective, the radiance of cubism in the first half of last century, or the creation of challenging decorative elements (knots, friezes, tilings) that in turn allowed the maintenance and dissemination of underlying mathematical tools.

Today, with the development of mathematics and of computer tools, old forms have been highly enriched, and newer have been created: more and more artists are seizing them. Naturally, museum curators are primarily working to support their rich artwork collections from the past and might be reluctant to integrate newer artworks (especially in old Europe), but such reservation should be overcome with time. We entered into a new era of human history, and contemporary artistic productions will reflect it, will represent it. In case galleries and museums are not accessible, the reader is invited to visit websites revealing to everyone all these novel and beautiful artworks:

http://www.math-art.eu/exhibitions.php,
http://www.imaginary.org,
http://www.ams.org/mathimagery/,
http://www.gallery.bridgesmathart.org/,
http://www.myweb.cwpost.liu.edu/aburns/sigmaa-arts/.

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Percepts & Parameters, a Prospective Approach of Architectural Materiality

Eglantine Bigot-Doll

Abstract From perceived realities weaving fictions, or figments feeding computer-generated geometries, a projective attitude in architecture is based on a virtualizing stance. Whether analogically imagined, whether computer simulated, these projections come true from successive translations from one language to another. Sketches, models, photomontages are classical techniques in the process of conception which computer aided designs intrinsically modified. Raising new paradigms in terms of information treatment, this research aims to explore the potentialities of such hybridizations through the measuring of subtle worlds. In the 1960s object-oriented programming (OOP) introduced the fundamental concept of encapsulation. A nodular black box, encapsulation is a syntactical concealed implementation through objects interacting together as building blocks. Broadening this concept to any sort of significant support, this experiment is a work-in-progress which aims to demonstrate how the shift from creative semantics to formalized syntaxes results in singularities. Identifying invariants or puncturing data sets from unexpected analogic territories such as lexical fields, fictions or matter convulsions, a group of students of Master at the Architecture School of Lyon, France, was observed to collect material for this investigation. For all intents and purposes, the goal is to extract advanced operational possibilities starting by implementing percepts as analogic fluxes into parametric geometries. In this pedagogical context, the investigations of the MAP-Aria—laboratory for architectural modeling—leads and observes the potentialities of such a prospective approach using digital and parametric OOP-like tools as crucial keys of control. We expect these tools to deliver singular ranges of aesthetics possibilities targeting unforeseen and innovative architectural materialities.

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Introduction

This article aims to articulate the experiments investigated during a semester with 17 Master of Architecture students at ENSAL (École Nationale Supérieure d'Architecture de Lyon, France) through an architectural projective approach over a prospective strategy. The conception patterns and tools employed are entirely new for the whole class and had been taught and lead side to side with MAP-Aria, institute for architectural modeling, while being faithful to the lab's main domains of research. This unusual "tactic as practice" uses analog and digital tools, orienting them toward matter at various scales: matter as an affective-perceptive stimulation on one hand, and, matter as the architect's structural legitimacy on the other. The fourteen weeks semester was composed of five main encapsulated stages passing from one significant material to another. The first and the last steps focus is matter, as detailed below, whereas the media at the intermediate steps involve formal, natural or geometrical languages in a view to mix up sensible insights through developed fictions and idiosyncratic identification of chosen parameters. Those cognitive jumps entailed by the series of encapsulations requires crucial stages of "mathematicalization" of perceived phenomena, which are actually the core of our investigation.

In terms of pedagogical approach, the focus is constantly on leading two studies mutually crossed and parallel: feeding and verbalizing perceptions as signified through significant fictions, while subtlety trying to quantify those by converting the signifier medium into a dissimilar "other one". As a result, the "shifted" information produces fecund signified alterations. At first this "distorted" material holds our interest in first place as part of the prospective process, creating original aesthetics meant to encourage the student to keep control of the digital parametric tool. Indeed, this is one of the very first observations acting as the impetus of this research: Computer Aided Design (CAD) creates a dominant bond on the architect, dramatically affecting his creative potentialities. By targeting materiality through structural proposals through the lens of aesthetics—itself carried by percepts and emotions, encapsulated into singular parameters—this research tries to demonstrate that our step-by-step approach takes equal advantage of the architect's (in our case, the student's) inventiveness and advanced digital tools offered.

This second exercise begins after reading Michel Foucault's text "Of other spaces" (Foucault 1967), each student establishes his own fiction, also fed by the fist exercise involving matter on a local level of examination. This text provides a taxonomy of Foucault's heterotopias—as built utopias—maintaining singularity in the program of a developed project, e.g., cemetery, motel, garden. The made-up fiction is the definition a cosmos rather than a structured narration. At first the exercise only consists of connecting words in a lexical field emerging from matter fancies and freaks scrutiny.

NB: SPACA[A]N[1] is the designation of the semester studio. It is a French acronym standing for, Advanced Strategies and Practice in Analogic and Digital [Numeric] Architectural Conception.

[1]See whole student work at archispacan.blogspot.fr (2014) and archispacaan2015.blogspot.fr (2015).

Perception: Gesture, Tools Versus Instrument

Staring at the matter to perceive as the very first step of our exploration involves the establishment of an intimate relation between the student—as a designer—and the matter. The imposed dimension of each hand-shaped object must be includable in a pill-box pointing to establish this singular connection through experiencing with substance. The early results of the exercise show that this experiment is mainly based on perceptions and emotions as a way to host the physical world. Gazing across clay convulsions or lineaments nodes is the adopted line of entry in a view to operate the essential deterritorialization (Deleuze and Guattari 1980) in such a project. Instinctively, the primary tool employed is the hand whereas the primary sense is the sight. The survey results all converge on this statement as the first session of the exercise (three full days) demonstrates it. The "pill-scale models" when strictly hand-modeled and "retinally" fed-back are still very well-ordered and, as a consequence, quite predictable and ordinary. That is why a second session (two weeks) is scheduled, pointing towards selecting a large amount of tools while verbalizing perceptions with words. However, touching the matter using hands and fingers ignites significantly the empathy toward its inner asperities.

During the first three-day session, a short selection of materials is imposed for the exercise such as: polystyrene micro balls (with two different radiuses) and polyester plush, nylon wire (with various diameters), white thin Bristol board and finally white clay, respectively introduced for zero dimension, one dimension, two dimensions and three dimensions. Actually combining these ingredients into a miniature scale, the question of dimension is a pedagogic ruse aimed at making the students realize that they manipulate matter at a point of fusion between structural, textural and substantial balances. Further on the second longer session, released from the previous short list of materials, everyone is allowed to choose his own reactants. Toothpaste, sugar, honey, inks, flavor, fabrics, cotton, effervescent pills, gelatin, nail polish, rice, cosmetics and mycelium denote a strong creativity developed in gathering heteroclite substances, revealing the significant desire to handle and engender singular bodies by the "micro-fiddling" attitude prescribed. Artists like Alberto Burri in the beginning of twentieth century (Braun et al. 2015) or more currently Michel Blazy,[2] actually inscribe their practice towards an engaged fascination towards the behaviors of matter. Where Burri—whatever it takes from miniature to monumental—obsessively maltreats and constrains matter staying in the apparently flat bi-dimensional space offered by the canvas, Blazy provokes the large scale proliferation of mycelium to build up his sculptures. Both of these references are introduced to the students as approaches sturdily facing on scales contrasts through deep explorations of substantial phenomena (Fig. 1).

By choosing a singular tool—which is now part of the exercise as a specific request—each student provokes unexpected phenomena through the "fiddling" step. The essential issue consists in picking utensils from "other" practices in a view to have micro transformations occur in the inner structure of matter. The tools selected are related to several fields, e.g., bakery, surgery, do-it-yourself, body/care,

[2]Exhibition «*Post-Patman*», Michel Blazy, 02.01-05.06/2007, Palais de Tokyo, Paris.

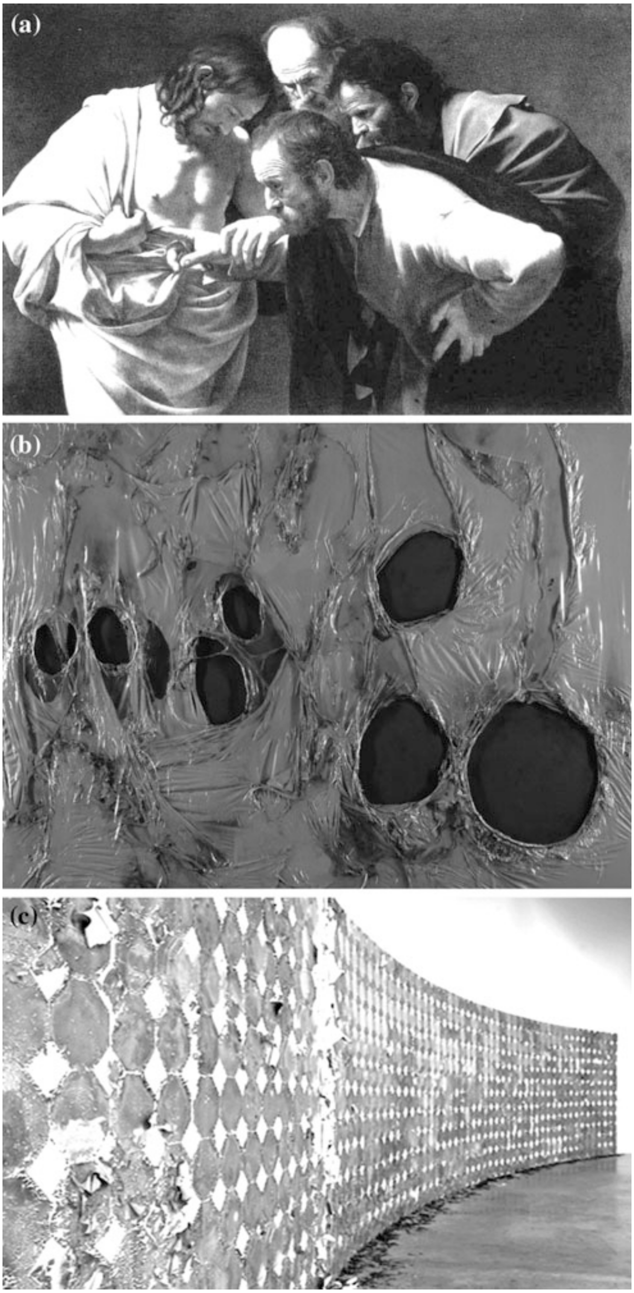

Fig. 1 **a** Caravaggio, Michelangelo Merisi da; L'Incredulità di san Tommaso1603. Bildergalerie, Postdam. **b** Alberto Burry; Rosso Plastica, signed, dedicated per Mario Dora, variously inscribed and dated 63 on the reverse, plastic, acrylic, vinavil and combustion on canvas 80 by 100 cm; 31 1/2 by 39 3/8 in. **c** Michel Blazy; Mur de poils de carotte, 2000, mashed carrots, mashed potatoes, water, Frac Midi-Pyrénées, les Abattoirs, Toulouse

Fig. 2 André Leroi-Gourhan's demonstration of language and proprioception relations due to brain contiguities

mechanics, dentistry, everyday life. The most recruited gears are related to any kind of precision tongs such as tweezers and surgical tongs, syringes and syringes needles, lighters, pills tablets as matrix molds and solvents. Thanks to this large range of tools and reactant substances, students *transform*, *accumulate and/or combine* by *mechanical action, chemical or thermic reaction* in a view to "bake a *figment*". We use here the term *figment* from its old middle-aged meaning: from Latin *figmentum* (manufacturing), derived from *fingere* (to form), figment is the physical substance of an entity shaped by imagination, a poetical fiction[3] (Fig. 2).

In accordance to what Gilbert Simondon used to call the indetermination range of a tool—a system composed of the coupling handle + head—the generated figment offers the singular sight of microspace through which the deterritorialization that resides and where belongs its inner distortions, folds and asperities. By selecting and combining a tool to a specific gesture, students subconsciously define possibilities and, in the meantime, indetermination domains. The pill-scale workable area aims to increase the variability in aid of what is "unexpected" bearing an assumed absurdity which reveals a paradoxical "making quasi-impossibility".[4] André Leroi-Gourhan in Gilbert Simondon's lineage studies, demonstrated the significant links between gesture and language structuration (Leroi-Gourhan 1964), investigated in the XX century by Bernard Stiegler towards digital techniques (Stiegler 2014) (Figs. 3 and 4).

[3]Definition picked from French Middle-Aged Dictionary (1330–1500) available on the CNRTL website, Centre National des Ressources Textuelles et Lexicales—http://www.cnrtl.fr/definition/dmf/figment.

[4]In French, "impossibilité du faire", phrase borrowed on Christophe Gonnet, artist and assistant professor at ENSAL.

Fig. 3 Tools taxonomy; Yuan-Meï Kan, Student SPACA[A]N 2015

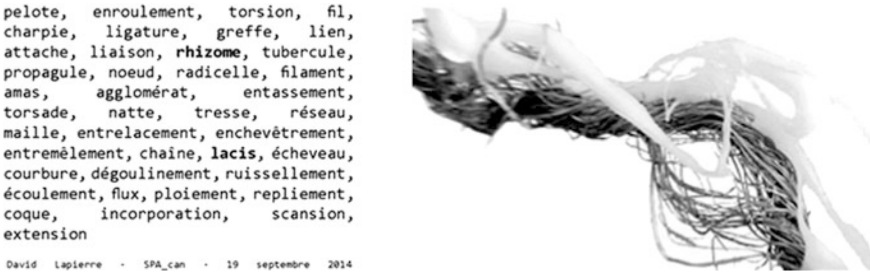

Fig. 4 Lexical field and associated pill-figment, David Lapierre, Student SPACA[A]N 2014

This Gulliverization[5] (Swift 2000) by matter, tool and "soma-technics hybrids" (Andrieu 2011) provides the original support needed in a view to impel a digital parametric posture. This involves a stage of "re-perception" as a second path through instruments. Whereas tools have a "making" function, instruments are bound to quantify through measurement. From this, as Bernard Cache points out the theory that computers are not necessarily digital objects (Cache 2011)—echoing Albrecht Dürer instruments for drawing complex curves (Vaisse and Pierre 2008) and Vitruvius' Tower of the Winds which actually computes the celestial sphere rotation from its location—the students are now asked to identify noteworthy and relevantly perceived parameters from their own baked figments (Fig. 5).

[5]Term borrowed on Jean-Philippe Aubanel, artist and assistant professor at ENSAL and Beaux-Arts de Lyon.

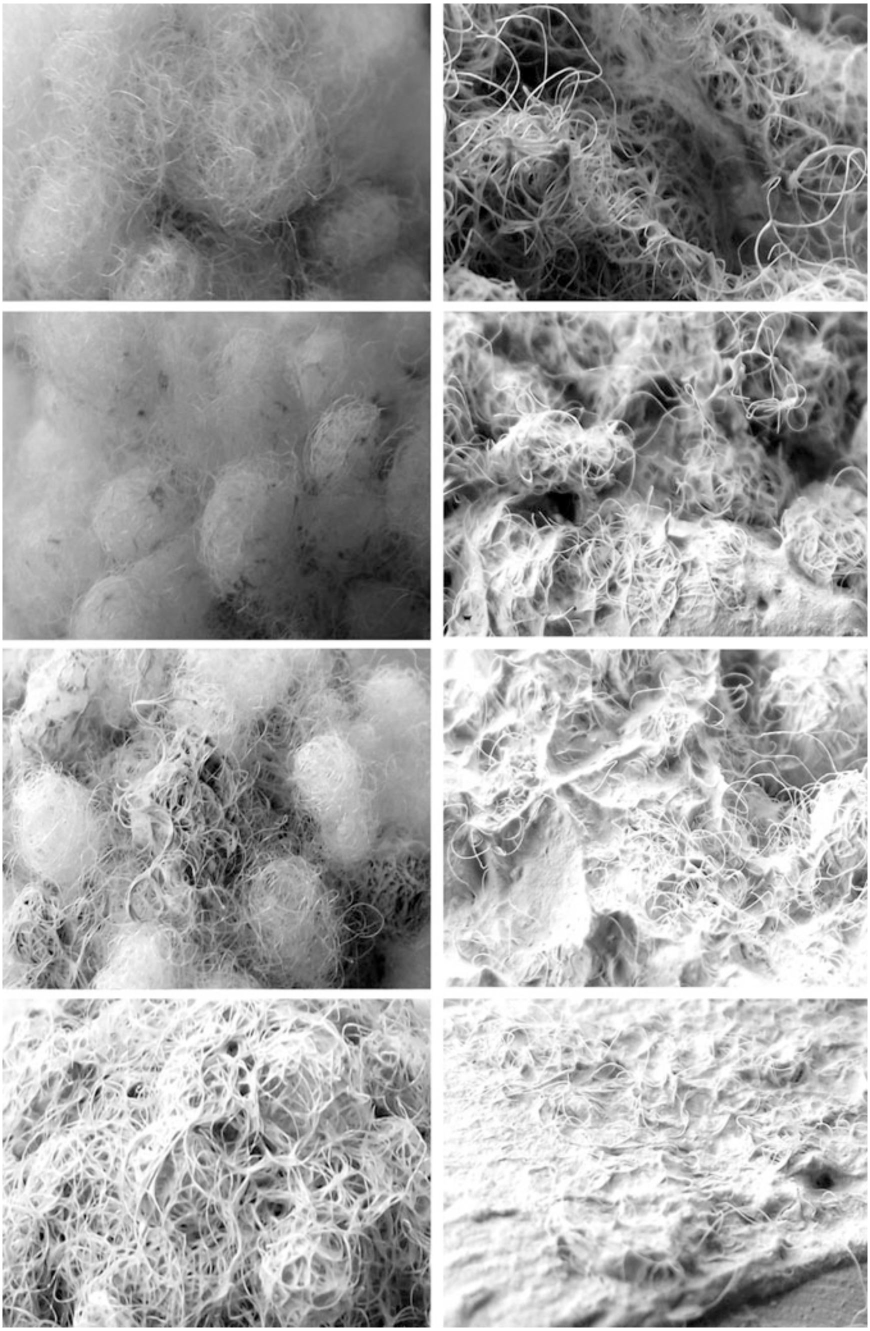

Fig. 5 Pills macro views: variations around polyester plush, clay and water; Laura Michal, Student SPACA[A]N 2015

Quantifying a Subtle Significant Through Perceptive Measurements

In Gilles Deleuze and Félix Guattari's first chapter of *A Thousand Plateaus* (Deleuze and Guattari 1980), the rhizome analogy leads the reader to a justification of the critical necessity to quantify any item (as a book) which apparently could not be, in a view to materialize a measurement's subjective unity and transform this item into a miniature-apparatus. Still in accordance with Deleuze and Guattari, the rhizome-like structured book can be read in any order apart from introduction and conclusion as the core chapters should have no line-like indices. These outstanding features of measuring sensible and analogic creations as brain secretions aiming to approach those as non-significant sequence, is the chosen method introduced to the students as the parametric design stakes for their prospective architectural work.

The very first hiatus to be pointed on is the paradigmatic dissimilarity which lives along and between an analogic posture and such a parametric thinking. Even if these two approaches seem to keep antagonizing to each other, these can actually get conjugated together. Human being is an analog creature, communicating information or behaving as he translates his thinking schemes to his mouth, language, hand, etc., whereas the computer calculates equations made of variables and invariants. Variables and invariants are what we will roughly call data and parameters faithful to the parametric digital modeler.

In practice, concerning analogic thinking and similarities in architecture, the theoretical basis students are given looks like rudimentary pieces of code. The procedure which consists in defining a fictional context and some characters paralleled with the computational method declaring a syntax and some variables are actually fairly similar on a formal level. The main difference lives along the paradigmatic crack residing between natural and formalized idioms. The fiction introduces affect and emotion while Python,[6] for example, is cold and devoid of any ambiguity (harsh in appearance only, let us notify that Python syntax name is a Monty Pythons' Flying Circus tribute). Aiming to operate the needed ideation step providing polysemy, one should intentionally mix up these to informational significant languages.

In order to print out some cognitive patterns such as jumping from natural to formalized idioms (and reciprocally), a few exercises involving poetry and mathematics are experienced with the students: poetry is a partially formal structure overlapped on a natural language, whereas mathematics syntax is purely formalized structure. Each group of two to three individuals is asked to select a theorem of his own choice in order to implement it in the characteristic poetic form. From "theorem to poem", "poem to scheme", "poem to pattern" altogether refer to the

[6]Van Rossum G (1991) Python™. Python Software Foundation.

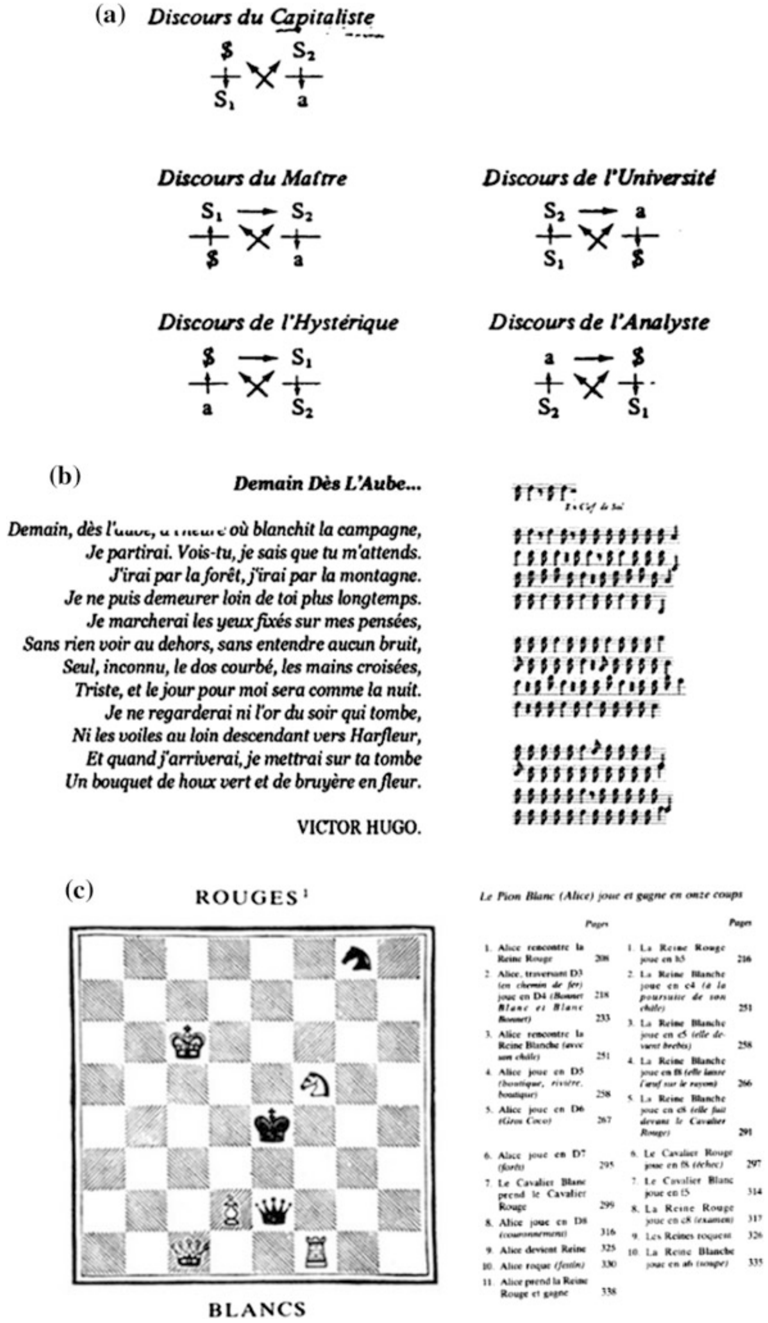

Fig. 6 **a** Lacanian Mathems. **b** "Poem To Theorem", Barbara Campelo Silva, Julia Couttet, Alexandre Valiente, Students SPACA[A]N 2014. **c** Lewis Carroll's chess play structure of a programmed novel (Figure adapted from the Gallimard french edition, 1994)

Lacanian mathems as an archetypal example of equationalization of psyche that deliberately breeds an original signified degree through the specific assumed ambiguity generated by idiomatic gaps.[7] These gaps and their mutations provoked by switching the significant medium are what we will generically call "encapsulations" in this investigation. "Encapsulation" is a term both borrowed from OOP[8] languages and cognitive sciences. In each field, the encapsulated item is the signified concept as borne information, whereas the significant medium is a syntax in one case, or synapses in the other (Fig. 6).

The students' works upstream demonstrate how these specific encapsulation experiences breed creativity while jumping from one langue to another. One of the selected examples accurately brings Victor Hugo's poem encapsulation through musical notation. Of course it makes more sense to select studies that show recurrences and rhythms which are easily communicable in English whereas the class is taught in French; it is also very remarkable to observe the way students deliberately replace the mathematical syntax—as a formalized language explicitly required—with musical syntax. Music is actually deeply formalized, and according to Deleuze (1988), the most resilient medium that is able to spread percepts. Thanks to a free software, the whole class listened the obtained result based on rhythms, verses, feet and positive/negative emotions cognitively implemented into musical values, tempo, etc.

Regarding cognitive sciences, global nativist theories point on the brain modules ability to involve informational encapsulations as specific interactions. According to Jerry Fodor during the last ten years, those are innate mechanisms which potentially trigger off abductive inferences as long as we consider these encapsulations as series of local phenomena (Fodor 2003). On the contrary, the Massive Modularity thesis supports the CTM[9] rationalist ideas which would actually reduce brain activity to syntactic processes made of inputs and outputs, avoiding thus any natural ambiguity. In our research, the gaps and bridges provoked by jumping from one significant medium to another, precisely belong to this theoretical rupture. From the statement defining programming encapsulations as a crucial abductive and concealed implementation of information, we assume that these gap potentialities actually enhance both fields: cognition and computation.

[7]Contrary to Wittgenstein's Tractatus theory, a strictly normative approach of philosophy implementation in algebraic language.

[8]Stands for Object-Oriented Programming.

[9]CTM stands for Computational Theory of Mind, a cognitive theory developed by Jerry Fodor between the 1960s and the 1980s.

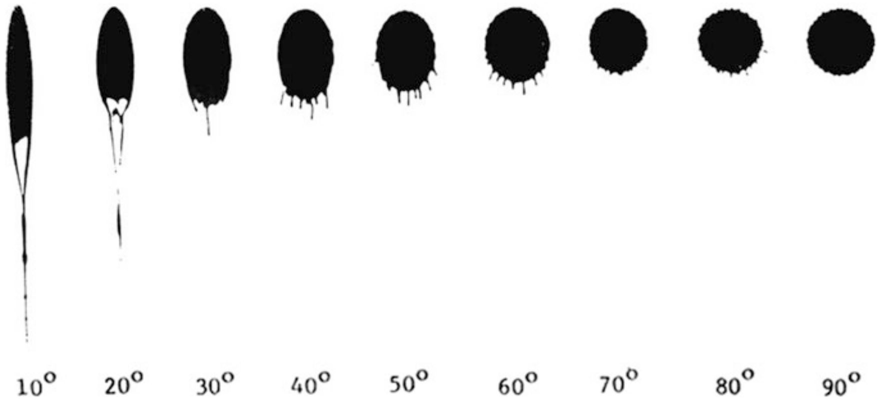

Fig. 7 Bloodstain patterns in forensic sciences and angles sagacity (Figure adapted from MacDonell, 1993)

Parametrizing via Abductive Fictions

Inference theories mostly focus on inductive and deductive reasoning whereas Jerry Fodor points out the lack of creativity proposed by such reductive inferences. Indeed, strictly thinking from particular to general and vice versa is quite sterile. Fundamental discoveries would never have happened without abduction, called sagacity by Umberto Eco and developed in his novel "The name of the Rose" (Eco 2012) and the related apostille (Eco 1987). As a detective method, abduction appeals to creativity over hypothetical postulates. As a consequence, forensic sciences and criminology, in matter of detective methodologies, are the chosen fields selected to illustrate abductive stances through a material thematic. These offer a large range of quantification situations from crime scenes with very little evidence (Martin 2002) and in this way developing the investigator's, i.e., the students', sagacity. Bloodstain pattern studies specifically tell us a lot by staring at micro-scale pieces (MacDonell 1993). Any stain outline reveals a lot toward parameters related to projection support type, speed, angle of impact, emission point, emitted from artery or vein, etc. (Fig. 7).

As a parametric-analogic (not computational) thinking, abduction justifiably brings the questions of analogies and ideation as a combination of abstraction, ambiguity and imprecision respectively generating simplification, alternative meaning and flexibility by overlapping different entities and images native to heterogeneous fields. At some point, abductive reasoning generates fictions as a projective *reductio ad absurdum* necessity. In terms of matter and form investigations, this parametric-analogic posture is even close to apophenia,[10] by extension, as an "almost misuse of language" (Fig. 8).

[10]Psychiatric disorder causing perception alterations.

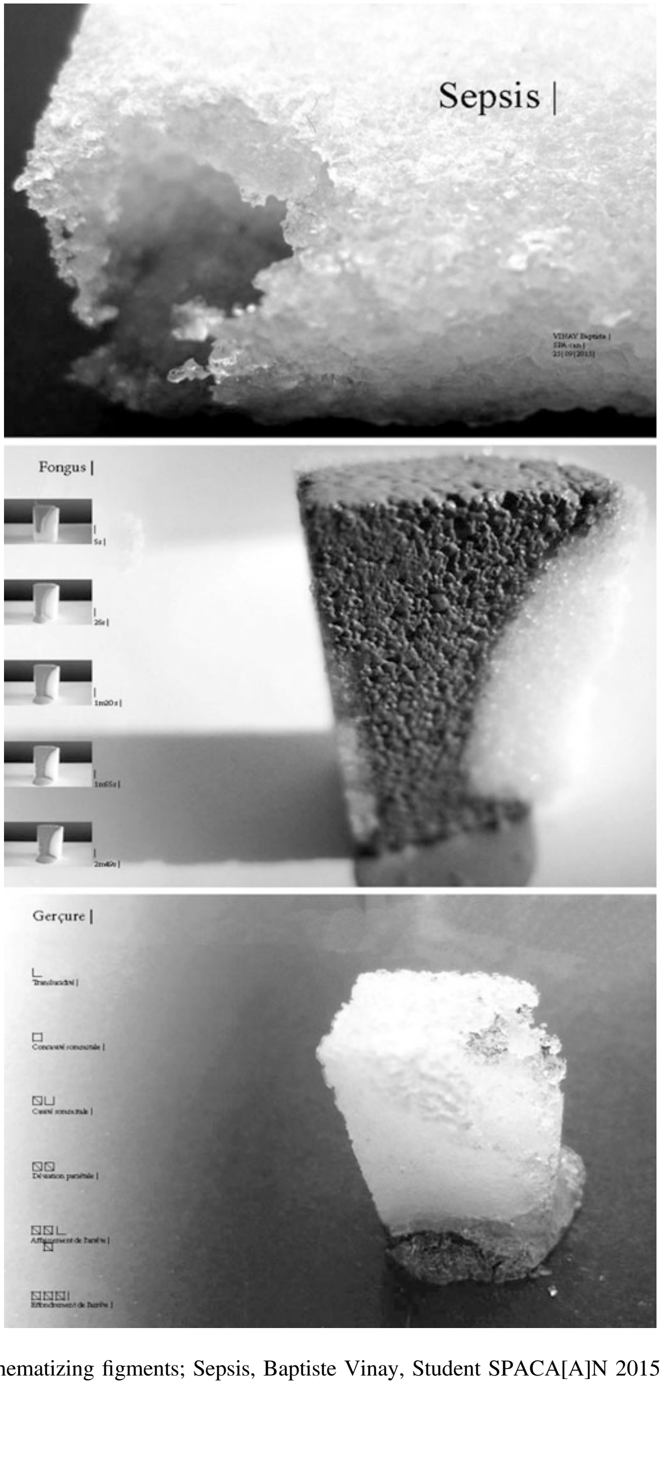

Fig. 8 Mathematizing figments; Sepsis, Baptiste Vinay, Student SPACA[A]N 2015

So we deliberately use the analogy of forensic sciences to introduce the stakes of abductive sagacity in terms of mathematizing percepts. Analogies as evoked in this research actually refer to Jean-Pierre Chupin's taxonomy of analogies in architecture (Chupin 2007). The way Chupin classifies these analogies, among a cognitive and creative line of attack, is mainly an apology to what Michel Foucault actually names *similitudes* as *aemulatio*, *convenientia*, *analogies* and *sympathies* (Foucault 1966). Those ignite the fiction relative to the necessary architectural projective scenario. From this, trying to mimick a programmed attitude by sticking faithfully to students' selected analogy, each group is asked to write a fictive heterotopic scenario as an encoded guideline for an upcoming architectural design, aware that the concept of analogy injected into parametric thinking is a paradox when it comes to digital instrumentation. Let us explore this hiatus.

Fiction as Practice[11]

As the famous avant-gardist French architect François Roche claims, fiction is (must be) quantifiable when it comes to the architectural project research. Conformably to our analogic line of attack enounced upstream, let us accurately illustrate the prescreened stance by facing on one hand the archetypal structure of a fairytale,[12] and an object-oriented based programming language pieces of code on the other hand: some questioning *similitudes* are emerging. As a pedagogic experiment, the standard enchanted scenario template and the syntax elements extracted from a few lines of code —written in Python language and implemented for Rhinoceros[13]—are mirrored as follows (narration is **bold**, code is `courier new`):

[11]*R&Sie, Roche F,* http://www.new-territories.com/.

[12]Extracted from the formalist approach of Vladimir Propp's fairytale archetypal narrative sequence.

[13]Rhinoceros 3D ©. Robert McNeel & Associates.

Once upon a time in a land far far away…
```
>>> import rhinoscriptsyntax as rs
```

Context setup
```
>>> srf = rs.GetObject();for coords in pts_coords:
```

Characters:

Hero
```
>>> pt = rs.GetObject("Select one point", filter = rs.filter.point)
```

Villain(s)
```
>>> repulsors = {}
```

Other characters
```
>>> points = {}
```

Story Starts
```
>>> rs.EnableRedraw(False)
```

Hero leaves home
```
>>> rs.EvaluateSurface(srf)
```

Hero told **NOT to do** something or go to a certain place. Hero goes there anyway and **meets** the villain
```
>>> for att in pts_coords […]
```

Hero is **tested**, helped or attacked
```
>>> if rs.VectorLength(rs.VectorSubtract(pt, attractors))<min_dist:
rs.DeleteObject(pt) […]
```

Hero **reaches** prize/treasure he is seeking
```
>>> End Loop […]
```

Combat between hero and villain
```
>>> if, elif, else […]
```

Villain defeated
```
>>> pt = attractors (??)
```

Hero heads for home
```
>>> else return
```

Story End, *Happily ever after*
```
>>> rs.EnableRedraw(True)
```

As we can notice in such an odd operation—overlapping fairytale and OOP language structures—the similarities and singularities highlighted illustrate quite literally the way form and medium can stay heterogeneous along a projective process. There are some examples in the history of literature which show this non-contemporary numerical approach. In his novel, "Through the looking glass and what Alice found there" (Carroll 1994), Charles Lutwidge Dodgson, famous logician better known as Lewis Carroll, wrote the first entirely programmed novel. Indeed, the story narrated is no more than the ferocious struggle between Alice and the Red Queen translated from a chess game in which each chapter represents the move of a pawn. From this fresh historically set approach of imagination and figures (Wilson 2008), now students can confront parametric matter embodiment on a smooth and disinhibited footing (Fig. 9).

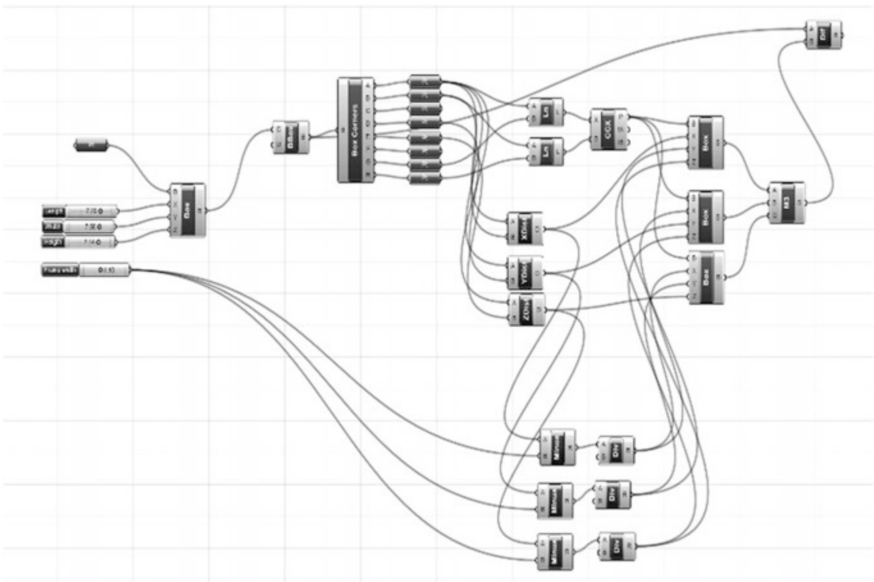

Fig. 9 Anatomy of a Grasshopper© definition

Inputs and Outputs: Matter Embodiments

The semi-programming interface offered by Grasshopper© (Payne and Issa 2009), is made of series of objects components which mainly resume the functions of an OOP formalized language. These components basically bear the commands of Rhinoceros©, the 3D modeler in which Grasshopper is added. Some of these commands are geometrical objects such as point, point clouds, various types of lines and surfaces such as NURBS[14] based surfaces and curves, or meshes. Any geometry can simply be picked from an existing model or entirely generated from input parameters in Grasshopper. This is the method described in this section. The other components available are vectors, logical statements, sets and trees, transformers, Boolean operators, etc., which essentially constitute Grasshopper's built-in default set. A large amount of specific components are also downloadable, accommodating extra playing fields such as connecting sensors, puncturing sets of numerical data from the web and social networks or connecting advanced manufacturing gears such as robots or computing structural dynamics. Each of these components—as any OOP-like object—is anatomically made of inputs and outputs trees (respectively from the left to the right). Inputs, hosting persistent and/or volatile data sets, once gathered up into the component, generate outputs trees, in turn self-producing volatile data as variables. Persistent data represents the invariants which have been previously established from

[14]Stands for Non-Uniform Rational Basis Splines.

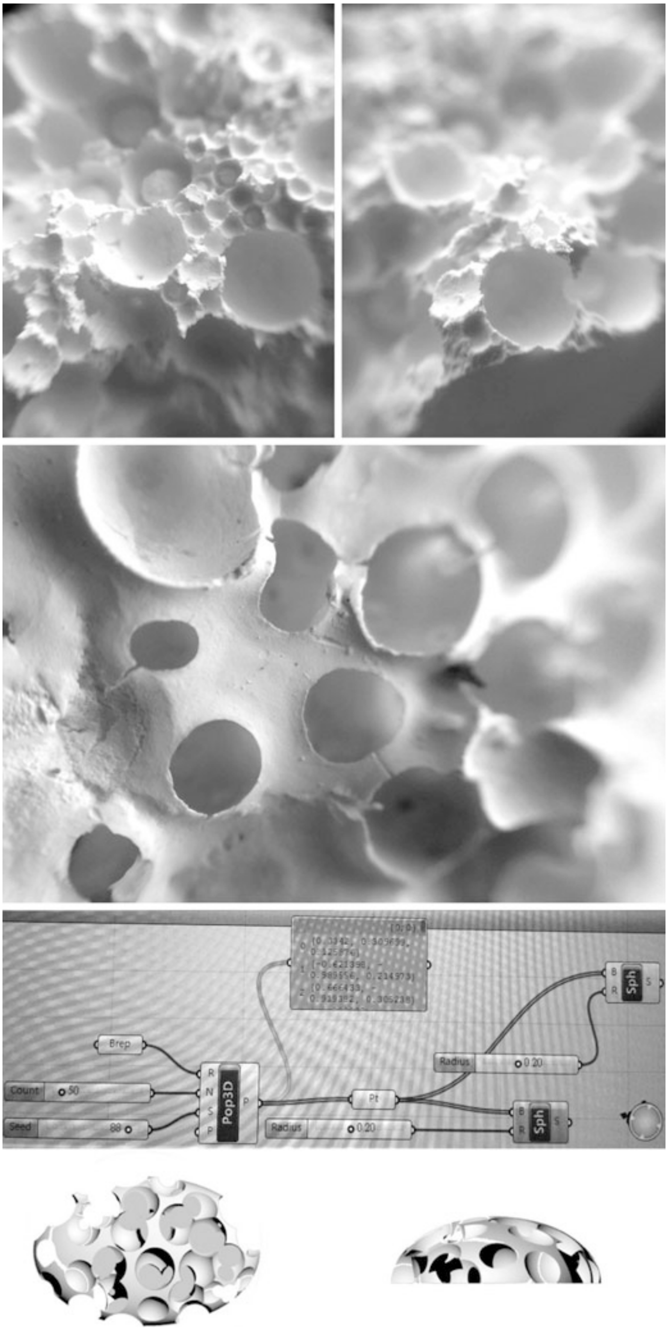

Fig. 10 Parameters selection from pill-figment, Yuan-Meï Kan, Student SPACA[A]N 2015

Fig. 11 Digital pills, analog models and 3d prints: gaps and similitudes, Anne-Laure Garry, Emmanuelle Révillion and Rachel Wagner, Students SPACA[A]N 2015

the model or manually set by the user, while volatile data bear the variability of the code, as they can be generated by imported figures sets. For example, these accurately remain updated in real time like data types such as market rates, GPS locations or even the brightness of a room as a numerical transcription of luminosity levels. The simplest method to handle variations using volatile data is the use of numerical sliders providing floating points, integers, and even and odd values included in a range. All these values can be randomized or mapped on graphs and patterns. Grasshopper is, on a pedagogical level, a motivating tool in the way it actually meticulously mimics programming languages' routines in a friendly interface sparing a rigourous coding apprenticeship. Complex and heavy lines of code that did not allow any typing or statement tabulation error in the past, are now fully avoided by this graphic environment while still providing the required skills. As we can observe on the following figure, the very first exercise introducing parametrics consists in modeling one of the pill-figments manufactured in the first part of the term. Here, Meï isolated parameters, such as cavities concentration and localization, on a solid ellipsoidal object (Fig. 10).

Now we introduced the "plug-and-play" functioning of the tool empowered by the students, we clearly identify the potential of such a commutative strategy. The user can set any data at first and replace it later on with a more elaborate (or simply imported) set fitting on the strategy he established earlier. This permits to approach parametrics in a smooth manner by interchanging groups of components as the designer modifies interactively a passage of his architectural heterotopic scenario. Still, based on the observation of practitioners, one of the most recurrent issues emerging from these operations is to preserve the seductive aspects of the very first analogic and spontaneous tests.

Indeed, a few cases also reveal, at first, an initial partial incapacity for the user to interact with his own creation due to a lack of skills and adroitness with the parametric software. To avoid this situation as much as avoiding the "white screen syndrome", a set of basic files are transmitted to the students aiming to encourage them to mix up components while acquiring a sharp dexterity and comprehension of parametric thinking through a "dissective" stance. Indeed, they are strongly encouraged to design their own parametric diagrams with the same surgical attitude they developed during the analogic and physical exercises: both part adventitiously and meticulously in the meantime. And, heading towards the design of an architectural space proposing new object schemes and usages, our encapsulating

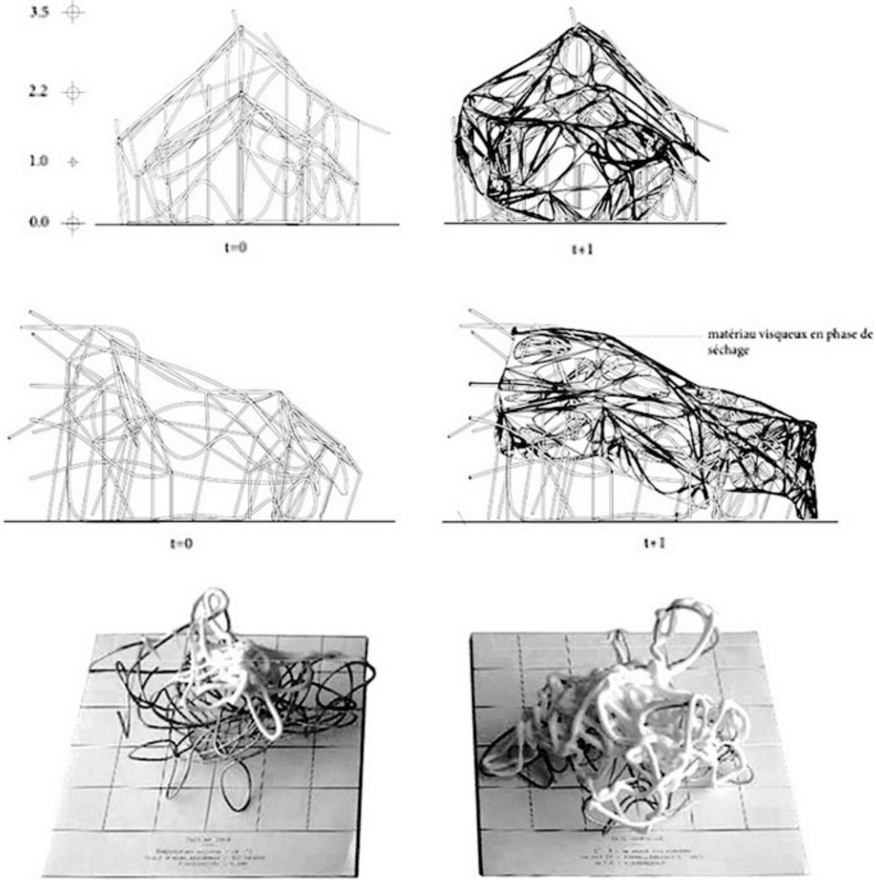

Fig. 12 Normative representations from physical-parametric model, Raphaël Masbernat, Olivia Rousseaux and Alexandre Valiente, Students SPACA[A]N 2014

pedagogical strategy implies a start from a previous, which is both digital and physical, both significant and analogic, engendering a new pill-figment (Fig. 11).

This exercise focusing on parametrically modeling (and then printing) this "digital-pill-figment" implies the identification and selection of parameters intuitively constituting the singularities of the previous analogic-pill-figment. By setting variability on these specific singularities punctured from matter, the results are logical and relatively unexpected geometries due to combined variation declensions. As a generic observation at this crucial stage of the experiment, we can clearly state that the usage of the slider button component (or digital cursor) actually establishes a visco-plastic dimension into the virtual object. This interactive approach of parametrics and architectural geometrics adds a new specific dimension of fluidity towards matter,

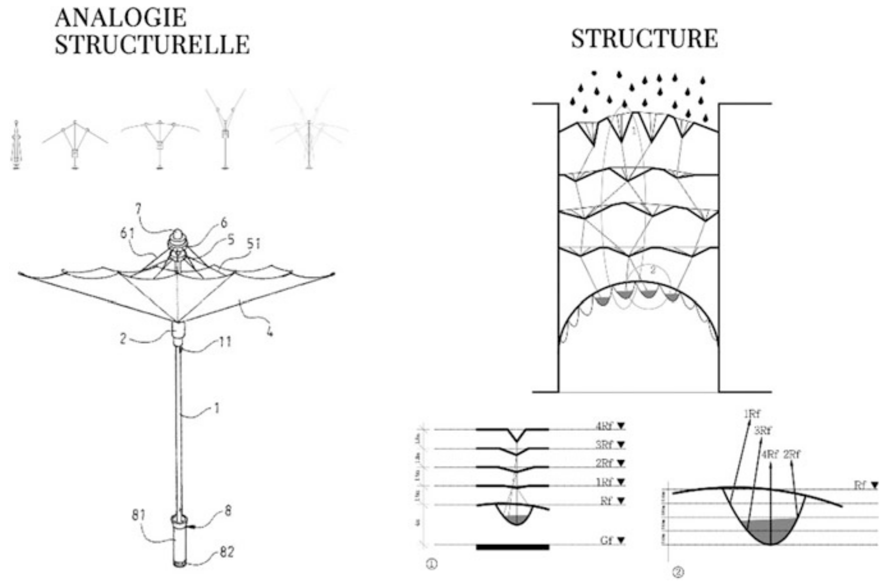

Fig. 13 Structural analogy of an umbrella, Anna-Andréa Obé-Gervais and Yuan-Meï Kan, Students SPACA[A]N 2015

implementing the targeted embodiment in CAD/CAM,[15] augmented by matter convulsions due to parametric variability and mutations. Concerning the use of a 3D printer in a view to generate digital figments, we observe that the constraint of producing a pill-scaled object involves the same issues toward matter that the students had to deal with analogic figments: even advanced digital CAM tools remain in an indeterminate range towards matter. This particular slice brings new un-expectable phenomena which accurately feed the prospective architectural project by the inclusion of virtual/physical hybrid geometries.

Matter Poetics as Structural Stance

In the last stage of the studio, structural materiality is still broached with the same paradoxical stance: preserving poetical dimension through analogies/analogic embodiment using a virtual advanced strategy. And, aiming on the structural development of a prospective architectural apparatus, the assumed stakes live accurately along the extreme care of the designer disinhibition thanks to variability in parametric via heterotopic scenarii. In this vein, two strategies are mainly and equally adopted: inventing a material and/or designing a new construction tactic following the guidelines

[15]Stands for Computer Aided Design and Computer Aided Manufacturing.

Fig. 14 Work-in-progress results, 2015 December: propositions for constructive and structural apparatuses, Laura Michal, Sophie Rullet and Baptiste Vinay, Students SPACA[A]N 2015

established through the directive fiction. This step is a crucial stage in terms of communication as a partly “normative” result legitimating the singular approach among the architectural project’s dogmas. Subsequently, we notice that the closer students get to the academic requirements related to the term’s final architectural achievement—as communication and technical necessities—the more their inhibition comes back as a “fear of commitment” (Burry 2014). The main issue for the student is to accurately evaluate the factual balance between the uses of dogmas as helping anchors, rather than as a fatality impoverishing the fertile results previously gained. The example in the figure below illustrates the relations which ostensibly and structurally arise from the translations of successive analogic/parametric/digital loops driving the students to the normative drawing of a fully original structure in matter of materiality and, as a consequence, intending a different way of covering space (Fig. 12).

This students’ work from the 2014 session led the research to offer a specific practice towards normative representation of structure on one hand, and technical drawing codes on the other. Subsequently in supervised practical sessions, each student is asked to select an object of everyday life (palpable) and a concept (impalpable) in order to translate those into conventional structural and technical representation schemes. First, the object must be embodied using red and blue lines representing compression and tension respectively as observed on the chosen system, while the concept must get incarnated using the normative codes of technical drawing (an example from one of the students’ project is: “what could the technical detail of a “kiss” look like?”) (Fig. 13).

Structural analogies and incarnations—as a disinhibition scheme—surreptitiously bring up once again the "supposed existence of a tight network of close relationships between constitutive elements of a fragmented world" (Lemarquis 2014). According to Pierre Lemarquis, French neurologist, analogic thinking remains some kind of wizardry, as an aesthetics empathy ("Einfühlung"). "Chimerazation constitutes one of the most essential resiliency processes, leading itself to cicatrization, recuperation and metamorphosis." Would this precisely mean that analogic thinking—we now assume that analogic can be parametric and digital in the meantime—is the required factor triggering the looked-for disinhibition? To pedagogically illustrate this stance, let us enunciate as an axiom based on the architects' famous *fff* that:

Form Follows Fiction[16]

…as fiction as rationality sharpening strategy (Reboul 2009) in architectural materiality prospects.

In the same way we previously encapsulated percepts to fiction, fiction to parametric formalized syntax and concept to object, let us inject these practice patterns into the last step of the project. Students are now asked to encapsulate the declension of geometries created earlier and faithful to their scenario into series of constructive apparatus taking care to envision an appropriate process involving a suitable materiality. But then again, as for the very first digitally parametrizing steps, since the architect (or the student) approaches scales bigger than 1/200° and broaches the rational structural stage targeted, we now know that we have the face "the fear of commitment". Despite an issue of such magnitude, normative drawing is one of the most crucial encapsulation aimed at getting constructible results, in order to communicate with the other indispensible building trades such as civil and structural engineering, designers, politic body, etc. (Fig. 14).

As of the moment this paper was written, the research is not completed and some prototypes are expected to be delivered. Will academic dogmatisms help or kill the creativity engaged until now? Early results show that half of the teams successfully engaged the required structural legitimacy, facing the rational and creative approach head-on, while others abandon one of the two Pascalian dimensions: geometrical spirit and/or the subtle (Pascal 2015). In general, inventing materials by replacing or combining existing fabrication process are the apparatuses which apparently seem to emerge from such an experiment. Apparatuses and especially robotics as chimeric embodiments (Roche and Lacadée 2014) are secreted by the architect's psyche conducted by analogic thinking, intrinsic to any natural creature. While analogic thinking involves mutations and metamorphosis by chimerization,

[16]*From Louis Sullivan's fff adagio: "Form follows Function" mixed up with François Roche's motto.*

parametric thinking operates variability and declension of these incarnations, wether they stand virtually or materially. Lastly, in terms of neurosciences, Pierre Lemarquis' revisited theories (Lemarquis 2014) observe and explain that aesthetics and poetry effectuates a dopamine secretion, a pleasure and reward neurotransmitter, which activates creativity in any field of action. This inspiration effect due to aesthetics stimulation was observed during some of the crucial stages of the term. From perception to action, aesthetics creates an empathic phenomenon prompting a deep desire for producing.

Conclusions

Analogies, apophenia, scenarii or fictions are *reductio ad absurdum* methods that Jean-Pierre Boutinet defines as necessary and inherent to any projective situation (Boutinet 1993) while parametrics and digital approaches bear the prospective thinking through the variability and mutation dimensions which remain. Those, as a matter of fact, enhance the stance defended in this paper as formalized apagogical strategies producing some advanced potentialities due to inflections and declensions—similar to any natural syntax—respectively generated by analogic and parametric thinking. With the purpose of reaching a fluid practice of these apparently heterogeneous attitudes, the extended notion of encapsulation seems to help the practitioner to smoothly handle both virtual and real objects head-on. Still, the concept of encapsulation remains the intrinsic but indispensable existence—as a disinhibition component—of a concealed part hidden someplace in a capsule, corresponding to its etymology. In OOP fields, any object element encloses itself in this black box, whereas an analogic scheme involves the transit of the signified information directly through the designer's psyche. Mixing these two significant encapsulating types, we can now consider the encapsulating object (brain, analogic tool or computer) as a mediator, like Jeanne Bamberger investigations with children demonstrates (Bamberger 1999). Encapsulations in creative projections establish signified contiguities making up the discontinuities due to the several heterogeneously significant media. In the continuation of Donald Schön's theories and research (Binder 1996), we could posit a first conclusion, practice as an embodiment of thinking in a projective and prospective situation involves a pattern of empathy driven by aesthetics, remarkable within classroom conditions and in the results of student work. As a last conclusion, geometries provoking new materialities in accordance with a heterotopic scenario, whether on a structural and/or aesthetics level, and, from pill-figment scale to an architectural fragment such as a prototype, engender new manners of covering spatiality through avant-gardist architecture, inventing new perambulations and perceptions of space.

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Part V
Neuroscientific Inspiration for Artists

Paintings as Complex Dynamic Systems

Sophie Lavaud-Forest

Abstract This chapter deals with the description and analysis of an artistic experiment: the *Matrice Active* project that aims to transform a work of art by Wassily Kandinsky painted according to the rules set forth in his treatise on pictorial composition *Point and Line to Plane* into a dynamic system. Details about the process of creation and realization of this project allow to present how the Distributed Artificial Intelligence technologies and more specifically agents based computer modeling used by scientists for the simulation of complex systems, provide new ways of expression to the visual artist and different modes of perception, participation, and action to the viewer. For the artist, it is to depict reality, not as a set of visible and stable forms but as a dynamic phenomenon of self-organization in which the form is emergence of behaviors and interaction processes. The shape emerges from a field of informational data, allowing the *system-image* viewer an enacted position that simultaneously locates him/her inside and outside this simulated reality. The painting image, in the Matrice Active project has moved towards the creation of a 3D dynamic virtual scenography composed of *Agents in interaction inside a complex system*, bearing witness to a paradigmatic shift in the economy of representation.

Introduction

The longstanding purpose of my artistic research is to put the medium of *painting* and the issue of pictorial field into new perspectives. I explore how emerging technologies together with scientific approaches to computer programming can expand the traditional issues usually raised by *painting* and the act of *painting*.

By doing that, I hope to offer new aesthetic experiences and writings to open the human spirit to different sensory experiences in agreement with contemporary shifts. Indeed, most people are now living in a world within which we communi-

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cate, act, and re-act by the way of technology: mobiles phones, Internet, Wi-Fi, wireless technologies, various types of sensors, cameras, and many other devices. We exchange words, images, sounds, and transform them dynamically while moving our body and our mind.

In such a context our experiences and perceptions of the world are changing. We now experience unstable and complex environments within which our relationships are increasingly mediated by technological artifacts. Consequently, it seems that *painting*, is no longer the only appropriate kind of system of representation to depict reality. Flows, exchanges, interactive processes and communication have replaced closed and fixed shapes. Now most visual artists conceive matter as energy and information. Ever since Einstein's Theories of Relativity contaminated the realm of Fine Art, shape has come to be seen as a dynamic relationship with both objects and persons. The ebb and flow of complex connections brings about a new mode of space, made of in-between movement and endlessly rebuilt. Therefore, as a visual artist, I was led to design the project *Matrice Active* that aims to transform a great work of art–the poetic, cosmic and symbolic world of the painting by Wassily Kandinsky, *Yellow-Red-Blue* (oil on canvas 1925)–into a dynamic system. Thereby, my research has become an interdisciplinary project that joins three-dimensional real time interactive technologies, a scientific approach, and both artistic and pedagogical objectives. It is this project that I will now describe and analyze.

Matrice Active: The Artistic Stakes

The key design objective behind this project is to make paintings come *alive*, to change paintings into complex dynamic environments with which the audience can communicate and interact, leading to a new sensory experience. Choosing a painting by Kandinsky as a starting point for such an undertaking does not happen by chance. In the early twentieth century, László Moholy-Nagy published with Zoltan Kemeny in the journal *Der Sturm* the manifesto "Dynamic-Constructive System of Forces".[1] At the same time, the Constructivists, the Futurists, Oskar Schlemmer, Wassily Kandinsky, and most artists teaching at the Bauhaus school, as well sought to energize space using "dynamic-constructive systems".[2] Applying the dynamic principles of life in their works rather than to perform static constructions based on the relationship between matter and form, they wanted to design structures like machines, but machines as dynamic systems in which matter's function is to convey energy. In the theatrical experiments of Oskar Schlemmer (*Triadic Ballet* 1922; *Ballet Mécanique* 1927), visual configurations are incessantly done and undone on the stage. Another example is *Pictures at an Exhibition*, a

[1] László Moholy-Nagy published with Zoltan Kemeny in the journal Der Sturm in 1922.

[2] Lavaud-Forest (2005).

"Gesamtkunstwerk[3]" by Kandinsky based on a musical composition by Modest Mussorgsky that was first performed at the Friedrich Theater of Dessau in 1928 as a «scenic composition», that is to say an abstract theatrical experiment. The main idea in *Pictures at an Exhibition* artwork, in which colors, forms, movements, and sounds are active agents, is to promote the concept of metamorphosis as a fundamental principle of art. Later on, artists such as John Cage and Merce Cunningham made chaotic events using simple rules to create complex dynamic systems leading to a new vision of scenic spaces inspired by the General Theory of Relativity wherein each point refers only to itself or to points that are very close to it.[4] Cunningham's choreographies evacuate any idea of hierarchized or centralized space to promote distributed energy flows, which are synonymous with the flow of the performance. Space is already treated as a network of energies and circularity of information. Sounds, words, movements, colors, lights interact with each other and with the scenic environment allowing new autonomous entities to appear, exploring virgin territories from which unpredictable, autonomous, and unprecedented behaviors emerge.[5] For Cage and Cunningham, the stage is a continuous field where the spectator's eyes have nothing to grab at. The choreography spreads out in waves as do the paintings by the American painter Jackson Pollock when covered by his interlaced drippings. These choreographies are a new form of theater very close to "happenings" and to the abstract scenery theorized by Kandinsky to renew the theatrical paradigms of his time. Furthermore, this is also close in spirit to the complex systems as exemplified by Cage's *Imaginary Landscape Number Four* (1951).

Building the world by means of dynamic architectures of information rather than representations of mere appearances is an idea that already contains a kind of technological thought and, as seen just above, this is a project that did not wait for electronic or digital technologies to exist. However, we are going to see how the evolution of techno-science and its accompanying applicable computer models have stretched the limits of the previous scenic experiments and now provide the visual artist with ways and means to invent new scripts that widen our prior system of representation. Hence, it's quite meaningful to say that digital technologies substantially realize some of the promises and hopes of the twentieth-century avant-gardes.

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[3]Attributed to Richard Wagner, the term designates a total work of art. In German, the three words that make up this word have this literal translation: gesamt (total, complete, all together), kunst (art), werk (work).

[4]Lestocart (2005).

[5]Lestocart L-J, op. cit., pp 495–523.

The Description of the Projet *Matrice Active*

The Derivation with Kandinsky

At the end of the twentieth century, the development of three-dimensional real-time Virtual Reality technologies, have made possible for me to design and implement a computer model that interprets the pictorial field of a painting while inventing what I call a “dynamic system picture,” i.e. a VR modeling of a painting into a sociable and living digital simulation that responds to the immersed viewer by means of position and movement sensors. 3D simulation of the painting represents the reality as a complex system whose dynamics is designed as phenomena of emergent self-organization where the elements interact with each other and with the user. This concept has been largely inspired by Kandinsky’s own artistic theories. Through his practical work and writings, this visionary painter and theoretician sought to “make the living work,” solicited “the spectator’s collaboration,” and wrote in his treatise on pictorial composition *Point and Line to Plane: contribution to the analysis of the pictorial elements* published in 1926: “Here again we have the opportunity to enter the work, there to become active and to live its pulsation with all our senses.”[6] For Kandinsky, the general goal of painting was the understanding of the general laws of the universe, and he also worked his whole life to regenerate the theater of his age with the design of what he calls an “abstract scene,” which tantamount to a theater of incessant changes. This, in turn, led him to write perfectly timed scenarios of the spatialization of his own paintings, which he called “scenic compositions.” As the artist, theoretician and academic Edmond Couchot says[7] my project *Matrice Active* is both a provocative and soothing, modern and classic work of art, and an experiment in sensory mediation that allows the interactor to literally embody Kandinsky’s theories and concepts thanks to Virtual Reality technologies. But with this *Matrice Active* project my work tends to go further: Kandinsky is a starting point that allows me to overcome and surpass Kandinsky’s thinking even while relying on it, to forge my own theories and set up my own artistic posture that seeks to explore the relationships between information, data and shape. So doing, the result is to free painting from its projection surface (the canvas) to let it live inside 3D virtual immersive scenographies.

Such an artistic context depicts Reality, no more as a set of stable shapes but as a self-organizing or emerging behaviors that Distributed Artificial Intelligence technologies usually used to simulate complex systems, can model.

[6] Kandinsky (1991).

[7] See the excerpt of my thesis defense report by Edmond Couchot, President of the jury: http://www.sophielavaud.org/?p=1396.

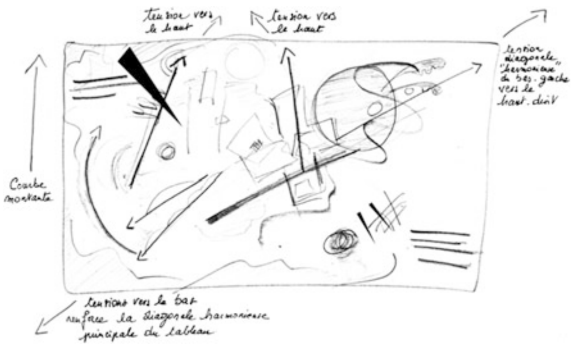

Fig. 1 Analysis of tensions at the global level

From Picture to System

The first step in the realization for this project is titled *Tableau scénique n*o *1* and allows the viewer an active and playful immersion inside the 3D modeling of the painting *Yellow-Red-Blue*. It consists of putting the image of the painting into a virtual scenic space modeled in three-dimensional digital scenery. From the interpretation of the image, I proceeded to list the elements which are determined by the shapes and colors created by the painter.[8]

I also analyzed the rules of composition and spatial organization, identified the tensions on both the global level—i.e. the whole picture (Fig. 1)—and local level—between two or more discreet elements—and finally made computational models of the artwork and its interpretation. Everyone knows that Wassily Kandinsky painted his paintings as fields of tension and interconnected entities of energy: the goal of my interactive device is therefore to make the viewer discover the rules of construction of the painting by inviting him/her to discover the spatial scenography both with the eyes and the hand (via the mouse), thereby offering a new reading of it.

The device becomes a "system-image" conceived as a complex dynamic system where the scenic elements—determined by the ones on the canvas—interact with each other and with their environment. To try to define what a scientist means by complex system,[9] I will quote here Guillaume Hutzler: "Complex systems are organized in levels, defined by composition of lower level elements, or resulting from self-organizing or emerging phenomena.[10]" We immediately grasp the complexity of this type of field and thus the need to define the new concepts raised by Hutzler's premise. For Hutzler: "The terms of self-organization and emergence have similar meanings, the first one originates from the physical and chemical sciences, the second one being more used in biology, thus also in Artificial Life

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[8]See the double entry table as a scriptwriting tool on: http://www.sophielavaud.org/wp-content/uploads/conception_tab_sceniquen%C2%B01.pdf.

[9]Briot and Demazeau (2001).

[10]Hutzler (2000).

(Cariani 1990; Steels 1991).[11]" Self-organization refers to the quality of a system that seems to obey fixed internal laws. The adult brain has, for example, a property that enables it to structure the chaotic flood of sensory information it receives. Moreover, we speak of emergent properties when a system, as a whole (the "global" or "macro" level), indicates behaviors that are not explicitly present inside each component of the system (the "local" or "micro" level), but are the result of the internal dynamics of the interactions within the system and/or its interactions with its environment. Thus, to carry on with the example of the human brain, it can be said that each individual neuron is a poor thing, compared to the strength of a neural network connected together to solve a problem and make intelligence arise. In other words, the whole is much more than the sum of its parts. In *Yellow-Red-Blue* by the inventor of abstract painting, the painter's language has reached a level of great maturity based on a combination of simple geometrical shapes (circle, triangle, square) and on primary colors (yellow, red-magenta, blue-cyan), organized in order to produce a complex two-dimensional scenic layout according to a mathematical equilibrium matching the criteria of construction so dear to Kandinsky. The painting was built as an architecture of relations between formal and colored elements wherein each one, taken individually, has little strength and whose meaning emerges from the overall construction on the planar surface of the canvas. In this way, can't it be considered that the painting might already constitute a complex system? The answer is that it does if and only if the process of its self-organization could be apprehended. But this is not permitted by the frozen device of clotted coats of painting, contrary to the "system-image," which deploys the painting in a virtual data world wherein elements based on Kandinsky's shapes and colors interact with each other and with their environment. Thus, I can assert that only the model from the computer simulation can reveal the dynamic structure underlying the painting and usually hidden in the fixed result. The virtual living painting whose dynamics derive from emergent behaviors reveals the complex creative process of the original painting and allows the interactor to access it by the means of his interfaced gestures.

The Technical Development Interface

The model conceived for the three-dimensional digital artistic creation based on Kandinsky's work was implemented using Virtools Dev technology, a specialized tool facilitating the construction of three-dimensional interactive virtual worlds. The idea is to split up the painting by Kandinsky into elements made up of shapes and colors and to give each one a sort of personality depending on its role within the painting. To build the physical model based on mathematical formulas, we[12] used a

[11] Hutzler G, op. cit., p 36.

[12] The team involved in the design of the first prototype *Tableau scénique n° 1* was made up of Yves Demazeau, research director at Centre National de la Recherche Scientifique and head of the

Fig. 2 The modeled stage with the elements (*screenshot*)

modular template that easily allows for adding new functionalities. For the elements and their environment, the physical model comes from classical mechanics: mass, position, orientation, gravity, speed, acceleration. Accelerations, dynamics, collisions, forces of attraction, repulsion, and tension were implemented for the interactions between elements.

The stage where the elements interact has been modeled as an hemisphere (Fig. 2) and the painting was split up into twenty-eight elements with specific visual attributes (shape, color, textures, reflectivity, transparency, diffusion, animation) and fourteen graphic elements (black and still).

I gave each a name, a role, and local behavior depending on its position inside the real painting and an aesthetic weight and a function according to my symbolic interpretation. Each element has a 3D visual representation in order to express its personality. Each has a physical "reality" in order to produce a fluid and realistic movement: a mass, a position, and an orientation within the virtual arena. They are situated in a physical environment: some attributes indicate when they are affected by gravity (downwards-oriented force depending on mass) and the Archimedes principle (upwards- oriented force depending on volume). In order to express the concept of force and tension, an element can be constrained by forces exerted by other elements so that it produces emerging movements of translation and rotation. In order to affect the behavior and aspect of the elements at the local level so as to make them seem like living beings as much as possible, they also have attributes that indicate their vitality (energy) and their internal state. The states of the elements are expressed visually (for instance, a peaceful state with the blue color) or dynamically (for instance, a state of lightness with a small mass). Changes in state

(Footnote 12 continued)

LEIBNIZ—IMAG laboratory at Joseph Fourier University, Grenoble, for the scientific aspects and Yves Gufflet, independent computer engineer for the implementation and myself for the artistic aspects.

allow the enriching of their personality as perceived by the user. Although changes in state are discontinuous, they are represented by continuous transitions so that the artistic effect is maintained. The energy value indicates whether elements are "dead" or still "alive." The "dead" elements do not interact anymore. Energy increases or decreases through interactions.

Relying on Kandinsky's work on theatre and scenic compositions involving abstract agents such as shapes, colors, lights, and movements, I chose to render them using a 3D model that attempts to be the most natural interpretation possible of the original 2D shape. For instance, a circle becomes a sphere, a square a cube and so on. I also added the setting of lights, some virtual video cameras that the user can easily move, and a choice of different views: front view, subjective view or user's view, inside-elements view (Fig. 3).

The elements become agents interacting in the scenography. They have to reach a state of equilibrium at the global level, i.e. a final position within the scene, depending on their local interactions. In the state of equilibrium from Kandinsky's point of view (the final state of his original painting), I want each element to have a final position, a final orientation and a final internal state (Fig. 4). In this final configuration, each element is motionless. That means its speed is null ("it is not moving anymore") and that the sum of forces by which it is constrained is null as well ("it will not move").

To summarize, I would say that in *Tableau scénique no 1*, the "system-image" is composed of the following structures:

- The *agents*: autonomous entities of the computational model set up according to the PACO (COordination PAtterns) Protocol developed by Yves Demazeau and based on the technology of Multi-Agent Systems (MAS), or what is also called "Artificial Distributed Intelligence." The PACO paradigm has been adapted from 2D to 3D space. Transposed to Wassily Kandinsky's work and to any painting, the agent-based approach allows the computer model designer to consider each element of the painting as an agent—i.e. a single autonomous entity which exists weakly on an individual basis but which collectively exhibits the strength of a complex dynamic system. In the *Matrice Active* project, the agents naturally converge towards their point of equilibrium (the one given by the position and spatial orientation of Kandinsky's original composition). So it

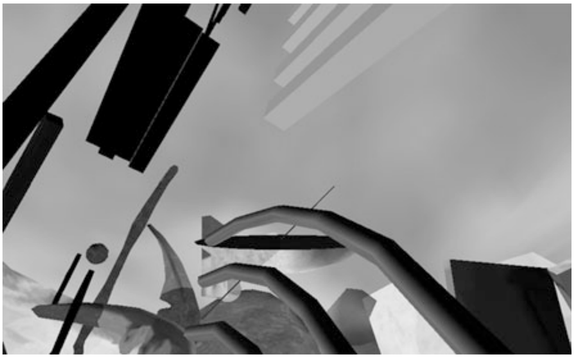

Fig. 3 An example of the inside-element point of view (*screenshot*)

Fig. 4 The state of equilibrium (front view, *screenshot*)

can be said that they "self-organize." Each of them is intended to occupy its equilibrium position by referring to the position of the other agents that are the closest to it. Thus, the set of internal interactions between agents (the micro level) leads to achieve the overall balance of the system state (the macro level).

- The *scenic elements*: they are the visual shapes borrowed from the language of Kandinsky, which somehow "dress" these agents to make them perceptible to the human senses. This is the term used when referring to the graphic context. They are part of the virtual agents driven by dynamic behaviors, which advantageously replace the "accessory bodies" in the scenic paintings actually realized by Kandinsky at the Friedrich Theater of Dessau (*Pictures at an Exhibition)* or theatrical productions by Schlemmer. In the interactive scenography I have conceived, they are simultaneously automata-autonomous by virtue of the interplay of forces of attraction, repulsion, or tension that underlie their motion-and puppets dependent on the movements of interactor that set them in motion and regulate them.
- The *virtual environment*: based on the arrangement of a physical model defining a place to locate the agents/elements. This environment is characterized by universal laws (law of gravity, Archimedes's principle) which apply to all agents. The PACO paradigm defines a model of reactive and situated agents. In this paradigm, each agent is considered as a partial solution to a global problem. Agents do not approach the problem holistically, nor do they have the ability to detect whether a global solution has been reached. These agents interact with each other and with the environment through forces. They have mass and, due to these forces, they acquire speed and acceleration. Forces are in general tensile forces that allow the model to simulate the granularity and stiffness of the desired solution. An agent reaches a partial solution when it places itself within the environment in a stable way. A global solution is reached when each agent within the system is stable. The agents are considered "reactive," because they do not have any representation of themselves, of others agents, nor of their environment. A local change within the environment produces an immediate search for a new stable state for this agent, and consequently, for the whole system, thereby leading the scenography through numerous more or less chaotic states (Fig. 5).

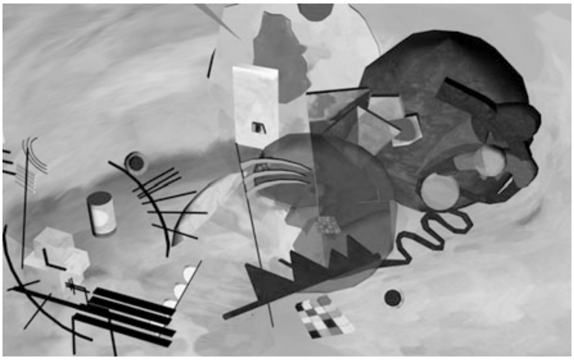

Fig. 5 One of the chaotic states of the scenography (user's point of view, *screenshot*)

The Analysis of the Viewer's Status

My work has developed through different versions that allowed an increasingly relevant writing/design of the interactions between the living painting and its viewer. These interactions were first designed in the *Tableau scénique no 1* for use of a mouse and keyboard.

Tableau scénique 2.0, which is for the moment the latest version of the *Matrice Active* project and logically builds upon *Tableau scénique no 1,* invites a large audience to move in the physical space of the scenography. The viewer's displacement and the different postures he or she has to adopt lead to a co-construction or co-deconstruction of the constantly changing virtual painting projected in front of him/her. The interface in this instance is a Kinect® sensor, usually used as interface in the entertainment industry, adapted here to an artistic pursuit. This artistic installation offers the audience a fun and interactive journey inside the painting, or rather its computer simulation. The interactor also "performs" as a vital force, just as the other agents do. He/she acts at the local level and his/her action has an effect on the global structural equilibrium. The setting in motion and in action of his/her body regulate the different states of the modeled "system-image" in varying degrees of order and chaos. He/she is invited to change the plastic composition of the picture in real time. Thus, each person can help define different states that produce new semantic constructions within the projected painting in a collaborative process. So, in *Tableau Scénique 2.0,* the challenge is not to represent movement but to let it emerge in accordance with the scientific meaning of emergence in complex systems—i.e., the dynamic result of both internal interactions within the system (the shapes linked by attraction/repulsion or tensile forces) and the external interactions with its environment, an environment which the spectator/interactor is part of, and is invited to set in motion, too. Since the 1950s, certain artistic practices have contributed to a reflection on the viewer's status and position taking into account that any shift in the knowledge of spectator's activities of perception leads to changes in the systems of representation themselves and vice versa. Video art, and more generally installation art led viewers to become aware of their status as perceiving subjects. The "system-image" enables artists to carry on with these discussions in a symbolic continuity that counterbalances the discontinuity introduced by technology. In the experiment offered by *Tableau scénique 2.0*, the interactor is transported into a fictional world not only by means of his/her eyes, but also by a part of his/her interfaced body, which allows him/her to simulate actions that are usually achieved in the "real" world. Taking or removing elements, walking in the environment, transforming the parameters of the environment, all of these actions are made thanks to an interface that can be "tangible[13]" or "sensitive.[14]" The real body is no longer a "phantom body,[15]" lethargic, motionless, like a body sitting in a movie theater; but a "bilocated" body. The body is both immersed in its natural and physical environment and in the virtual data world on which it acts. While they inhabit the ongoing experiment, the body and the digital world mutually build each other by changing their intentions and goals. The interactor, in a state of "enacted" consciousness,[16] becomes a negotiator for his/her perception rather than a contemplative observer of a pre-established perceptual illusion. This "bilocation" is either global, when the interactor acts on the entire system, or local. This is what happens in *Tableau scénique 2.0* when "inside-element view" mode is on. The physical and mental body is bilocated not only globally in its physical environment and in the picture, but locally, living inside one of the elements of the scenography. It can adopt not only its point of view but also its way of being. To embody a virtual element is not only an experience of a physical position (spatial coordinates), but also a positioning of being (an instance of Dasein, or being-there[17]). Being in something else that we can act out/upon lets us be something or someone else. The point is to become another and to interact with others (the alter-egos), while remaining oneself. Here and elsewhere: this is the ubiquitous or bilocated position that I have set up for the interactor in the scenography.

[13]On which the body knowingly acts via keyboard, mouse, touch screen, joystick, and microphone.

[14]When there is no direct touch or voluntary action from the body to manipulate it (environmental data sensors, cameras, detector).

[15]Huhtamo (1995).

[16]Varela et al. (1993).

[17]For Pierre Lévy, this term means "in particular *existence"* a "truly *human existence*—being a human being" in the tradition of classical philosophy and German phenomenology (e.g., Heidegger). For Lévy, the most salient point is that *to exist* (a word etymologically derived from the Latin *sistere*, be placed, with the prefix *ex*, out of) is "to be *there* or to go *out*" (italics added). Lévy's position is reminiscent of Michel Serres' in his book *Atlas*, specifically how Serres considers the themes of the virtual and processes of virtualization (imagination, memory, knowledge, religion, computers and digital networks) as "out-there." In Lévy (1998).

Towards New Perceptual Behaviors

The *Matrice Active* project has been developed further since 2003 and still stimulates my research. It falls within projects that try to explore the difficult issue of what is the act of perceiving. Thus perpetuating the legacy of a pictorial tradition that questions the phenomenon of visual perception. In *Matrice Active* the endogenous interactions based on physical models allow elements to move, to self-organize; and also facilitate the emergence of a combination of formal compositions and semantic solutions based on the interactor's behavior, bringing him/her to new modes of perception, participation, and action. Neither passive escape, nor disembodied communion, the immersive experience in *Matrice Active* is active, cognitive, "enacted" within the meaning of Francisco J. Varela, and as such is in harmony with the British theoretician Roy Ascott's idea of a "cyberception," understood as a product of active negotiation rather than contemplative reception.[18] The spectator doesn't passively encounter the representation anymore; he/she is an active part of the computerized simulation. By moving his/her body and by performing certain gestures he/she triggers hidden mechanisms in the dynamic artwork. He/she is the "developer" who, by his/her physical and cognitive behavior, makes visible linkages and relationships among the elements of the virtual painting (colors, shapes, textures, light, rhythms, movements, and dynamics). These relationships are usually hidden in the fixed result of the real painting. The living virtual painting reveals the process of creation that the audience perceives in a phenomenologico-aesthetic experience close to what Ascott calls "an aesthetic of apparition" instead of what is called, in a Cartesian spirit: "an aesthetic of appearances." The phenomenology of Husserl and then Merleau-Ponty[19] has to do with the idea that we have a body, that we are embodied in a physical and mental body,[20] and consequently that we experience the world simultaneously as we construct a representation of it. Such is the experience of the interactor in the *Matrice Active* project.

The painting has changed into "image system" interfaced with the body's flesh, an artwork conceived as a complex dynamic system combining internal and external interactivity and facilitating new aesthetic and symbolic constructs that are rich in communicative potential and are designed for, we hope so, an augmented interactor's sensorium.

The artwork becomes the product of virtual and human elements that interact amongst themselves and with their environment, coinciding with Gregory Bateson's[21] notion that the mind is an assemblage of parts or components similarly in interaction amongst themselves and with their environment.

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[18] Ascott (2002).

[19] Merleau-Ponty (1999).

[20] Berthoz (2003).

[21] Bateson (1979).

In the wake of the painter Wassily Kandinsky's visionary thinking, we are now bearing witness to a paradigmatic shift in the economy of representation. The *Matrice Active* project transforms paintings based on rules set forth in *Point and Line to Plane* into a work of art based on the paradigm of "Agents in interaction inside a complex system." This is the theoretical approach which I defend.

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Time: Active or Passive

Olga Kisseleva and Claire Leroux

Abstract Science created the concept of time which is connected with space and supported by a congruence of natural and perceived phenomena. Epistemology has transformed it into duration and given it a direction. Experimentation, perception and intuition make it relative, even evanescent. Only art can act on it to give it responsibilities or to turn over it, which is what Olga Kisseleva does in her works of art.

Four Different Times

Time is not the same everywhere, in other words it's not a fixed magnitude, but a relative one: it doesn't unfurl at the same speed everywhere in space. Close to an important mass, time flows more slowly; far from any mass, time passes quickly. Thus, for an observer on the surface of the Earth, a yardstick sent close to the center of the Earth, if measured through the distance traveled by light during a time t, would appeared shorter than the same yardstick measured on the surface of the Earth, or than the same yardstick if both the yardstick and the observer would be close to the center of the Earth. Similarly, the acceleration, and consequently the trajectory, of a satellite is influenced by the mass of other celestial bodies, a phenomenon that can be also described by considering that celestial bodies disturb the

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space-time continuum: when we fall, we fall along the curve of space-time. In other words, movement provokes the slowing down of time, or time dilation. We can say, therefore, that space and time are relative, and that we cannot see it and experience it because our speeds are too weak.

In addition to this objective time, a *physical time* with physical qualities, there's a *biological,* a *psychological time*, and maybe a *social time*. For each one of these notions, there's the possibility of having an objective measure of time, of the past, the present, far away time, nearby time, that are not all the same.

Time therefore possesses a scientific definition that one can apply thanks to scientific formulas. This first approach creates a distance between this notion and ourselves. Yet, time is something we actually live in, that we experience. Thanks to biological science we know that our body has its own clock, which dictates a way of life, communicated by signals such as fatigue, agitation, etc. This hypothesis, that the organism has a biological clock, was already present in the 19th Century.

The so-called "circadian" biological clock (i.e., a daily rhythm) would be defined as an internal structure capable of indicating to our organism what it must do, and how it must react. Which means that each one can synchronize his/her activities in tune to alternating day and night. Our organism is "programmed" to wake up when it's daytime and feel sleepy when it's nighttime. This biological clock allows us to properly adapt to the environment in which we live. According to biologists, such biological rhythms are punctuated with specific molecular structures, which act like clocks. We all have a sort of internal clock, which we call our "biological clock". This seems to govern certain phases of our metabolism, giving a rhythm to our days, so that our physiology is "affected" or controlled by this biological clock, as the brain also responds to this rhythm.

As such our organism has its own notion of time, influenced by an "internal rhythm", a sort of psychological time.

But we should also look at another visible measure of time on our body: aging. Our body has a biological clock that establishes a daily, cyclical rhythm that can bring the notion of time closer to something continually re-starting. Nevertheless it is obvious that our body is also submitted to the effects of continued and finite time. The aging of cells, and therefore of our body, is the most visible aspect, which reminds us of our finiteness.

Thus, man can distinguish two sorts of time: one continuous, which reminds us of our finiteness through the aging process with time passing, which is close to physical time, Einstein's theory of relativity and the presence of a "time arrow". And a second time, that's cyclical, which is felt in the renewal of days, of seasons, supported by our biological rhythm that's regulated to a 24 h cycle that seems to restart indefinitely.

It also appears that we have a perception of time that's different from our body's and for the one shown which shows on our watches.

Psychic time is that of "lived" duration. Our perception of time changes with events, and the feelings experienced. For example, one might think that the more important moments of our lives lasted longer. That time fluctuates. Our senses do not read the environment continuously, but intermittently in order to avoid a saturation of information; this selective sweeping is also linked to our feeling of time. This frequency of information absorption seems to vary with age; the perception of time seems to be perceived longer for children than for adults: children live more events per unity of given time, which is perhaps why the same interval of time seems longer for a child than for an adult. This explains why we say the older we get the more time seems to speed up.

We might ask, therefore, if it's possible to modify our perception of time. This phenomenon can happen sometimes, for example with martial arts: fighters optimize their reactions in front of very quick moves, and as such modify their perception of time. Therefore, we have the capacity to accelerate or slow down psychic time, as our brain assesses time as something that we experience thanks to our senses.

St Augustin spoke of the "present of the past, the present of the present, and the present of the future"; this is close to Husserl's thesis when he claims that in each present instant there is a part of the past (memory) and a part of the future (anticipation), which allows us to live "within time".

Once we've defined this notion of time according to several physical, biological and psychological points of view, we can say that we perceive it, through these three domains, in a very complex way. Physics explains why we use so many spacial expressions when talking about time. Biology teaches us that our body possesses its own clock and that a lot of our acts are suggested by this mechanism. That means that time is experienced differently by our psychism. The human body has several instruments with which to measure time. But we can distinguish two main ones, the time that we live as established by calendars and clocks which provide us with hours, minutes and seconds, and the time that our mind and our body experience. Grouping the biological rhythm of the body as well as our feeling of the fluctuations of time experienced, one being more objective and imposed, the other "intimate" subjective and individual. It is close to the domains of cognition and philosophy in terms of its belonging to that of thought, reflexion, inscribed in our conscience and our memory.

Olga Kisseleva's installation "It's Time" is the expression of our capacity to act and modify the duration and perceptions of those three intermixed times.

It’s Time

Olga Kisseleva & Sylvain Reynal *It’s Time*, interactive bio-art installation, exhibition *Time in Action,* Louvre Lens, France, 2013

It’s Time,[1] created in collaboration with Sylvain Reynal, a quantum physics researcher, consists in a large digital clock that responds to the emotional state of the visitors. It displays soothing messages and slowed down time when the visitors to the exhibition are in a peaceful mood. Conversely, a stressed visitor causes the clock to accelerate time and send messages instructing him or her to hurry up. *It’s Time* addresses one of the crucial issues of our post-modern society: the acceleration of time. This change in perception of time occurs at a collective level and significantly increases the individual’s level of stress and personal frustration. Our research concerns various issues related to the perception of time today, the consequence of this perception on the individual conscience and the limits of individual thought’s influence on changing the collective consciousness.

[1] 1st Ural Industrial Biennial of contemporary art, *Shockworkers of the Mobile Image*, NCCA, Ekaterinburg, Russia, 2010;
Olga Kisseleva, *Brave New World*, Contemporary Art Centre Rurart, Poitiers, France, 2010;
Time in Action, Louvre Lens, France, 2012–2013;
Olga Kisseleva, *Contre Temps*, Rabouan-Moussion gallery, Paris, France, 2014
Olga Kisseleva, *Sensitive Worlds*, CDA, Enghien, France, 2014.

It's Time was created for and in conjunction with the Contemporary Art Biennale of Ekaterinbourg, in the Ural region of Russia. The city is well known for its industrial past. The Uralmash factory, famous for building the T34 soviet tanks and later on the intercontinental missiles, is located there. Most of the town's citizens work at the factory. While Ekaterinbourg is slowly moving towards a more diversified economy, it still shows the traces of its industrial past.

The installation *It's Time* was purposely located at the main entrance to the Uralmash factory. During the Soviet regime and especially in time of war, discipline there was merciless. Life at the factory was implacably ruled by the sound of the siren activated by the main clock. A workman who was late could be severely punished, by being deprived of his meal for instance. So the daily rhythm at the factory was regimented by this clock, feared as a "dictator of time" by the employees. The installation addresses this particular situation, and, more widely, speaks about our perception of time and our relationship with the passage of time in our contemporary society. However, in this work, the artiste have given to the workmen ability and power to regulate the clock according to their own biological rhythm, thereby reversing the existing situation, where it is no longer the mechanical historic clock that dictates time.

Catherine the Great founded Ekaterinburg (as the name suggests) as a window on Asia. Peter the Great thought that Europe was the natural partner for Russia and that exchange with Europe should be increased, whereas Catherine the Great felt that it should be Asia. The town is in the Ural Mountains where there were large deposits of iron and other rare and precious metals. Russian industry was born there: all the metallurgy, the machine and equipment manufacture is based in the Ural Mountains around Ekaterinburg, which is why it's called the "factory-town". Whereas Peter the Great constructed a fortress, palaces, castles and trading areas in his town, Catherine built factories and mines around which there were workers' living quarters. This is how the town developed, and then the Soviets arrived and continued to construct armament factories, during the 20s and the 30s in preparation for the future war. There were, of course, factories in the european part of the country (in Moscow and Saint Petersburg), but when the war began they all moved to Ekaterinburg. All the weapons, the famous T-34 tanks and the missiles called "Stalin's organs" were made there, in Russia's biggest military factory.

There had never been any art center in this city, nor cultural events. Against all odds, in the 2000s, the municipality decided to create a Contemporary Art Biennial in the factories. There are 500 factories in the city, and each artist was invited to work with and in an entire factory. One could use the material and work with the people working in the factory. The exhibition visitors went from one space to the next by bus. Olga Kisseleva was one of the first artists invited and so she could get to choose the enormous military armament factory where the tanks and missiles are constructed, and which is almost a legend in Russia.

Above the factory, there was a clock which is very famous because it's hooked up to an alarm which would wake up the entire city in the morning, as in the 30s the workers didn't have watches. The 5 am siren woke up the whole town, and then at 5.30 am it rang non-stop for a quarter of an hour, and at 5.45 am all workers had to be at the factory. They ran to get in while the siren was still ringing. If a worker arrived after it stopped, he wasn't allowed his meal; he still had to go and work, but wasn't allowed to eat at lunchtime. The third or fourth time you were late, you were directly sent to the Gulag. In the 1930s, during Stalin's time, people weren't paid, they had to work in exchange for lodging and food. The same siren would ring when it was time to stop or start work again, for the children to go to school, for the relief team of workers that turned up at midday, in fact the whole town's life would be punctuated by this clock.

When Olga Kisseleva arrived there, she was shown the clock, and learnt of its history. She also was shown how the town was built a bit like Versailles: at the entrance of the factory, there were three axes so that everyone could get there efficiently, without crowding. When she realized that this was the link between her own personal questions about time, and relationship to her alarm clock, she decided to use this famous clock for *It's Time*.

Right where the workers came into the factory we placed several biological sensors which gaged their emotional state and which made the clock go forward according to their emotional state, in order to overcome this time dictatorship. The time could go slower or quicker than the time given by the clock. The idea was to upturn the so-called objective time which in fact depended on Moscow, i.e., the time of the State, of Stalin, the time according to the military industry that was imposed on the population of an entire city.

Olga Kisseleva wanted to overturn the device so that people could dictate their own personal time to this clock. Then, she made a portable, museum version for the Louvre. The first version stayed where it was in Russia. The Louvre's version which was the only one 21st century piece presented in the Louvre Lens inaugural exhibition *Time in Action*, is precious wooden sculpture composed with two parts: clock and interactive borne connected by bluetooth. Despite it's smaller dimensions the interactive sculpture include the same technology elaborated with the Uralmash scientific team.

Olga Kisseleva & Sylvain Reynal *It's Time*, interactive bio-art installation, 2011, the National Centre of Contemporary Art collection, Ekateribourg, Russia

To build this complex art-work Olga Kisseleva worked on creating the system in collaboration with a cardiologist.[2] So from the technical point of view, we put very high precision tools that are used today in tanks. When a soldier sits in the seat of a missile hunter, which goes extremely fast, then before anything happens there's a machine which controls his physical state. It's all compared, of course, with standard data, but then the report is measured notably in relation to his normal heart rate. This is the technique the artist used. Everyone has a specific, ideal heart rate for her/his body. Then other tools are employed to measure the heart rate of a precise instant in relationship to his/her normal heart rate. This comparison allows one to ascertain whether the person is in a relaxed, calm state, or rather in a stressed, accelerated state.

One can't really talk about this piece, in terms of "objective" time, because time is subjective. It's a matter of democracy. Democracy as we know it today is not nuanced enough for the artist. Voting is "for" or "against", an election is always a choice between "this one" or "that one", while with *It's time*, there's a choice that's not voluntary, a subtle choice. If a visitor makes the clock go twice as fast, it's going to influence the course of time further than someone slowing it down by just 2 %. At the end of the day, when objective time, Moscow time, says It's 7 pm, the

[2]Arina Krasnikova.

It's Time clock might say it's 9 or 3 pm. This time is more democratic because it's been chosen by all the workers together. It's a sort of collective intelligence.

This time, which is collectively felt and directed, is a kind of social time, a time decided by a group of people doing a specific activity in a specific place. But it's also an economical time. This installation is a fair illustration of the proverb "Time is money" but it's much better directly expressed in another of Olga Kisseleva's installations: *Time Value* in which we can experience the same virtuality interdependence/interplay between money and time.

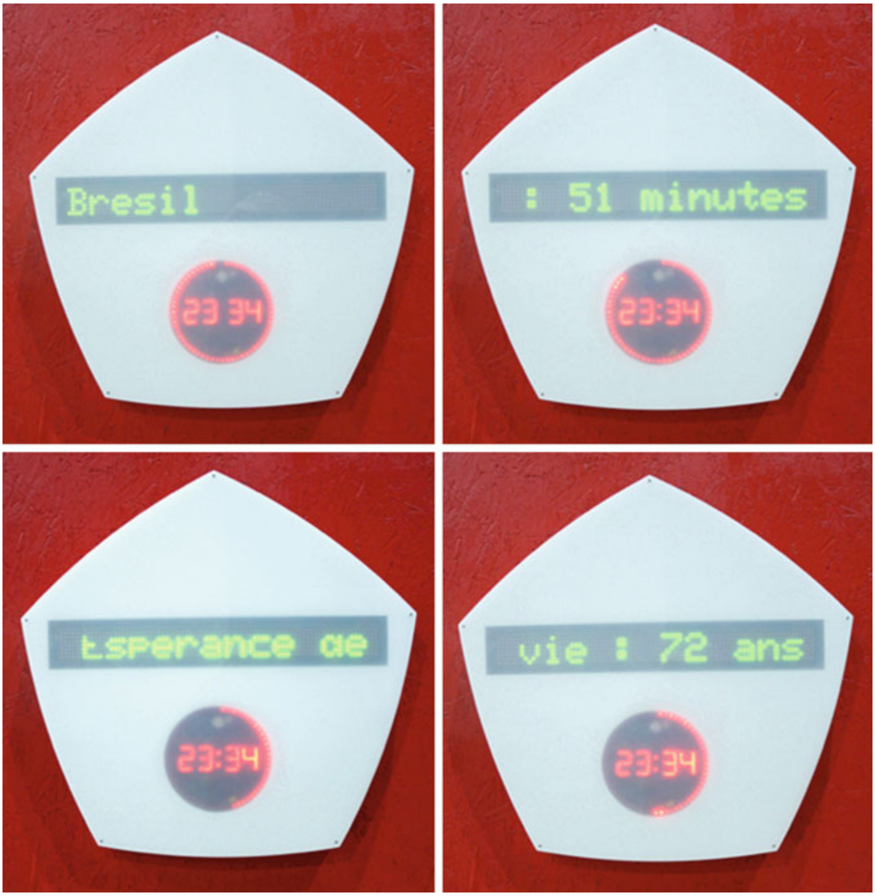
Time Value

Olga Kisseleva *Time Value*, interactive installation, 2012

With *Time Value* the artist gives a perspective on current developments and cost saving in industrial business.

Ten interactive electronic clocks are connected in real time on the n-value servers from different countries of the world. The time shown by each of the clocks flows at a rate proportional to the time worked by a person for one euro. The clock also displays the real-time data used to calculate the value of time: the duration of life, number of hours worked in the year, security index…

The installation *Time Value*[3] takes the concept of *n*-value as it's starting point. *N*-value is a system set up by the development department of multinational groups. This system allows them to optimize the location of their production units. The system is based on the ratio between the cost of hand works and raw materials on the one hand and transport costs and risks on the other hand. Time value and life expectancy are linked. It's simulated from the standard value of the hourly cost of work. The more the value is low, the more the life expectancy is short, and conversely.

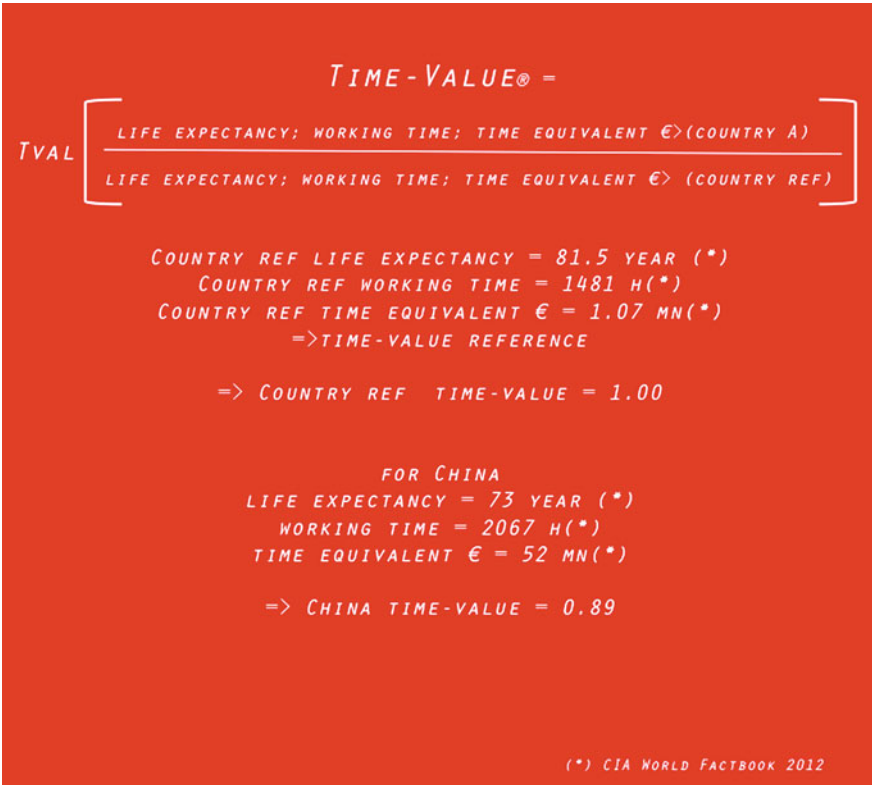


Olga Kisseleva *Time Value*, interactive installation, 2012

[3]Olga Kisseleva, Crossing Flow, Château des Adhermar, Centre d'art contemporain, Montelimar, France, 2012

Art and Economy, collaboration with CCIMP, Palais de la Bourse, Marseille, France, 2012;
Olga Kisseleva, Contre Temps, Rabouan-Moussion gallery, Paris, France, 2014
Olga Kisseleva, *Sensitive Worlds*, CDA, Enghien, France, 2014.

Time Value derives from *It's Time* in the frame of the phenomenon of geo-localization. Depending on our geographical localization, we don't live at the same rhythm: time doesn't go at the same speed in the suburbs of Nairobi, in the Kilimanjaro crater, or in Hong Kong. We imagine that the time in the Sahara remains eternal compared to a megacity hurtling along at an incredible speed, but there's something else that we don't think about that much, i.e., that "Time Value" is an official value used in businesses. It's thanks to the determination of the value for each localization that businesses choose where they're going to be and, in the end, their de-localization. In France, for example, the "time value" is high, time goes quicker, time is expensive, placement is expensive, the hourly rate of human work is expensive, so businesses leave. In other countries, such as Rumania for example, the "time value" is a lot less, so businesses rush to set themselves up in the country, and all of a sudden life is activated. The "time value" is an interesting function as it includes the hourly cost, but also the value of an individual life. The lower the "time value", the less interesting that would be. It's proportional. In Botswana, life expectancy is forty years, time flows more slowly and life is shorter.



Olga Kisseleva *Time Value*, graphic piece, 2012

In a way, from a temporal point of view, the overall value is the same, since a shorter life corresponds to a slower time, whereas a longer life corresponds to an accelerated time. If you live slowly for a shorter time, then you've had a temporal experience that's comparable to that of someone who's lived longer but more rapidly. It seems very logical, but at the same time, remains ruthless. But it's possible to feel another experience of time by bringing at home one of the clock and deciding to live according to Botswanan or Indonesian time even if it's a metaphor.

Tweet Time

Olga Kisseleva *Tweet Time*, interactive net-art installation, 2014

Tweet Time is another experience of the social time. It's based on the Twitter social network. The idea of Olga Kisseleva is to offer everyone the time he wants, deserves, or that corresponds to that person. There are other questions too: how can one adjust the different temporalities? How can they meet and cohabit? Another point of reference must be found between these individual times so that one can come together in a common time that is less of a dictator than today's objective time.

The artwork uses the social network Twitter as its source element of interactivity. Each time a tweet containing the idea "I don't have time" is emitted, the *Tweet Time* clock slows down, creating a progressive shift in relation to universal time.

With *Tweet Time*, which was produced in collaboration with engineers at the ARNUM laboratory (ESIEA), Olga Kisseleva continues to reflect on the notion of time. The installation takes two different forms: a first simulator that's runs directly on the web and a physical clock (actually at the level of the prototype). In a world in which everything is accelerating, taking time out to reconsider one's daily habits, reclaim one's own choice of rhythm, and be aware of our limits, seems ever more vital. The artwork uses the social network Twitter as its source element of interactivity. Each time a tweet containing the idea "I don't have time" is emitted, the *Tweet Time* clock slows down, creating a progressive shift in relation to universal time.

The aim of this piece is to create a timeless interstice corresponding to the requirement of strangers who find the time on the Web to show the planet that they don't have enough (time). All these wasted seconds used creating tweets are therefore offered up to those looking at the piece. When they first confront it, the artwork will present them with a new time as defined by the clock which will mathematically provide them with more time in the museum space. The apparently negligible lapse of just a few seconds will lengthen according to the interactions with Twitter over a fictitious period during which the time, and then the date, will no longer be acceptable. The critical dimension of the piece is to be found in the way it presents a fictitious space-time obtained through the recycling of tweeting time.

Art and Science Collaboration

If we used to say that art and philosophy asks questions and science brings answers, relationships between art and science aren't so dichotomous. It's just like those times described above, an only one notion for many conceptions, in the same time objective, directed by physic and biology, but easily questioned, even returned with philosophic and artistic proposals. Both conceptions are finally linked by a spiritual dimension difficult to explain and even more difficult to share, leading often, to it being ignored for fear of appearing obscure, cutting the information flow and, potentially hindering the success of the project.

This understanding of the spiritual dimension is vital to the production of common ideas which can transform a simple construction project into a true collaborative process. And it is exactly this which is at the heart of a successful and on-going collaboration between art and science. Such a project should bring a great deal to both camps as illustrated in the Olga's Kisseleva's works of art.

“The Experiencing Body”, for a Combination of Movements

Pascale Weber and Jean Delsaux

Art is what makes life more interesting than art.
(Robert Filliou)
It is entirely possible that behind the perception of our senses, worlds are hidden of which we are unaware.
(Albert Einstein)
The artist is the one that shows to the most human people a world in which they appear and nevertheless don’t see.
(Maurice Merleau-Ponty)

Abstract This paper describes our experiment as artists, concerned by scientific investigations, that led us to “declare” and helped us to develop our creation/knowledge: we have been practicing various technologies, have confronted our investigations to neuro/cognitivists, sociologists, ethnologists, engineering scientists and roboticians, mathematicians, psychologists, but we have also met shamans (in the Indonesian jungle, in the Norwegian Sapmi, by the Innus of Quebec). Our practice of art allowed us to cross-study these various ways of considering the world around us, and if necessary to behave in it. Considering Gibson’s ecology of perception, Maintier, Rybak, Zinke’s experiments and theories we have also described, our performances and cross studied what a practice of Art performance and scientific experimentation can tell each other and how they could most probably give their take one another. The main point for us is here the place of the body, its perceptions and actions, its breathing, its interactions with the environment, we develop the theme of the spiral as a fundamental pattern for our investigations as well as the turbulences of the air, around and exhaling from the body.

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Introduction

For Merleau-Ponty (1945), the body is a structure that itself structures the experience of the world: a system of systems devoted to the inspection of a world. It is most likely this very body, and first of all the question of its presence which makes the difference between art and science, if we consider their respective nature, methods and purposes.

Barnett Newman said once "I don't manipulate or play with space, I declare it.[1]" Artists are practitioners of perception, which means they are not only feeling the world, but also build new perceptions, as perception is proactive and, within the creation work, consciously elaborated. As far as Symbolicity is the mode that connects the understandable and the sensitive, we can say art is particularly concerned by symbolicity. Various artists already wrote about their works and some of them anticipated discoveries of cognitivist sciences, using different ways to achieve their reflection. Art is an interesting field for scientists, as science for artists. Art can be a perfect field of observation for scientists and science can be inspiring for artists as it gives models, conceptual tools that can be used in their practices. If various science commentators (Jean-Marc Levy-Leblond, Etienne Klein…) have felt the need to simultaneously understand the specificity of sciences and their mutual relations through their own practices, we consider as well that the approach of the reciprocal specificities of art and science as well as of their mutual relations through their own practices is of equal interest and corresponds perfectly to the purpose which has been given to the present book.

We are going to explain hereafter what our experiment as artists, concerned as many of us by scientific investigations, led us to "declare" and helped us to develop our creation/knowledge: we have been practicing various technologies, have confronted our investigations to neuro/cognitivists, sociologists, ethnologists, engineering scientists and roboticians, mathematicians, psychologists, but we have also met shamans (in the Indonesian jungle, in the Norwegian Sapmi, by the Innus of Quebec). Our practice of art allowed us to cross-study these various ways of considering the world around us, and if necessary to behave in it.

We also take in consideration theories which are not always acknowledged by some parts of the scientific community but which nevertheless question, following an holistic approach, the phenomena with which we are confronted, within our actions, our perceptions, our reflections.

In the first part we shall define, leaning on our experience of performance, what covers the experiment of space, for the body or the glance, then, considering art and science as symbolic systems, we shall analyse the stakes and the methods of representation of body and movement. Finally, we shall evoke the *simple machine* in order to catch the dynamics of an artistic mechanism.

[1]Barnett Newman, *Selected Writings and Interviews*, Knopf, New York, 1990.

The Art/Science Couple, Weirdness of Two Poetries

Spatial Experience

Ecology of Perception

Following James J. Gibson, it is impossible to understand the perception and to analyse a behaviour by subtracting the individual from the world, one has to consider contrariwise the perceiving and acting being within his relation to his environment and the constraints imposed by this environment.[2]

> Perceiving is an act of attention, not a triggered impression. (Gibson 1979)

Our perceptual system is thus active and not passive, it provides multiple informations concerning our environment (exteroceptive data) and our moving body (proprioceptive data). What does it mean for a body to experience the space? To answer this interrogation, it seems important to quickly review several concepts Gibson is referring to in his ecological approach of perception. The latter, distinguishing indeed the environment from the proper world, the milieu, the substance and the surface, allows considering the spatial experiment as a relating of the body (acting, embedded, in motion), with the glance (observing, active) and the space which is still to be defined:

- Environment only exists by whoever shares it with others, the environment's characteristics depend on the species or on the animals that are linked to it: human environment, equestrian environment. On one hand, the environment of a species is shared by all the animals of this very species; on the other hand, the environment of each animal is unique, for it is linked to its point of view. Animals can one after the other, for example if they move, share the same points of view.
- The proper world of an animal is the world as it perceives it: following its own experience. Every species equally perceives a proper world according to its biological properties and its way of life: what is significant at the scale of an animal is different from what is significant for a human being for example.
- The milieu is the matter in which we move: air, water. The milieu tends to be homogeneous, when its composition changes, it is transformed gradually, without breaks, and due to this quality of the milieu one can move in it, the

[2]This ecological approach of the perception opposes to the cognitivist one, which considers it is from the image on the retina, coded, then transmitted to the brain, that the latter generates a mental representation on which it carries out symbolic processing's. According to Gibson, visual perception is not about fixed images of our field of vision but with ambient visual flow. Our whole visual perceptive system can distinguish among invariant elements present in the structure of our optical field, what changes (in the presence of light for example) and moves or gets closer because we move. It is changes in the visual flow that highlight invariants of structure: so according to Gibson the perception emerges by means of the movement (Gibson 1979).

vibrations can be transmitted, the visual, sound waves, the smells… can be spread. The milieu also allows perceiving.

- The substance can be gaseous, liquid or solid, it forms the objects, it allows insuring its survival, feeding… Only the water is at the same time a milieu for some animals and a substance for others, human beings in particular.
- Remains finally the surface, which often corresponds to our perception of substance, the envelop of what we touch, of what we see, the ground on which we walk. Leonardo da Vinci's definition of the surface—opposing it precisely to the substance, the bodies, the air—is perfectly in tune with Gibson's:

> Surface is the name we give to what separates the bodies from the surrounding air, you shall maybe prefer to say: what divides or separates the air from the things embodied in it. (da Vinci, "Atmosphere", *Notebooks, I–XVI*)

For Da Vinci (1942),

> the surface has no body and thus does not need any place,

A way, could we understand, to say that the surface, as the border between two states, has no physical reality, but a symbolic, mental one. The surface indicates the shape of the bodies, says he, to equally describe the link between the outline drawn by the painter and the perceived surface.[3] Vinci nevertheless equally says:

> If the atmosphere and the body touch each other, no space shall be left between them, and we shall conclude from this that the surface has an existence, but no space. (Vinci, "Atmosphere", *Notebooks, I–XVI*)

In creation, and in performance art particularly, we wish to associate this spaceless (bodyless) existence phenomenon, to the principle of presence: making present by the body a substance, a medium variation that one does not yet perceive, that perhaps does not yet exist (Fig. 1).

Art Performance and Space Experiment

To "experiment", what does it mean for an artist? Obviously something very different as what is expected in the field of sciences. Experimental Music is defined by testing various technical situations allowing the composer (Cage for example) to obtain unexpected results among which he is going to select interesting propositions that this randomly testing allows to produce new elaborated experiences.

[3]"The outline is a surface which is neither part of the body, nor part of the air, but a middle interposed between the air and the body. The side outline is the term of the surface, the line of an invisible thickness; you thus, painter, don't circle bodies with lines especially for things smaller than nature, which cannot reveal side outlines but have, at a distance, invisible members." (Vinci, *Precepts of the Painter*, G37r).

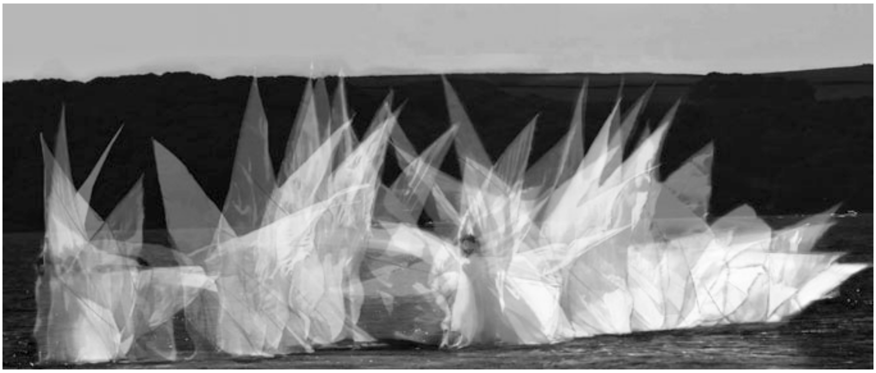

Fig. 1 Crossing the breakwater (Hantu n° 18-*Dancing a line in the Sound*, July 2013, Plymouth, UK) (Hantu n° 18-*Dancing a line in the Sound* was performed on the invitation of Plymouth University and the Visual Arts Research Group of the Faculty of Arts.): seeking a fluidity of the movement through an optimal energy saving, while composing with elements rather than opposing to them

Experimental literature consists inversely (Oulipo[4]) to give previously to writing a strict rule (avoiding the letter "e" for example in an entire novel) to the author.

The senses of "experimental", "experiment" in art can be rather weird for a scientific audience used to a more fixed conception. Using these words, we are not trying to give a more scientific aspect to our work; we use them in the field of contemporary art that has its own methods, concepts and goals.

What does it mean then for us exactly Experiment? It's a question of giving the primacy to the intent rather than to the result, because to one intent may correspond a multitude of possible results, and it is the experience of this range of possibilities that creates the work of Art.

For example the intent can be to walk a space, a scene, a studio, a breakwater. The experiment (here the performance) will be to differently walk across these various places, inventing each time various positions, various connexions of the different parts of the body, until exhaustion.

The first level of "results" if we can use this term is to observe that when you move forward you move your shoulders forward and when you move back, you move your shoulders backwards; then you can analyse more accurately this results and approach *Awareness Through Movement* and *Functional Integration* of the movement and of the various locomotion patterns, using the Feldenkrais method for example. But these are the technical practices of a dancer or performer, not yet a work of art. The experiment in performance is to use these various body control abilities to really explore a space, a time, an environment, a circumstance, in

[4]Oulipo is a group of writers and mathematicians who defined constraints for the writing. They defined themselves as "rats constructing the labyrinth from which they aim to get out.

relation, immediate or not, with an audience, whatever happens and to react in real time to these elements and micro or macro events.

The conclusion the performer can draw from this is purely subjective, but it is the condition of a poetic approach of space and time, of a non-mediate relation to the world. Thus experimenting allows further explorations; it is the fuel of our creation, not only its method.

But our work also consists in making visible. While one is performing, the second one takes pictures and we project these pictures for the audience, during the performance itself or after it when it's about in situ performances. We also take photos that are re-elaborated afterwards and take part in this attempt to "make visible".

Again this supposes to invent displays according to the experiments and to invent the gestures, points of view, techniques that shall make it possible to give a particular feedback first to the performer, then to the audience. As a show, a fiction, not as a scientific discovery. The performance is a permanent exchange of what we know and what is going to surprise us, if we can compare with science it is in this way: intent is for us like hypothesis for the scientist, it proceeds from a questioning and addresses to an object, then we proceed by trial and error, and our result is a shape, a gesture, an event, a work in progress.

What it results from the experience is a better knowledge of what we are in this world, and hopefully what we share with the spectator and allows him to experiment from his own point of view.

The Breakwater

The Breakwater belongs to the British Navy. We were authorized to go there for a couple of hours. A skipper dropped us there. We couldn't rehearse our performance. It had to be done one shot. When, for such a performance, we move in an unfamiliar space as the Breakwater, we renew our perception and thus our proper world; we observe and feel in a greater effort of perception the milieu, the matter of the milieu in which we evolve, the air of the coast which comes from the open sea (beyond the Breakwater) and arrives on shore (Plymouth). This "atmospheric passage" equally evokes symbolically the passage from the oceanic (Atlantic ocean) environment to the man-made built space. The Breakwater is a land road in the middle of the water. It's a surface on which one can walk, and a solid substance, a wall, an obstacle, which rises from the bottom of the sea, which stops the waves and is covered, in high tide, by the water. This space has thus the qualities of a transition medium. The crossing body can feel, in a very simple and direct way the different kinds of aerial forces operating in each of the places, the open sea and the dry land (Fig. 2).

Performing allows experimenting mechanisms that extend the medium in which the human being commonly evolves: poetry has the capacity to make familiar to us what is unfamiliar and to make unfamiliar what in other occasions would seem familiar. By his intrusion and the perturbations his unusual active presence stirs up in a foreign medium, the artist makes event: he modifies the environment, as well as

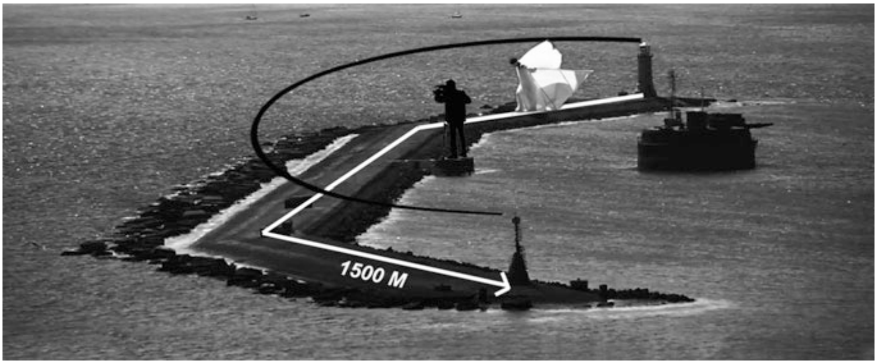

Fig. 2 Spatial experiments of the crossing body and the revolving body (the observer/image-maker)

the ebb tide, the arrival of the night make event. In the mechanisms we propose, we invite the spectator to experience, physically and symbolically, a singular space. Each spatial experiment is defined as:

1. Event (an action with a beginning and an end)
2. Movement (moving of the body and projection by the regard)
3. Experiment of perception (perception emerges due to the movement and the event: suddenly it’s dark, silence, it’s cold…)

The Spatial Experiment of the Regard/Through the Look

In the film of the wandering on the Breakwater, we try to grab the movement, the dynamics, the adequacy of a walking body with the space it is covering, but also with the atmosphere that surrounds, suffuses, impedes or carries it. It’s about, to resume what we have seen above, to grab the outline describing the shape, the movement of the body in the atmosphere and the boundary between the ground (as an evolution surface) and the air. It’s also about choosing: cutting out from the visible, following a unique or mobile point of view, the space portion in which this wandering takes place.

The dress conceived for the event evokes just as well the wings of the seagulls as the veils of the sailing dinghies. It facilitates or hinders the progression, forces, in order to progress, to compose with the rising wind. Standing 750 m away from each other, it is difficult for the cameraman to perceive, in spite of the optic, if the other moves forward or evolves on the spot during all the beginning of the performance: reading the space and the movement which is completed in it, remains a matter of closeness. Beyond a certain distance, we deal with the interpretation allowed by the experience and the empirical or technological measurement methods.

The fixed point of view of the camera constraints the operator to a contortion which can drive to tetany. Shooting a linear progress which from 750 m on the right passes in front of you, then moves away again, 750 m on the left, implies a rotation the kinematics of which accelerates and then gradually slows down again (Fig. 2) and the control of this non homogenous and slow transformation causes a contraction of the body in tension towards the follow-up of what becomes a never reached target, permanently captured, never caught. The haptic drive of the look which always misses its goal is here on stake: the encounter with the other, when the look is uncoupled from the body, when it is taken in a sort of torpor of which one has to beware by maintaining a constant attention, so as to synchronize the rotation with the partner's progress inside the optic field of the objective. There, where the non instrumented look makes jerks, selects and sorts out what it keeps from what is perceived, leaves peripheral zones in the fuzziness, estimates—and possibly turns away a brief moment—the camera which pretends precisely to be objective, forces the cameraman to operate a mobile cutting in space and time, an obviously subjective selection of what is going to be recorded in accordance with a projection onto an isomorphic and isotropic plane. What leads the operator to extract oneself from the optical sighting of the camera in order to see for himself, from time to time, how things stands on the real scene he is trying to catch.[5] It is not only the body of the cameraman which is immobilized by the imaging device, but the time as well, it seems that this one does not flow, that one is in a continuous present in which every instant is equivalent to any other one.

During this performance on the Breakwater, the movement of the bodies, the veils, the fabric have gradually matched up, revealing the circulation of the air masses and the dynamic insertion of the crossing body as of the sailboats or the birds into the same environment. The video recording, which testifies of the spatial experiment from the viewfinder, has also showed how the lack of ground landmarks, allowing to restore the depth, acts on the perception of the objects in space[6] and has allowed to match up the scale ratio between the body and the sailboats: when, on the horizon, in the frame of the camera, some boats appear, they seem to evolve inside the same space as the body on the Breakwater, as if the distance unifying the planes would give dynamic coherence to moves nevertheless endowed with heterogeneous kinematics.

[5]The decoupling of the eyesight from the rest of the body, within the rotation movement of the shooting lets risk a break into the regularity of the panning as it is no longer the neck muscles, carried by the rest of the body potentially free and relaxed that move the reception device (the eyes), but the entire clenched body, and especially the shoulders and the arms that pivot the camera on its tripod, the head making it possible for one eye to control what is displayed on the viewfinder screen.

[6]The size of the sailboats, and of the dressed up body whose figure of which reached, arms up, 4 m. high.

The Atmospheric Body

> Any body located in the bright air fills circularly, with its pictures, the infinite parts of the air; it is whole in the whole and whole in the part, and goes reducing its images through the equidistant space which surrounds it […]
>
> 1. The stone thrown into the water becomes the center of various circles, and these ones have for center the hitten place.
> 2. Likewise, the air is full of circles having for centers the sounds and voices which are formed inside them. (Vinci, *Atmosphere*, C.A. 345 r.b)

Vinci underlines the permanence and the reciprocity of the exchanges between what we expel and the space in which we are immersed. These exchanges are linked to the qualities of our body and of the place in which it evolves: their organic, liquid, atmospheric constitution, their structure and their energy… A micrometeorology reveals our internal structure: turbulences and fluid humours and air flows, pressures and depressions, true hurricanes caused by the cough or by violent sneezes. Due to the verbal language, the body projects itself outwards. For Gibson, one has to study the manifestations of the body within its spatial spreading out, and not through the recordings and tracks of these manifestations:

> The point is to take the sounds, the phonemes, just as they are in the air. (Gibson 1966)

Serge Maintier is interested in the specific morphologies of external phonatory turbulences. We have met him and we follow his seminary about the art of the speech in order to study the phonoplastic form of breathing and song (and to deepen the work we make beside on vocalizations and diphonic singing). Maintier takes up and deepens the researches of Johanna Zinke and Boris Rybak, still so little known and disseminated. Zinke "was, as early as 1962, the first to highlight *the air forms of the sounds of language* at the mouth exit" mentions Maintier in the thesis he defends at the University of Franche-Comté on this matter. Zinke is interested by the *phonoplastic* of breathing and wants to grab the form of the unfolding of the blown and of the voice when we expel the air out of ourselves. The moving air forms that come out of the mouth appear on photographic and filmic registrations in a structured and reproducible manner. Zinke lists this micrometeorology that seems to echo a wider movement, the one of the cosmos. Zinke's pictures do not only record the effects of the voice, they give shape to the manifestation of the speech.

The biophysicist Rybak discovers, some years later without being aware of Zinke's works whirling structures and aerial forms of the word sounds at the exit of the mouth. He calls these reproducible aerodynamic and aero acoustic phenomena, the *external phonatory turbulences* and he manages to highlight them in 1980, using interferential strioscopy. Maintier uses laser light technology (tomoscopy) to gain more precision. All these pictures simply confirm the intuition of singers, actors or artists like Leonardo da Vinci (in "pronunciation of the vowels", "articulation of the human voice", "acoustics"…) who analyses the voice and the acoustic phenomena:

> The noise of the shawm[7] is nothing but a disintegration of compressed air. (Vinci, L89v)

> This is born in the air where the sound arises from the instrument, crosses the valley and spreads, according to the greater or lesser force used to chase the air. (Vinci, E4v)

While evolving on the stage, speaking, singing, breathing, an artist knows how far his body exchanges with what surrounds it. His body informs the world of its presence. The artist's work consists precisely to ensure the quality of its presence, for it is this presence that engages the public. More generally, everyone's presence has an impact on one's environment and reciprocally (Gibson 1966). To grab the (micro) perturbations we're causing, we often have to calm down the multiple requests of our senses to develop a targeted acuteness. This exercise of attention develops in two opposite directions: a micro perception felt by the body (mind/body wellness connection, Mabel E. Todd, Moshe Feldenkrais, Gerda Alexander, BMC…) and the perception of universal laws that exceed very widely the mere experiment of the body (Physics, Fluid dynamics…).

The Listening Body

Space is not a container initially void, filled with matter. It would rather be a kind of overlapping and successive inclusions of spots, places, likewise, the time would be an intermingling of events that follow each other and overlap, inserting modifications into the environment shared by individuals (Gibson 1966). Thereby, what we describe—in performing art, in experiencing devices of real-life physical situations, particularly in the landscape—by "silence" and "void", feeds back to a stretching of perception. Pacing up and down desert and silent spaces allows us to browse in our soundscape, our visual/tactile/olfactory landscapes scales of perception values that renew *our proper world*. Insisting on the reciprocity of the exchanges between what proceeds from our own body and the space in which we are immersed, we consider that being listening consists in paying attention, in the same movement, to what tells our body and what tells the nature aware of our presence (Fig. 3).

Standing Still

Prolonged immobility is not confortable. An alive and awake body is in motion, otherwise it stiffens up, and it gets cold… Total immobility is a physical constraint that precisely allows highlighting the natural mobility of the body. At this point we shall say about a body that it is motionless for it is physically inactive, namely that the movement of the body can only result from an external action or energy: the body is still inside a train in motion, a still body can be dragged by the wind, drifted on the water. Motionless and in movement, the attentive body measures then the

[7]The Shawm is an ancient musical instrument, ancestor of the oboe.

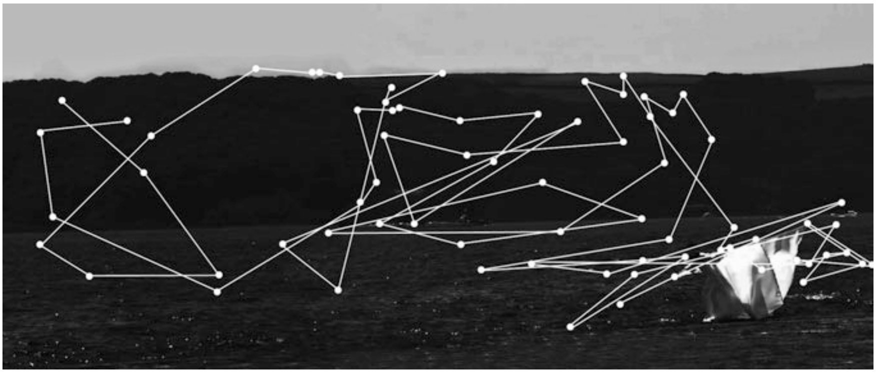

Fig. 3 Arabesques drawn in the air with the veils of the dress progressing against the wind (We guess the efforts made to gain speed and strength by accelerating the low and horizontal movement before throwing arms in the air and “raising” the sails.)

dynamic forces that act around it. Everything is movement. Marcel Duchamp with “Young sad man in a train” or Richard Baquié with “Once he often would take a train to transform his anxiety into tiredness” have questioned the body moved in or by vehicles such as the train. The problematic of the moved body appeared with the twentieth century and the motorized locomotion, the accelerated speed. Speed indeed modifies our perception of movement, for our vestibular apparatus is not intended for such a dynamics: from a speed equal or superior to 200 km/h, if we overtake another car, we don’t have the feeling that we get closer to it but that it is bouncing towards us (conversation with A. Berthoz). The twentieth century is equally the century of the sliding sports: ski, hang-glider, motor sports, bungee jumping, with which the point is not to produce the muscular effort of propulsion, but the control of the trajectory and of the balance, in order to remain on a vector which provides mobility (E. Couchot). Our experience of the world is thus modified. Our imagination and our representations are henceforth transformed.

We have performed, a year and a half after Hantu n° 18-*Dancing a line in the Sound*, a second piece called Hantu n° 12-*The Drift.*[8] We have then worked in collaboration with scientists of the Marin Institute, meteorologists, specialists of the sea currents concerned by the phenomenon of the drift of a body in the water, biologists working on the marine fauna and flora. These meetings have allowed a slow work of objectification, the passing from a poetic idea (letting oneself drift from a river to the sea), to the physical experimentation:

- Of an inactive body immersed for 2 h in a water at 14 °C (hypothermic evolution, perception of time and of the travelled space, loss of the landmarks, particular accuracy and decrease of the senses).

[8]On the invitation of Plymouth University and the Visual Arts Research Group of the Faculty of Arts.

- Of the passage from the fresh water to the salt water (overlapping of liquids which don't really mix; obviously different quality of the water in the river Yealm and in the mouth of the estuary). There is indeed a difference of measure when a scientist quantifies the salinity of the waters in a laboratory, and when an artist feels this differential measurement with her own body.
- Of the modification of the current both according to the river (near the banks, in the center, according to the depth of the river bed and the sandbanks), of the approach of the sea (opposite currents, or less legible as in the river; claimed inertia of the surface), of the accelerated progression of the ebb tide (Fig. 4).

Making no movement. Waiting for the drift to be done without helping it by one's movements. Extended, this spatial and temporal experiment modified by the cold and the absence of muscular requests is uncomfortable and dangerous: the body has to revalue its control and comfort zones… The information provided by the visual perceptive system are then almost exclusively exteroceptive (they moreover allow to perceive the environment with an exceptional accuracy) and very scarcely proprioceptive, for the body makes no voluntary movement (except when it is rushed by the current and tipped over on a side and it tries to rotate onto its back). The body has to overcome this proprioceptive deficit to interpret what it feels (its efforts, its tiredness or well-being…). As meditation practices show, the "density" of silence and inaction acts on our perception of space. Each time, our senses have to do a work of accommodation, like our eyes accommodate in darkness (Fig. 5).

Two boats tirelessly turn around the body. On board those who observe the drift only see the surface of the water, the slow undulations of the fabric and notice from time to time that the landscape has changed. When the boat moves away, the frame of the camera widens, when it comes nearer to the drifting body, it offers a more empathic vision of the latter. While diving in his turn, the image-maker discovers another reality, subaquatic, and a different closeness. The visibility in this glaucous world, dull blue-green does not exceed 2 m and reduce the space. The soundscape, the fight against the cold, the difficulty to work in apnea, everything modifies the perception one has on the boat, on the other side of the surface. In this other world, the scrolls of the dress are in 3D, fish shoals come to view this microcosm and the wish comes to stay there, to live a common and individual experiment. The shooting is tricky for the body has to swim, and keep the adequate position. The sky suddenly appears as a continuity of the world, as taking part in the observed space.

Spiral as Fundamental Movement

Animals use, in their ways, the forces that the vortices release to move in the water, in the air, to improve their speed, and their manoeuvrability. Insects manage to capture and use the energy of the turbulences. As for every animal, the human being who wishes to evolve with fluidity has first to be attentive to his environment that is to understand or have the intuition of the water current, of the air movements and

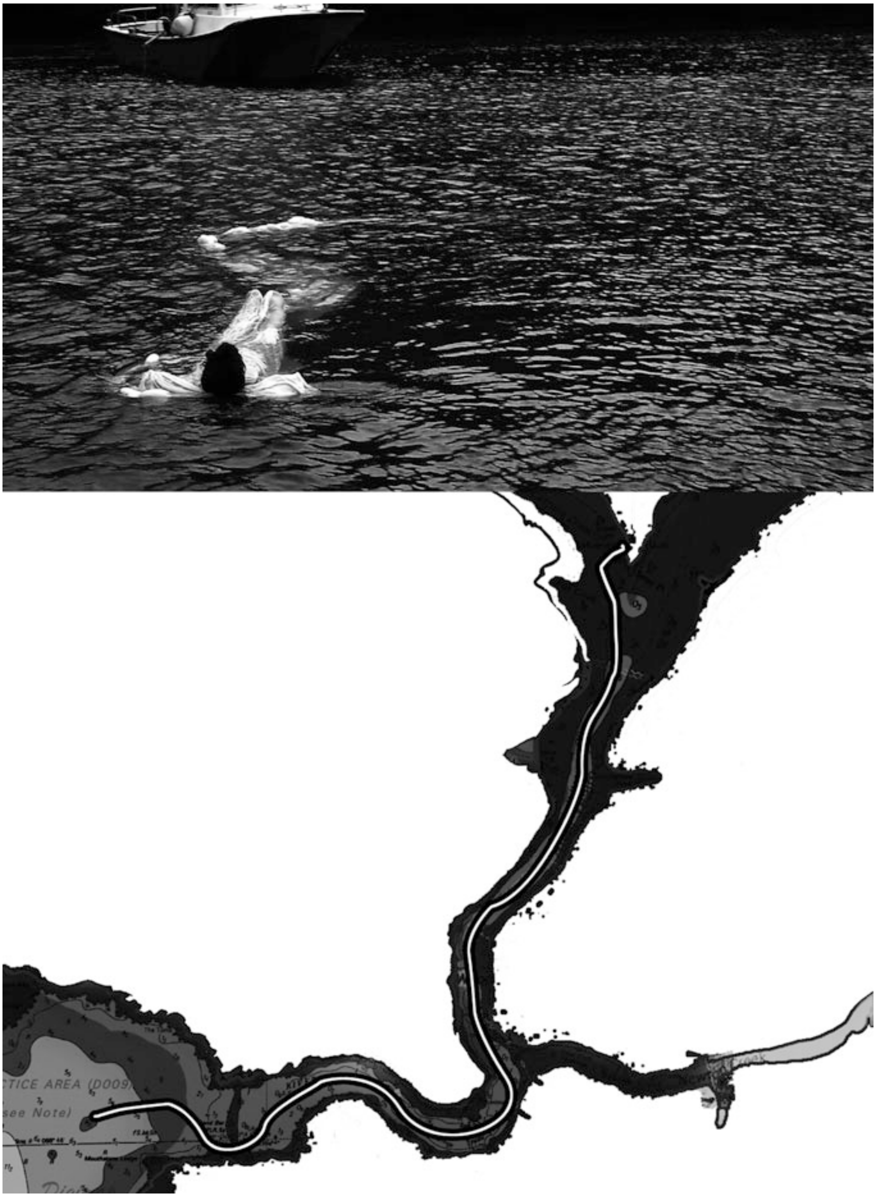

Fig. 4 A drift of 2 h, down the river Yealm to the ocean: the body is pulled, sucked down by the low tide (15/09/14, Plymouth, UK)

Fig. 5 *The Drift*: the dress unfolds itself on and under the surface of the water. How to represent the air and aquatic mediums' proximity and the passage through the surface of the water?

perceive the slightest changes, in order to modulate and adapt his movement, his position.

Gesture, Movement, Trajectory

There is a difference between gesture and movement: it's the intent. Likewise the speech the gesture has its own language that each in his own way explores. Actors, dancers, sportsmen so as all the performing persons… The studio practice allows going back to gestures operated in particular artistic contexts, to transform

Fig. 6 *The drift* highlights the overlapping four "dynamic spaces", that of the drifting body, of the "filming satellite body", of the motorboat which secures the performance and of a bigger boat (*off-camera*) which diverts faster and sails wider *circles* to control its trajectory in the channel

movements into intentional gestures, to inscribe them into different temporalities. The gesture's intention confers to the body a posture, a tonicity, energy… a presence. The difference between gesture and movement is often more difficult to catch in the practice of art or sport. Let's take the example of the walk. Walking requires for any of us learning, and then becomes an automatic movement, refined throughout years, which adapts to the unexpected as well as repetitive circumstances. All of us sooner or later learn not to stumble at the end of a moving walkway. Walking on a stage is something else, walking under the look of someone, under multiple looks, to show one-self off walking, means necessarily to have an intention, would it be not to have one (Fig. 6).

Yet the trajectory is the graphical expression of the intention which arises upstream (projection) and downstream (reconstitution) of the movement. Astronomy characterize apparent trajectory as the description of the trajectory perceived from a terrestrial observation point. Describing a movement trajectory reveals the will to organize the various stages of a movement into a precise gesture, perceived from a precise and stable point (the terrestrial observer is necessarily moved by the motion of the earth). In the study of a performed movement in Butô, in dance… the gesture is at first a passing (so as shown by Figs. 7, 8, 9, 10 and 11), a sequence to repeat until certain fluidity is obtained. The trajectory becomes mental path or score. The tireless repetition of a gesture, the one of a painter, of a dancer or of the discobolus, of the skier leads to the possibility to not think any more to this gesture, to return as far as possible to the movement, to free it from any intention. That's exactly what painter Shih T'ao says:

> Painter ShiT'ao (Guilin XVII° century) claimed the importance of *hsü-wan*, "the void wrist" in his writings on painting (the *void wrist* means nothing less than a forceless hand when the painter hold the brush. In the contrary, it is the result of a great concentration, of the full tensed in the extreme. The painter can only begin to paint when the full of his hand reaches its peak and suddenly gives way to the void.). (Cheng 1979, p. 48)

The artiste is precisely looking for this state of internal void a closeness of sensation with himself, the outside world and with the world he is projecting onto the canvas, the stage, into the action he carries on. The trajectory can thus be a semi conscious or interiorized representation of a movement, as it can help the modulation of a movement, the redefining of a possible. The method developed by Moshe Feldenkrais is about that much inspiring. It allows by repetitions and tiny movement modulations to perceive very finely kinaesthetic sensations caused by gravitation, movement, and displacement of various tensions while one is distributing differently the body's efforts. The thousand exercises proposed by Feldenkrais allow to precisely reinventing trajectories of movement by preserving and fostering the flexibility of the joints. As we exercise automatically many gestures, after having laboriously made the learning of them, modifying their organization (after a wound for example) in a more harmonious, softer, and more efficient way implies to understand how, from the beginning, we coordinate it. On this condition, it is sometimes possible to reinvent a new path, to reorganize the feature, the mobility of the rib cage, of the pelvis, the flexibility of the backbone…

Winding as a Dynamics of the Whirling Movement

If we have evoqued the mental score about the trajectory, we do not consider however the movement according to the mechanistic approach, as a series of positions, but as the expression of a synergy of articulated dynamic events (Fig. 6). This synergy produces a gesture and this gesture propagates within a medium that is not neutral, but fluid, compressible, and in motion. But how to grab the movement and to codify its dynamics/extent/intensity/spreading out in an environment which pertains to its quality?

In the *Sensitive Chaos* Schwenk (1962) researcher in fluid mechanics and fonder the Institute for the Fluid Sciences (Herrischried), presents magnificent photographs of "essential water movements", its qualitative changes and the passing, for example, between the moving water and the still water. He also shows, comparing

Fig. 7 Practise "crossing" movements performed on the Breakwater: arms' involvement in the walk, extension; arm thrown forwards advances the whole body whereas shoulders engage the pelvis, legs thrown towards the back push back the bust and the arms, pelvis disengages shoulders (*4*), correlated movement between the left hand and the right leg (*1*), between the right hand and the right leg (*2*), movement perceived when the observer's involved physically in the gesture (*3*)

Fig. 8 Practise positions of the *The drift*, then crawling on the back/passage from a side to the other one/arms' and shoulder blades' involvement in the sliding/connections between the sliding of shoulder blades and undulations of the pelvis 3—The dynamics of a meeting space

Fig. 9 The trajectory of the drift observed on the surface is just the smoothing of a chaotic undulation, the underwater images of the 8 m dress give evidence to the various circulatory currents bound to the last phase of the low tide

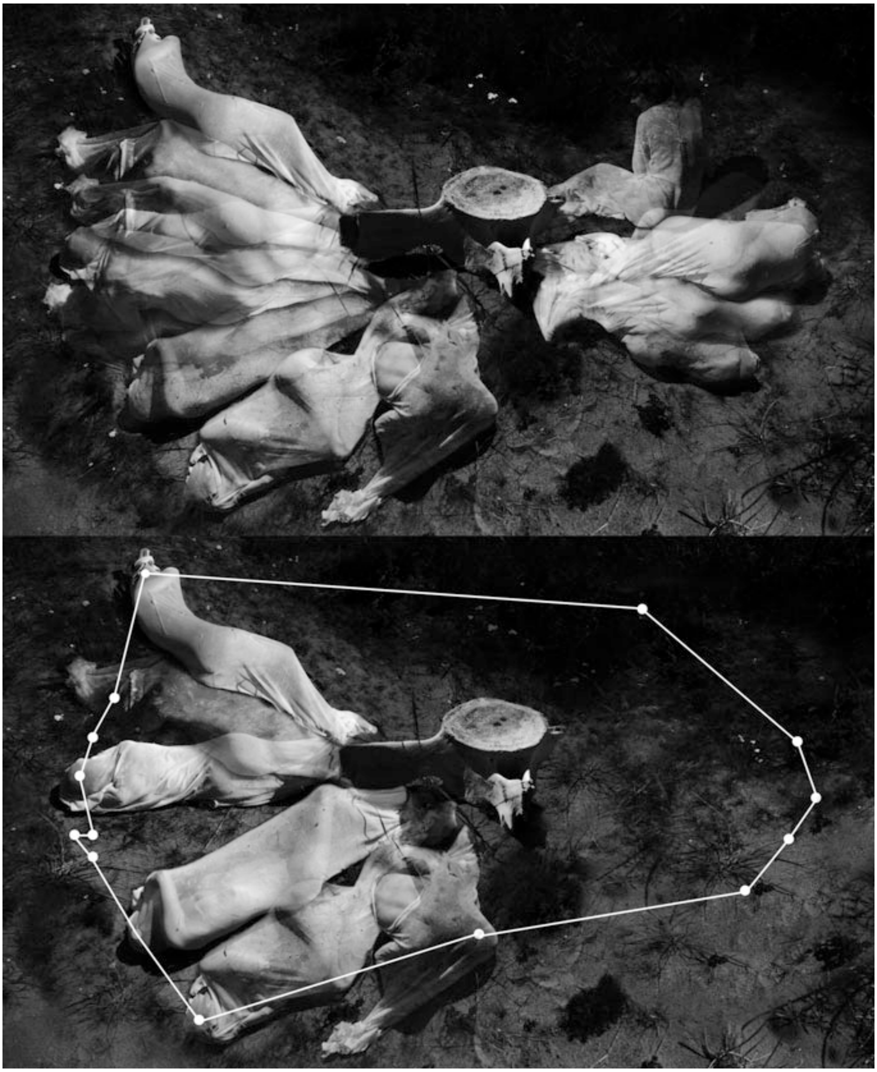

Fig. 10 Hantu n° 18-*Kegaska* (performed in the North of Quebec, on the Labrador's border, summer 2015): anchoring a rotary movement around a vertebra of whale

the movement caused by a water drop which falls into various liquids: water mixed with detergent, drinking water from the tap, and spring water, that the more the water is pure, the more it gives forms which are rich and harmonious.[9] Schwenk

[9]"The more a water is loaded in cosmic energy, the richer and harmonious are the shapes it gives," says precisely Raymond Abellio, in the foreword of *Sensitive Chaos*.

Fig. 11 Practice the rotary movement of Hantu n° 18-*Kegaska*, trying to keep the same feet anchoring in the ground, exploring the rib cage’s/the pelvis’ mobility, and the vertebral column’s flexibility

describes water as “the sense organ of the earth”[10] which allows the life and death to go along side within an unbroken movement, and as a force that shapes the surface of the earth. He classifies the spiral whirling movement of the water into 3 different orders: orbital, rotary and circulatory.

- The orbital movement is an endless spiral, like the swirls of a motorboat helix. It’s towards this harmonious movement that the body performed on the Breakwater
- The rotary movement is made around an axis, like that of the earth around the sun. This movement inspires Hantu n° 18-*Kegaska*, performed in the north of Canada, mobilizing the body around the whale’s vertebra we shall describe the set hereafter.
- The rotary movement, like magnetic currents or those linked with the magnetic field of the moon, whose influence on the tides is well known. The body is involved in this kind of elementary energetical movement in *The Drift*.

[10]This is the title of the second chapter.

The winding of the body in the three performances we evoked is thus referred to the spiral. This figure resounds poetically and metaphorically, it evokes the spreading out of the shape, of the gesture that sets itself as a work of art. But the spiralled whirling movement is above all a physical, mainly hydrologic phenomenon which imparted to the water "its living colloidal structure, its oxygenation, to name only two of its fundamental qualities"(Maintier), perceived inside and by the body. Finally the spiral is a mathematical model.

Presence, Movement and Their Representations

For what reasons are artists interested in sciences? We think that it is about linking immediate experiment with a formalisation of universal laws that allows projecting the experiment on other scales. Can the operative representations of the world that science provides dialog with the ones the world of art provides? We think that from its confrontation with science, artistic activity learns to define and precise its stakes (the esthetical order) and its method (fluctuating, dynamic).

The philosopher Ernst Cassirer trying to establish in the beginning of the twentieth century a system of symbolic knowledge fitted to integrate data from very various fields, insists on the complementarity of the different symbolic systems:

> We must, without any prejudice or dogmatic theory of knowledge, try to understand each type of language, within its particularities: the scientific language, the artistic language, the religious language, etc.; we have to determine the importance of their contribution to the edification of a *common world*. (Cassirer 2000, p. 123)

We presume that science is a way to consider and analyse the world with the purpose to understand it and to answer fears and desires of safety, power, conquest, domestication or control. Science measures, classifies, operates, modifies, explains, discovers regularities, elaborates laws. Science carries out experiments whose results have to be reproducible. Science is operative, or is supposed to be, it determines its postulates and develops its hypothesis by verifying them. It describes phenomena, states, matters, and carries out on those, operations that transforms them.

Art is a way to consider the world in order to experience fears, desires, dreams, perceptions and their interpretations. Art formulates hypothesis which it diverts or shifts, or even goes beyond without having the crucial need to verify them, to call into existence or make visible what is not and whom one doesn't always wish it could.

Meeting of Symbolic Systems

Can we compare the research in science and in art? Art and science are two symbolic systems, whose functioning and stakes are mutually unfamiliar and developing different methodologies. How to speak about epistemology in art when every artist develops his/her own method? This question testifies of the difficulty to win recognition for the status of art facing the natural sciences for example and the embarrassment as soon as one tries to characterize and then validate the specificity of the tools and methods of an artist.

Between Perception and Representation

When someone manages to "see" a complex curve/surface from the simple reading of an equation, one can say it concerns a perception/representation, an internal perception, and the same applies when a musician is able to "hear" a music just by discovering its score. The point is not only the knowledge of the associated representation (visual or auditory), of the abstractions, the codes (mathematical, musical), of the writings we have stored in our cultural memory, but also a capacity to "visualize" and "hear" from these complex codes.

It takes a daily training likewise for the art of archery, the ice-skating, or any other physical activity allowing projecting the body into the space. "Seeing" the equations, figuring an N dimensional space proceeds from the same kind of requirement. Beyond the simple representation that symbolizes and fixes, which *presents* or *presentifies* what is absent, arises the question of the presence for the mind, of the embodiment, of the recognition of what is seen by imagination. We do not argue any more about abstractions, but about something that takes shape in the consciousness.

The artist adds a requirement, the one to dismantle the acquired characteristics, the cultural consensus, he/she explores the evolving possible. Non-immediate perceptions thus exist, completely intellectually elaborated, but nevertheless perceptions as they have an obvious relation to the body and show that the intelligence of the world is never complete unless it is embodied. If perception is always proactive, remains the question of the presence, of the presence to the perceived subject, within what establishes it as a perception: the feeling, the presence of the body.

> "Only by working do I understand what I see" once said Giacometti. (Giacometti 1993)

Indeed, if the experiment shows that it is possible to "visualize" some complex situations as 4 dimensional spaces, it is only on the condition to practice regularly, to dedicate frequently the theoretical writings concerning these spaces, to daily maintain an intuitive and quasi-physiological understanding of these situations. It's enough to release one's effort to loose very quickly contact with "visualizations".

Exploratory and Poetic Gesture

The Breakwater, where we performed Hantu n° 18-*Dancing a line in the Sound*, was built in the middle of the Sound, the bay of Plymouth. Its access is prohibited for the public. What is impossible most of the time, becomes possible (although under control, naturally), in the frame of an artistic gesture, because the economy of the poetic gesture has nothing to do with the intention of an action in general: the intention of the gesture is poetic but the poetic intention is contained in the gesture. It is not external to the gesture. There is no other expectation horizon except to satisfy the desire to fully accomplish, without restriction a poetic gesture. It is not necessarily spectacular. But within its economy, it is correlatively the affirmation of the body, its inscription, or the place it occupies in the space, the action it performs in these circumstances.

On Knowledge in Art, by the Exercise of Art

Sensitive Impressions: Practice and Empiricism

The image technologies, since the silent movie accustomed us to a decoupling of the sound and the image. If Deleuze characterizes cinema by this disjunction of image and sound, if Eisenstein as well as Chaplin fought this heresy even trickery that the speaking cinema represented for them, this disjunction has thus allowed the emerging of the audio-visual grammar. Cinema and later on video don't pretend to imitate the real, but propose at the most a lecture of it and a symbolic shaping. They allow us to establish new relations with time and space. Marey's experiments testify of his concern for physiological knowledge of movement. Abel Gance invents new sensitive equivalents in his *Napoléon*, throwing a filming camera during a snowball fight to give the point of view of a flying snowball. As well as there are in the nature, opposite telluric or meteorological strengths, the artistic practice plays dynamically with unforeseen, contradictory energies, inversions, and reversals of assertions.

Making and Unmaking Models, the Plastic Energy at Work

Science proceeds by models that are as many dynamic representations. However all the representations (equations, musical scores…) are not models. Models are

> What is of use as object to the imitation. (*le Petit Larousse*)

But today the notion of model exceeds of a lot this simple definition. The point is not any more a question of mimesis but of simulation. Simulation of an existing reality, but also of projections with the aim of a realization. Nevertheless the simulation, if it "looks like", in the sense Magritte understands, it does not look like a pre-existent reality, but at the most a model, for a very thought, like something which is going to arise and which was yet never there, something one *simulate* as the architect simulates the building before to build it. On paper, or "on computer", simulation is not enactment.

> The operation which extracts from a situation a figure allows in return to fix an ideal type and supplies a paradigm for the reconstruction of this situation. […] The model, in the evolved sciences, serves to fix the laws onto a well structured object, and this fixation favours in its turn the conception and the experiment: Both major senses of the term of model, which is a representation and at the same time a master plan, confirm each other and conjugate more or less. (Encyclopaedia Universalis[11])

Sciences have gotten us used to this particular mode of representation which is not simply a redoubling of the reality, even increased, of an idealized image with prototypal aim, but also a tool at the same time deducted from the experiment, from its theorization, and which by the simplification it presents allows to feign situations, behaviours, to make vary the parameters which compose it, and so to move forward in the analysis of complex phenomena. The model intervenes in return in the improvement of the theories that aroused it. It is thus a manipulable representation susceptible to represent the general features of an appearance (formal, behavioural, logical). Like geometry, the model is neither true nor false; it is more or less effective. It has to present a number of qualities that make it relevant with regard to what it models… And when, in Encyclopaedia Universalis, the author specifies that:

> It is by trying to reduce the phenomenological aspect of appearances in a description (Geometrical, analytical) where from the peculiarities resulting from the observation are gradually excluded, it is in this walking towards what Einstein calls "the extra-personal" that the physics conquers the particular and imposes its object.

We shall see here a characteristic feature of these digitals fields where arises, the "impersonal" (Couchot 1988). Not any more in a common fund of perceptions, actions and practices, but in a representation which aims to be cleared of affects, prejudices and the contingent subjectivity, to go towards a "most objective possible" knowledge of the phenomena. Even if it means that the success of some models brings them in their turn to enrich the cognitive experiences of the group and that they so become integrated into an increased common fund; becoming dynamic cultural objects[12] at the same time as tools organizing the knowledge. The models bind in a dynamic way the representation and the experiment. Much more, the models contribute actually to fix a common fund from which the artist is going to be able to assume his/her subjectivity while anchoring it in a shareable corpus. Another characteristic of the model is its complexity: the model is not a sluggish, totally abstracted sign that it is necessary to associate to others in a statement[13]; it is in itself a theoretical, experimental production and representation at the same time.

The arts of time and the arts of the space are the traditional categories that structure the fine arts: the music, the dance and the singing inscribe themselves in time, are transformed, give rhythm to a duration, whereas the fixed image invests

[11]CD ROM Edition.

[12]In the sense that "Nuvola" is a cultural object for Francastel (1967).

[13]In this way, it would be closer to the ideogram, but the model anyway is not a sign, it is a symbolic tool.

the space. We also speak about models, musical model and plastic model, associated to the arts of time for the first one, to the arts of space for the second. The aesthetics is the field of an essential reflection on the status of space and time and on the overtaking of both orders: make and undo the models. To categorize the art should allow the connection in the same creative drive of a model and its opposite: at the same time giving some plasticity to the musical world and some musicality to the plastic one, this is what exactly try the most recent artistic mediums by investing at the same time the space and the time: the installation (which invites the spectator to roam in a space), the performance (stemming from a meeting between stage and plastic arts) and the video and/or multimedia art (which proposes following the example of the cinema an image-time).

Dynamic of a Meeting Space

Order and Disorder, Chance and Predictability

We saw it earlier, the act of creation is realized in tension: On one hand, the artistic practice develops simultaneously towards the mythical thought and the elaboration of a pure plastic "logic". On the other hand, the abstraction and the symbolic formalization take place without giving up the intuitive dimension of the gesture of creation. So every device establishes itself as a system and develops its own tools and coherence. We practice in studio or in situ in both cases in a dynamic way around opposite, structuring and destructuring, strengths. The actions punctually performed in situ are rarely repeated (meaning physically prepared nor repeated) and in this case the discovery (of an environment, a situation) is an essential element. More than events they are advents, creating the conditions so that something happens. The performances are followed by a work of objectification, interpretation/representation/structured shaping (reading of trajectory for example: geometrization of the movement, the lines of force, composition of a body in a space, an observation of the interaction of both bodies). The work in studio allows us to resume certain movements out of context, to repeat them and to modulate them to seize more exactly their impact on the body and on the feeling of presence. Figures 7, 8, 9 and 11 show the work in studio whereas we practice gestures performed in situ. It is about writing with and in a body that would develop its own method. In studio, the body adjusts its gestures, in order to distribute better efforts, to decrease tensions and fight against the will of performance, to put in perspective the notion of ideal movement by looking for other options. The in situ performance often requires a physical effort of adaptation and efficiency, a toughness, an impulse. In studio, the body does not look for either the effort, or the performance, or the expression of the will except the will of a fluidity of the movement. The staging and the re-enactment of circulatory spiral movements allows to re-revitalize the movements which have lost their spontaneity, but also, to seize in the energy of the spiral, a way of moving in variable speeds and experimenting unexpected forms of manoeuvrability.

Spiral of Time and Announced Disappearance (Hantu n° 18-Kegaska)

By the seashore, on the border of the Labrador, a body, taken in a net, evolves around a broken vertebra of whale. This marine mammal is considered by the autochthons (Indians, Innus and Inuits) as master of the ocean. The whale is the archivist in almost every tradition, one is fascinated by its disproportionate size: the whale is the stomach of the sea, it can gobble up everything, it is a sanctuary and the place of a revival at the same time (Jonas’ myth). As for the vertebra, it is obviously, as all the bones, a symbol of the death. An embryonic body in its whitish envelope makes a swing of the pendulum. Here, we try to give a representation of time, of the course of time. We also see there the movement that would make around an axis a pendulum as those whom use certain dowsers… The dream, the poetry allow to imagine scenographies that are also simulations. It is by the body that we visit the Amerindian myth of the cetacean, and it is by the body that we discover and that we understand the physical phenomena: the anchoring, the exit of the axis, the progress, the acceleration, the breathlessness of a rotary movement. The performance is a way of taking the measure of the body. Here it seems hardly bigger than the vertebra, this small fragile bone in disproportioned dimensions (Fig. 10).

We have resumed the rotary movement of this performance in studio: the body stretched out on the ground turns around an imaginary vertical axis, which would pass by one or the two feet. The body drills and runs, so that the movement is as harmonious and the least struck as possible, arms successively have to comply and to unfold, pulling the rib cage, whereas legs have to fall over without feet leave the ground and pull in their turn the pelvis. During a crossing of the space in a straight line, as performed on Breakwater (with moments of running, jumps or a series of jumps) the movement builds itself linearly by accumulation (acceleration), unloads (impulse) and exhaustion (deceleration) of the energy. In the rotary movement on the contrary, the various parts of the body take turns to precipitate farther the body, which winds on itself. The movement can be very slow and very dynamic at the same time (the “washing machine” effect: a continuous and moderate gesture), the passage of the dorsal position in a lap position is enough to see out the movement. The most natural epilogue of this movement seems to us to be the vertical push towards the seated station, knelt down or squatted with legs more or less unfolded, according to the energy released by the rotation speed: the gesture runs out in an upward push.

Conclusion

Art is an exploration of the world by representation of sensitive experiences, given so we may share it. This sharing differentiates art from, on one hand, the simple perception, which distinguishes invariants from the perceived matter and projects on the world pre-constructed patterns, and on the other hand, the science which aims to deduct effective laws from the invariants (to develop knowledge and allow actions). Senses are neither functions, nor tools, we assume that senses have to be considered as systems of perception. These systems allow to become aware of the external world and to develop self-awareness.

The artist doesn't attempt to eliminate the subjectivity of his work. On the contrary, his work is an assertiveness of the presence of the body, and in the Performing Arts in particular, it asserts the role of the body in the depths of the artistic process, in the site he measures and transforms. And so, he declares the impossibility to separate the artistic creation from the singular existence of a subject: "Art as Life"(Kaprow) or "Art is what makes life more interesting than art."(Filliou). This way he ponders the status of his activity: is the art a purpose or simply a means? Is it a life experience or the appearance of the need-to-feel alive, by giving a sensitive equivalence to every single sensation felt by/inside his body?

The assertion of Filliou is an ethics. Let us imagine one moment to apply it to other fields: "science is what makes life more interesting than science ", or " religious belief is what makes life more interesting than religious belief". The wish of Cassirer to set up a global symbolic system of knowledge to integrate the characteristics of scientific, artistic and religious languages, seems achievable provided of subjecting these languages to a higher authority: "life" says Filliou, "construction of a common world" says Cassirer, "Politics" says Aristotle, regarding it as the highest of *tekhne*, because it establishes the good of all by means of the justice…

In this text we have wished to regard the complementarity of art and science as systems of symbolic knowledge, looking at the perception and action, means for its experiment and its representation. This isn't so much the control of technical skills; it's the exercise of the active presence of the body and the refusal to rank the knowledge that allows art to give a sensitive representation to " hidden worlds of which we are unaware". It 's while borrowing from different kinds of representations, from the mathematical figure, to a dynamic model of turbulence, a body's trajectory, from a " sensitive chaos ", to a simulation, a symbolic sensitive or perceptual equivalence that the symbolic shaping of a sensation or an impression comes to life. While appropriating, with a certain freedom, the scientific definitions and concepts of milieu, substance, surface, proper world and environment as much as the animistic principles, the energetic continuity and the systems of equivalence between the strengths of the forest and those of the Uma,[14] the artist renews the modes and typology of representations.

[14]Traditional house in the island of Mentawai.

For most scientists, the observer is supposed to modify and perhaps corrupt the result of the experiment he is performing. For us as artist, the body of both the performer and the videographer are in stake, in the heart of the work of art. Scientific knowledge can help us, give us patterns, understanding of part of the phenomena we are experiencing, but our goals and methods differ and it is still very difficult to have a real mutual understanding, to be able to really collaborate further than artist as an interesting object to observe, scientist as an interesting support for providing models.

A real collaboration between art and science would have to begin by the mutual recognition of the goals, methods and achievements, and then to define from scratch a common procedure that could allow to benefit of the antagonistic specificities of the two fields.

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Part VI
Modeling and Naturalizing Aesthetics

An Introduction on Formal and Computational Models in Popular Music Analysis and Generation

Moreno Andreatta and Gilles Baroin

Abstract This article provides a first introduction to some formal and computational models applied in the analysis and generation of popular music (including rock, jazz, and *chanson*). It summarizes the main philosophy underlying the project entitled "Modèles formels *dans* et *pour* la musique pop, le jazz et la chanson", which constitutes one of the research axes of the GDR ESARS (Esthétique, Art & Science). Initially conceived as an extension of the MISA project carried on by the Music Representation Team at IRCAM, this research axis aims at bringing together researchers from different horizons, from the traditional MIR community of Music Information Retrieval to the most sophisticated approaches in mathematical music theory and computational musicology. It also includes an epistemological and critical evaluation of the relations between music and mathematics, together with some programmatic reflections on the possible cognitive and perceptual implications of this research.

Introduction

There is an increasing interest within the computational musicological community for formal and computational models applied not only in the analysis but also in the generation of popular music. With this label, one generally includes repertoires—such as rock, jazz, and *chanson*—which are not considered as belonging to the art or contemporary music.[1] The common point among all formal and computational methods

[1]This paper summarizes some aspects of this project that have been described in details in Andreatta (2014a). For a pedagogical and large-public introduction to mathematical models in popular music, also see Andreatta (2014b). A more technical presentation of the main concepts described in this paper and addressed to the community of researchers working on computational musicology is given in Bigo and Andreatta (2015).

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described in this article relies on the relevance of the interplay between geometric and algebraic approaches in music theory, analysis and composition.[2] This postulate applies equally well to contemporary art music and popular music repertoires, which opens interesting questions about the possible articulations between these two study domains.[3] Moreover, the tools described in this paper also apply to the field of folk or traditional music, which is—according to a programmatic article by Philip Tagg on theoretical, methodological and practical aspects of popular music studies (Tagg 1982)—one of the three possible kinds of music (together with classical or art music and popular music).[4] This is possible thanks to the flexible nature of geometric representations, which enable to grasp equally well the logic behind the songs and "chansons", from The Beatles to Paolo Conte, as well as the harmonic construction of rock/pop pieces (from Frank Zappa's to the songs by Depeche Mode).[5] After briefly describing some theoretical aspects underlying the geometric representations used in the field of computational (popular) music analysis, we will show some new visualisations of musical structures and processes

[2]According to the Field-medallist Alain Connes, "concerning music, it takes place in time, like algebra. In mathematics, there is this fundamental duality between, on the one hand, geometry—which corresponds to the visual arts, an immediate intuition—and on the other hand algebra. This is not visual, it has a temporality. This fits in time, it is a computation, something that is very close to the language, and which has its diabolical precision. […] And one only perceives the development of algebra through music" (Connes 2004). This duality constitutes a major common point between music and mathematics, allowing proposing a common basis for the creative processes in both fields of music and mathematics, as suggested by Alain Connes in his dialogue with Pierre Boulez on creativity in mathematics and music (Boulez and Connes 2011). See Andreatta (2010) for a detailed description of the "mathemusical" research that has been carried on in the last ten years within the MISA project (*Modélisation Informatique des Structures Algébriques en musique*), with a special emphasis on the interplay between algebra and geometry. See Andreatta et al. (2013) for a description of a category-oriented framework for describing the creative process in music and mathematics.

[3]This question has been explicitly addressed in the conference "Musique savante/musiques actuelles: articulations" (Contemporary art music/popular music: articulations), hosted by IRCAM and organised under the auspices of the French Society of Music Analysis, in collaboration and with the financial support of the IReMus (Institute of Research in Musicology, UMR 8223, Paris-Sorbonne) and the BPI of the Centre Georges Pompidou and with the participation of the French component of IASPM (International Association for the Study of Popular Music). The Proceedings are forthcoming in a special issue of the multimedia online journal *Musimédiane* (Andreatta 2016). For a first attempt at analysing the necessity of substituting this typology with a finer taxonomy based on computational models focusing on musical objects and making use of different theoretical approaches in order to carry on computer-aided music analysis, see Bergomi et al. (2015).

[4]This typology constitutes what Tagg calls an *axiomatic triangle* of musical genres, each of which being characterized by criteria such as the usual or unusual mass distribution, the existence of a circle of professionals or a circle of amateurs who produces and transmits it, the principle modality of storage and distribution (ranging from oral transmission, in the case of folk music, to the recorded sound, in the case of popular music), the anonymous versus authorial character of the underlying compositional process, and so on.

[5]For a recent analytical application of the formal tools discussed in this paper from the perspective of a geometric-based automatic classification, see Bergomi et al. (2015).

making use of a recent model providing some additional tonal information with respect to the traditional *Tonnetz* representation.[6]

Geometric Representations of Musical Structures and Processes

Although sometimes very far from a stylistic point of view, there are pieces belonging to the rock, pop and "chansons" repertoire which somehow share the same "musical logics" concerning the harmonic organization. More precisely, if one restricts the analysis to consonant chords (major and minor), it is possible to find interesting common points between stylistically-different pieces in the way in which the chord progressions are constructed. In order to make these similarities evident, the (computational) music analyst can use several geometric representations of harmonic spaces, including the circular representation, the different types of *Tonnetze*, the orbifolds, the spiral array and many others.[7]

In this paper we will focus on the *Tonnetz*, a geometric representation of the pitch space originally proposed by Euler (1774) in the second half of the XVIII[e] century as an alternative to the well-established circular representation previously introduced by Marin Mersenne in his *Harmonie universelle* (Mersenne 1636).[8]

The *Tonnetz* is a symbolic organization of pitches in the Euclidean space defined by infinite axes associated with particular musical intervals. Although these graph-theoretical representations have been rediscovered later by music theorists, musicologists, and composers (including Arthur von Oettingen, Hugo Riemann and Henri Pousseur), the interest of the computational musicology community for this type of structure is very recent. The model is currently used to represent chord

[6]Two main models, the "Polarized Tonnetz" and the "Spinnen Tonnetz", originally conceived by Hugo Seress and Gilles Baroin, represent a very interesting way of integrating some tonality-based constructions within transformational music analysis. For a critical presentation of these two models and their comparison with other tools belonging to the transformational musical analysis tradition, see Seress and Baroin (2016).

[7]See Bigo (2013) and Bigo and Andreatta (2015) for a historical description of the main geometric representations in computational music analysis. Algebraic topology has provided a very elegant theoretical framework for describing all these representations, as shown by Bergomi (2015) in his recent doctoral thesis.

[8]The reader interested to learn more about the three main contributions of Leonhard Euler (as a mathematician, physicist and music theorist) can refer to Hascher and Papadopoulos (2015).

progressions within the so-called neo-Riemannian transformational approach,[9] whose application includes post-romantic tonal music (Cohn 2012) but also rock, jazz and pop music repertoires (Capuzzo 2004; Hascher 2007; Briginshaw 2012; Bigo and Andreatta 2015). From a generative perspective, this model has also been used in contemporary music (for example by the French composer Jean-Marc Chouvel), as well as in popular music contexts, leading to a geometrically constrained-based series of Hamiltonian Songs (Andreatta 2014b; Bigo and Andreatta 2014).[10]

Mathematically-speaking, the circular representation and the *Tonnetz* are equivalent ways of formalizing in an algebraic way the structural properties of the equal-tempered system (i.e. the division of the octave into twelve equal intervals, as in the piano). The main computational property is the possibility of generating the system by using combinations of major third (i.e. four semitones) and minor third (i.e. three semitones) intervals, as depicted in Fig. 1.

As the previous figure suggests, we are interested in the computational aspects of the geometric representations, and in particular in the fact that they can be implemented in programming languages for computer-aided music analysis and composition. For example, to compute the compactness of harmonic trajectories in different automatic-generated *Tonnetze*, the computational musicologist has a new geometric way of handling the problem of style classification, which is one of the most interesting research areas in Music Information Retrieval. We will not enter here into this aspect of our research, which has been largely addressed in several recent contributions (Bigo et al. 2013; Bigo and Andreatta 2015; Bergomi 2015; Bergomi et al. 2015), but we will focus on visualisation techniques as applied, in particular, to popular music repertoires. Figure 2 shows the *Tonnetz* as generated by three musical operators (P, R and L), corresponding to the three possible ways of transforming a major chord into the corresponding minor chord having two notes in common with the initial chord. These operators are respectively called the "parallel" (indicated by P and transforming, for example, the C major chord into the C minor chord, and vice versa), the "relative" (indicated by R and transforming, for

[9]Neo-Riemannian music analysis is a formal methodology developed after the writings by the German music theorist Hugo Riemann (1849–1919). Following David Lewin's transformational turn in music theory and analysis (Lewin 1987/2007; 1993/2007), which integrates neo-Riemannian techniques within a much more general approach, one may speak about neo-Riemannian transformational music analysis as a structural methodology combining the two independent approaches. See Gollin and Rehding (2014) for a comprehensive textbook on Neo-Riemannian analysis.

[10]Hamiltonian Songs are so-called after the Irish physicist, astronomer, and mathematician Sir William Rowan Hamilton (1805–1865). In graph theory, a Hamiltonian cycle is a path passing through all possible nodes of a graph and ending precisely where it started. It is well known that there are exactly 124 Hamiltonian cycles in the *Tonnetz* (Albini and Antonini 2009) which can be classified by using their inner symmetries (i.e. the possibility of decomposing a given cycle into sub-sequences that repeat identically in order to generate the entire cycle). The complete list of Hamiltonian cycles with some examples of Hamiltonian Songs is available at: http://repmus.ircam.fr/moreno/music.

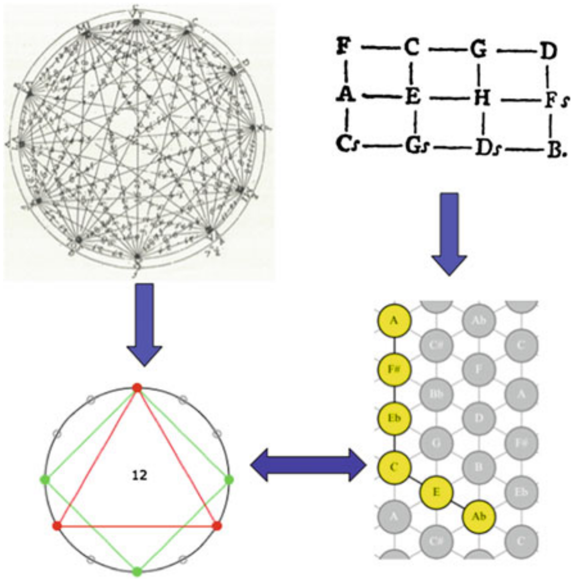

Fig. 1 Two mathematically equivalent representations of the family of pitch-classes within the equal-tempered system: the circular representation, whose origin goes back to Mersenne (*on the left*) and the "Speculum Musicum" by Euler, which is the ancestor of the *Tonnetz* (*on the right*). The circular representations and the *Tonnetz* are obtained respectively by using the OpenMusic visual programming language (see Agon 2004) and the *Hexachord* software (see Bigo 2013)

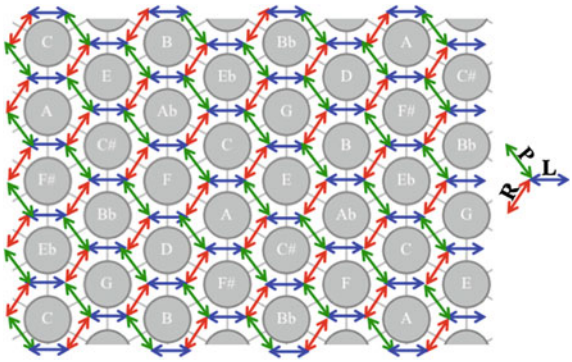

Fig. 2 The *Tonnetz* as a hexagonal tiling of the plane where each major (respectively minor) chord is transformed into three minor (respectively major) chords via the three P, R L operators preserving two of the three notes of the initial chord

example, the C major chord into the A minor chord, and vice versa) and the "leading-tone" (indicated by L and transforming, for example, a C major chord into a E minor chord, and vice versa).

Circular Representations and Tonnetze for Popular Music

In order to show how the circular representation and the *Tonnetz* constitute two complementary approaches in the analysis of harmonic progressions, let us stress a little bit more the relevance of the notion of symmetry in music. An interesting starting point is provided by two stylistically different pieces having the same

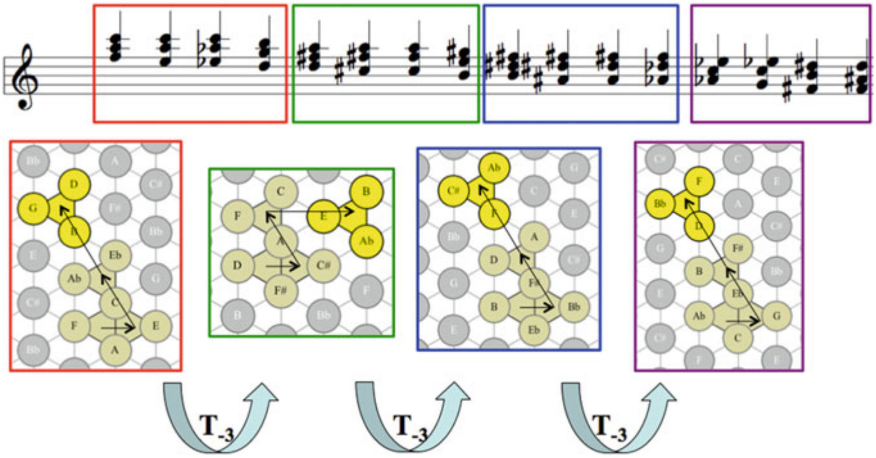

Fig. 3 Harmonic progression in Zappa's piece *Easy Meat*, seen as a series of transpositions (of a minor descending third T_{-3}) of a same cell (the first one, in *red*). The four cells generate therefore the same trajectory in the *Tonnetz* (where apparently different shapes correspond in fact to the same trajectory because of the toroidal structure of the *Tonnetz*) (color figure online)

"spatial" logics with respect to the harmonic organisation: *Easy Meat* by Frank Zappa and *Madeleine* by Paolo Conte.

Let start with Zappa's piece *Easy Meat* and one of the most recurrent harmonic progression in the piece.[11] This progression, shown in Fig. 3, contains sixteen chords and can be decomposed as a repetition (via the transposition operation) of a given cell of four chords. Each cell contains the same series of neo-Riemannian operators, as Fig. 4 shows.

The figure shows the progression represented in an unfolding *Tonnetz* representation conceived by Gilles Baroin, corresponding to the two-dimensional projection of his *Hypersphere of Chords* (Baroin 2011). In this case the trajectory of a cell is rigorously translated in space, metaphorically providing a kind of composer's "signature" for the piece.

It is interesting to compare this type of chord progression with a different harmonic progression used by the Italian "chansonnier" Paolo Conte in his piece entitled *Madeleine*. In this song, the harmonic progression of the verse, repeated several times all along the piece, is also constructed in a similar way. There are four blocks, the first three of which are obtained by transposing an initial cell by an ascending third. They therefore correspond to a same trajectory in the *Tonnetz*, whereas the symmetry breaking due to the fourth block, structurally different from the three previous ones, enables the chord progression to come back to the initial chord. This progression is given in Fig. 5.

[11]The interest of using Neo-Riemannian techniques to analyse this passage has been originally pointed out by Capuzzo (2004).

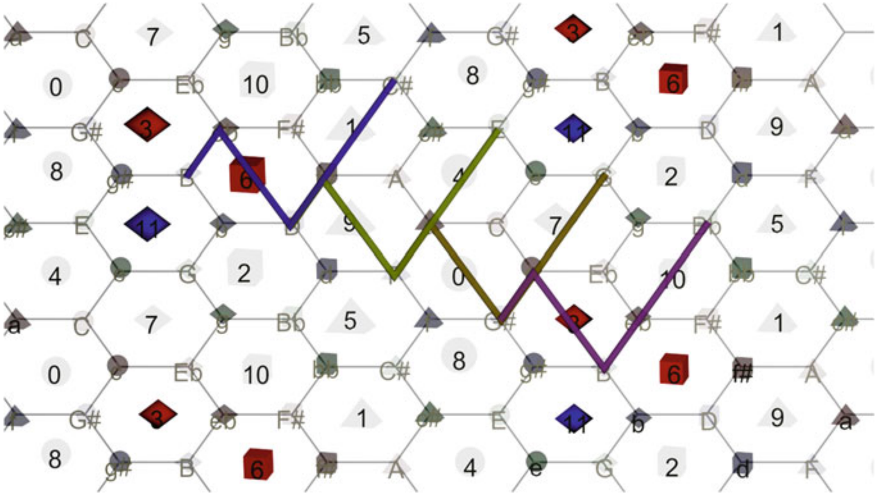

Fig. 4 Zappa's "signature" for the piece *Easy Meat*, represented in Gilles Baroin's visualisation of the *Tonnetz*

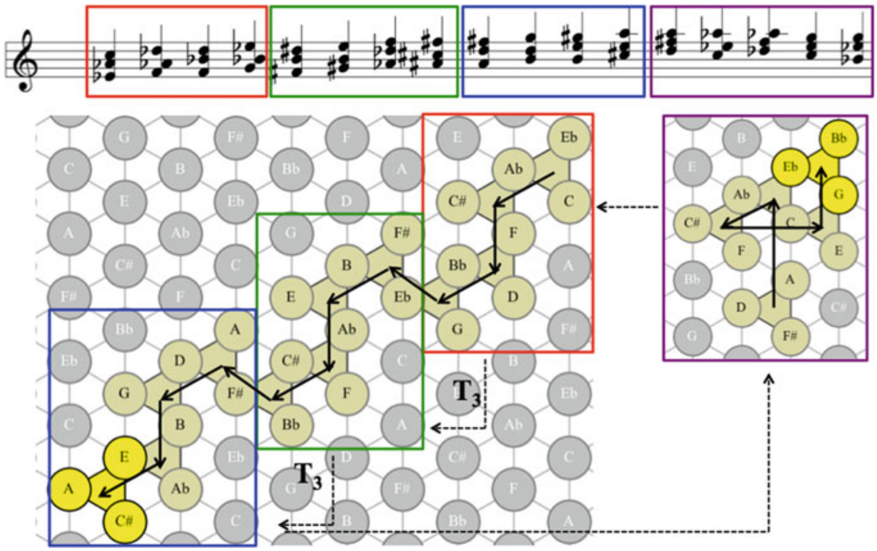

Fig. 5 Harmonic progression used by Paolo Conte in his song *Madeleine* represented as a series of spatial translations of an initial cell containing four chords. The fourth cell, containing five chords, functions as a new trajectory "forcing" the progression to come back to the initial tonality

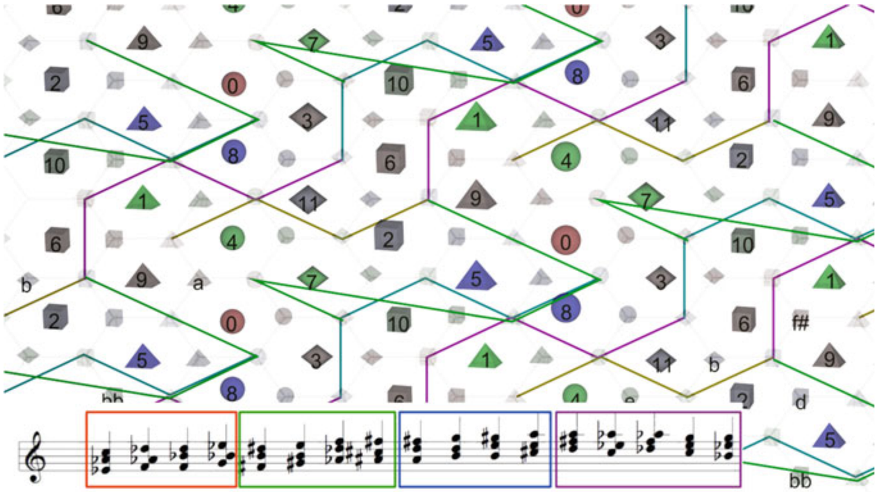

Fig. 6 The "almost perfect" covering of the harmonic chromatic space by major chords and their transpositions in Paolo Conte's *Madeleine*

Despite this superficial analogy between the two pieces, the compositional process in *Madeleine* has a remarkable property which makes the chord progression "qualitatively" very different from that used by Zappa. In fact, up to a single chord, which is missing, it constitutes a *covering* of the chromatic space by major chords and their transpositions. This covering property is much more evident in the following *Tonnetz* representation provided by Gilles Baroin (Fig. 6).

In other words, the harmonic progression of the piece corresponds to a trajectory which passes through (almost) all twelve major chords (with repetitions). This property admits a natural mathematical generalization by considering the traditional *Tonnetz* as a graph whose vertices consist of all major and minor chords and by studying trajectories passing only once through all major and minor chords and eventually coming back to the starting point. In this case, such paths are called "Hamiltonian cycles" and have been enumerated and classified (Albini and Antonini 2009) according to their inner symmetries. There are in fact Hamiltonian cycles which are "redundant" (meaning that they are generated by the repetition of a given pattern) and other cycles which are "maximal" (meaning that they are not obtained as a concatenation of a same pattern of P, L and/or R transformations). Such maximal Hamiltonian cycles have been used by one of the authors in the instrumental parts of the song *Aprile,* inspired by a text from the Italian decadent poet Gabriele D'Annunzio (1863–1938). More precisely, three structurally different Hamiltonian cycles have been used, with the goal of systematically frustrating the

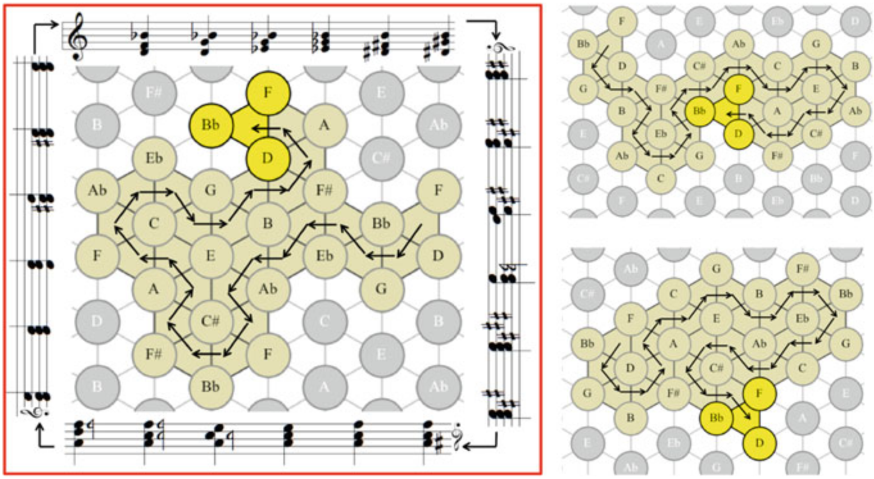

Fig. 7 The three maximal Hamiltonian cycles used in the instrumental part of the song *Aprile* by Moreno Andreatta, inspired by a Gabriele D'Annunzio poem (1863–1938)

expectation of the listener, whose perception cannot find the logic in the three selected progressions of chords (Fig. 7).[12]

The previous example shows the interest of using Hamiltonian properties of chord progressions in a popular music context. Despite their intriguing character, Hamiltonian cycles are challenging objects for music perception and cognition. One may question their capability of providing harmonic material that the musical mind can process, without getting lost in the underlying maximal variety principle.[13] Since evidences of the perceptual relevance of these geometric and combinatorial structures are still lacking, it seems reasonable to try to add some inner symmetries in the Hamiltonian cycles used in song writing. Redundancy in the inner structure of the Hamiltonian harmonic progressions has been used by one of the authors (Moreno Andreatta) in the song entitled *La sera non è più la tua canzone* and based on a poem by Mario Luzi (1914–2005). Hamiltonian cycles are not only used in the instrumental parts, but—more challenging—in the verse, which obliges to create a melody capable of supporting a continuously changing harmony. Due to its inner

[12]The Hamiltonian trajectories of the song have been visualised by Gilles Baroin by mixing his *Hypersphere of Chords* representation and the traditional *Tonnetz*. It is available online at the address: (www.mathemusic.net).

[13]Note that "hamiltonicity" does not only concern popular music strategies, but it plays an important role in contemporary art music. The history of Twentieth-Century music shows that Hamiltonian properties have been implicitly used by composers such as Pierre Boulez or Milton Babbitt, who developed combinatorial strategies as natural extensions of the twelve-tone compositional system. Both composers and music theorists claimed the necessity of having a "maximal variety principles" in composition, in order to precisely question the notion of expectation in the musical listening process.

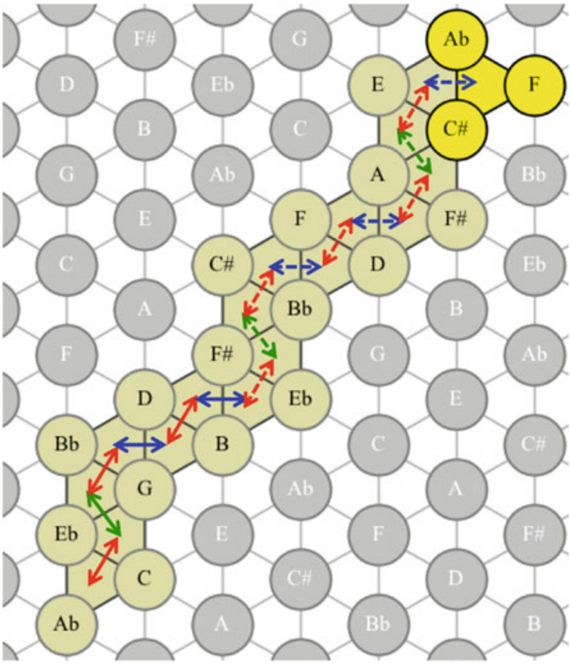

Fig. 8 The redundant Hamiltonian cycle used in the song *La sera non è più la tua canzone* (music by Moreno Andreatta, based on a poem by Mario Luzi)

symmetry, the cycle of length 24 is obtained by repeating four times the pattern LRLPLP of six transformations, as shown in Fig. 8.

The Fig. 9 shows the visualisation of the redundant Hamiltonian cycle utilized in the song *La sera non è più la tua canzone* in a new *Tonnetz* representation called the *Spinnen-Tonnetz*.

Although one of the main features of the *Spinnen-Tonnetz* is to provide a tonal centre to a harmonic progression, hamiltonicity makes the recognition of a tonality impossible in the case of the previous song. This fact opens interesting questions about the capability, for the musical mind to grasp these mathematical representations and to follow the logics of continuous modulations. One of the objectives of the "Math'n Pop" project, which is carried on within the GDR ESARS, is precisely to go deeper into the connections between cognitive neurosciences and algebraic/geometric formalisations of musical structures and processes. As shown by Zatorre and Krumhansl (2002), the mental key maps are related to the way in which a major (resp. minor) chord is surrounded by minor (resp. major) chords having two notes in common. Although the authors do not make any reference to the neo-Riemannian transformations, the geometric space they suggest to use is precisely the traditional *Tonnetz*.[14]

[14]We analysed the relations between mental and mathematical representations of music in Acotto and Andreatta (2012).

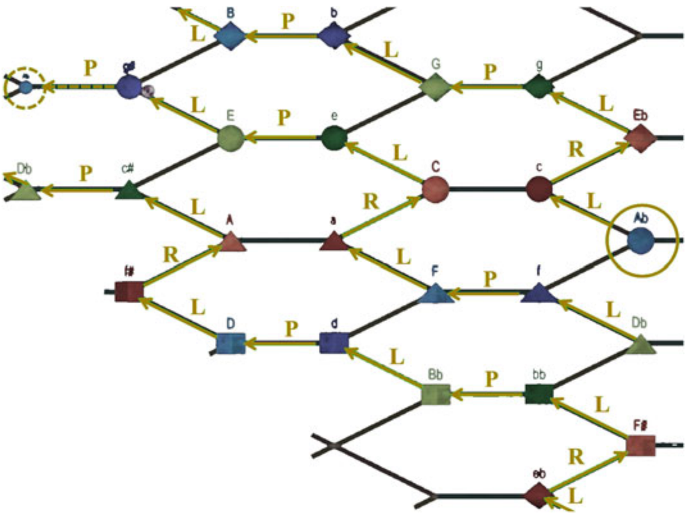

Fig. 9 The visualisation of the trajectory corresponding to the redundant Hamiltonian cycle used in the song *La sera non è più la tua canzone* in the *Spinnen-Tonnetz*. The *circle* shows the initial chord of the Hamiltonian progression (which—because of the cyclic character of the path—is the same as the final chord, indicated with a *dotted circle*)

Conclusions and Perspectives for Future Research

Starting from the analytical examples presented in this paper, together with the compositional applications that we have briefly sketched, it is clear that the popular music repertoire (including pop music, jazz, rock and *chanson*) can largely benefit from the use of formal and computational models. Although we have focused our attention on symbolic approaches and, in particular, on algebraic and geometric models, one interesting research area is precisely the interaction between symbolic approaches and different techniques based on signal processing within the field of Music Information Retrieval (MIR). A first attempt at filling the gap between these two main components of MIR has been carried on by using dissonance functions and advanced tools in algebraic topology in order to deform the original *Tonnetz* into an anisotropic structure (Bergomi and Andreatta 2015; Bergomi 2015; Bergomi et al. 2015). An example of deformation of the vertices of the *Tonnetz*

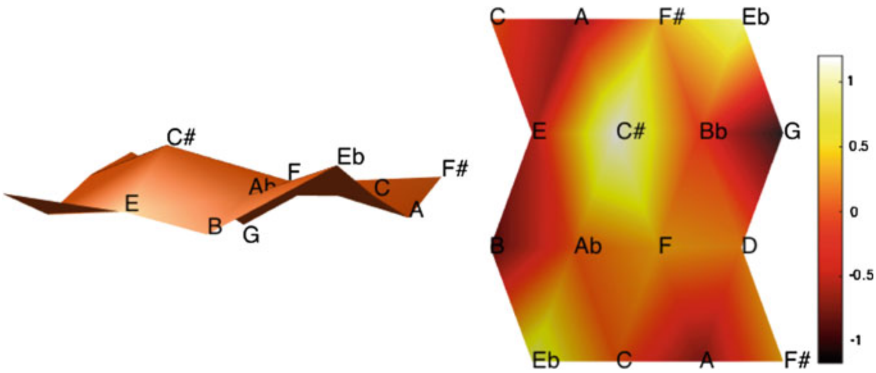

Fig. 10 The anisotropic *Tonnetz* whose vertices are deformed by a dissonance function (in this special case it is the dissonance induced by a C major chord. The figure is taken from Bergomi and Andreatta 2015)

leading to an anisotropic geometric space is shown in Fig. 10. This new structure might be an excellent case study in order to fill the gap between the computational musicological community and the neuroscientists working on the cognitive aspects of the geometric formalisations of musical structures and processes.[15]

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[15]A special issue of the *Journal of Mathematics and Music* has been devoted to this specific problem with precisely the aim of bridging the Gap between Computational/Mathematical and Cognitive Approaches in Music Research. See Volk and Honingh (2002).

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The Evolution of Aesthetics: A Review of Models

Julien P. Renoult

Abstract The evolution of aesthetics has become an increasingly popular topic over the last few years, both for evolutionary biologists and for scholars from other disciplines who want to broaden the historical perspective of their findings. Different models have been proposed to explain evolution of aesthetics, all inspired from research in sexual selection. In this chapter, I review three of these models: beauty as an indicator of quality, Fisher's model of aesthetic coevolution, and the exploitation of efficient information processing. I argue that only the last model can simultaneously explain the ubiquity and universality of aesthetic experiences, and the diversity and extravagancy of beautiful stimuli. The model fits both to empirical results from psychology and image statistics showing that beautiful stimuli are efficiently processed by perceptual and cognitive systems, and to neurophysiological evidences supporting the concept of "disinterestedness" in philosophy of aesthetics. The exploitation of efficient processing uniquely offers a workable model for evolutionary biology that further articulates with concepts and results from other aesthetic sciences.

Introduction

Aesthetics is a vibrant topic, one of those that enthral societies and equally enliven researchers from all fields. For more than a century, research on aesthetics has become a real science, with a methodology and accumulative evolution of knowledge similar to those classically observed in biology or physics. Works in cognitive sciences in particular have much contributed to unravel the proximate

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mechanisms underlying the aesthetic experience.[1] As usual, however, the haecceity of a biological thing or phenomenon is best understood when framing its study with an evolutionary perspective. This chapter will review three models that evolutionary biologists have proposed to explain aesthetic evolution.

In evolutionary biology, little attention has been paid to the definition of aesthetics and beauty, either treated as synonymous with preference, or with attractiveness, or not defined at all. As argued at the end of this contribution, this casualness may have hampered progress in our understanding of aesthetic evolution. For present purposes, and to stick with the referred literature, I will define aesthetics very roughly as the feeling experienced by individuals facing a stimulus and that could be talked out with a "wouaouh!!". Although not scientifically sound, this definition allows readers who already experienced aesthetics to grasp the type of feeling that is discussed in this review (see also Palmer et al. 2013). Thinking out aesthetics in terms of "wouaouh!!" further allows listing basic criteria that could characterize aesthetics and beauty without too much contentiousness. First, aesthetics seems ubiquitous. We enjoy starring at very different kind of stimuli in a variety of contexts, including art exhibitions, starlight, potential mates, or a she-cat licking her kitten. Second, focusing on a specific kind of stimuli and contexts, beautiful stimuli seems highly diversified. There are for instance plenty of artworks that have the power to delight us, and even for one particular type of artworks, say abstract paintings, aesthetic possibilities seem infinite. Third, many beautiful stimuli appear extravagant. This is particularly true for organic communicative stimuli. Extravagancy may not be a necessary condition to beautifulness, but it certainly contributes to make us appreciating the abundance of forms and colours in birds of paradise (Paradisaeidae), the frantic dance of Blue butterflies (Polyommatinae), the loud and penetrating call of the indri lemur (*Indri indri*) or the immoderate excessiveness of the labellum of the Lizard orchid (*Himantoglossum hircinum*). Last, despite this huge diversity of beautiful stimuli and aesthetic experiences, people seem alike bewitched by the same stimuli. Sunsets, for example, wow people from over the world. Certainly this last point will not be taken for granted by everyone at this stage, but it will be thoroughly discussed in the following. These four criteria will be used as a guideline to evaluate the ability of the different models to provide an encompassing explanation to aesthetic evolution.

The first model discussed is the indicator of quality, which is the most notorious model of aesthetic evolution, although probably not the best understood. I will then review a model rooting far in the first half of the twentieth century, but which has been only recently valued as a primary model of aesthetic evolution: Fisher's runaway. Last, I will conclude with studies supporting that aesthetics is a by-product of perceptual and cognitive adaptations to efficiently process information.

[1]Throughout this review, *beauty* will refer to "the inherent property of a (visual) stimulus" and *aesthetics* to "the subjective experience elicited by beautiful stimuli" (Redies et al. 2015). *Aesthetic valuation* will describe the mind process of placing a stimulus on a scale from ugly to beautiful. *Aesthetic appeal* is the attractiveness of a stimulus due to its beauty, and *aesthetic preference* the aesthetic appeal of a stimulus relative to that of other stimuli.

Beauty: An Indicator of Quality

The evolution of aesthetics has been mostly investigated by evolutionary psychologists. The goal of evolutionary psychology is to understand the design of human mind using the principles of evolutionary biology (Barkow et al. 1995). In fact, evolutionary psychology has focused so much on adaptation as the main determinant of evolution that one can fairly qualify this field of research "an adaptationist approach to evolution of the human mind". For evolutionary psychologists, perception, emotion, cognition and the actions resulting from these mind processes all are adaptations designed by natural and sexual selection having allowed people to survive and reproduce during the evolutionary history of our species. Aesthetic valuation is a product of the mind and thus a manifestation of these adaptations (Cosmides and Tooby 1987). By extension, aesthetic valuation itself has been considered an adaptation. Aesthetic valuation is a psychological manifestation that, consciously or not, evaluates the benefit of the environment (including both its inanimate and living constituents) in terms of survival and reproduction (Thornhill 2003). We see beauty in what or who increases our likelihood to survive and to produce offspring, and ugliness in what or who is a bad omen. Beauty is thus a stimulus indicating the quality of what is perceived.[2]

According to the model of quality indicator, those forebears that were lucky to have a mind manifestation for appraising the quality of perceived objects and organisms survived longer, reproduced more, and thus transmitted this (originally fortuitous) ability more widely to next generations. This adaptationist model assumes that aesthetic valuation is determined genetically, and that aesthetic preferences are universal or at least shared between individuals or populations proportionally to their genetic similarity. In the following, I review some of the studies on the quality indicator model of aesthetic evolution that dealt with two types of stimuli: landscapes and the face of potential mates.

Landscapes

The quality indicator model of aesthetic evolution proposes that our ancestors' minds have been selected to find landscapes beautiful when they were safe and plenty of resources. According to the so-called Savannah hypothesis, we have an innate preference for landscapes reminiscent of the savannah biome in which our African ancestors evolved (Orians and Heerwagen 1992). Accordingly, Balling and Falk (1982) found that American children expressed a significant preference for pictures of savannah rather than of other natural biomes. However, other studies revealed patterns that can be hardly explained by the Savannah hypothesis. In one study, Coeterier (1996) found preferences for landscapes with traces of human control. In another study, Han (2007)

[2]In aesthetics, the expression "quality indicator" originally comes from research in sexual selection and refers to the quality of potential mates. Here, "quality" should be understood in the wide sense and can include quantitative aspects of the valuated stimulus.

was not able to replicate Balling and Falk's results when explicitly asking subjects to evaluate scenic beauty (in the original study, reference to beauty was only implicit). In their study, the authors found the highest aesthetic merit for coniferous and tundra biomes. More importantly, the basic assumption that our ancestors' minds should have adapted mainly to savannah biotopes does not fit archaeological evidences that during the last hundred thousand years of it evolution, our species experienced important climatic variations, shifting cyclically from temperate to tropical conditions. It thus seems unsupported that landscape aesthetics is an adaptation that evolved to evaluate the potential quality of one specific biome.

Studies on landscape aesthetics nevertheless evidenced several seemingly robust and generalizable patterns of preference (Ruso et al. 2003). First, we have an overall preference for natural over artificial landscapes (Kaplan and Kaplan 1989). Naturality is well known by urban planners to increase the aesthetic appeal of cities. Our propensity to grow tropical ferns indoor and to sow flowered lawn may reflect a deeply-rooted pleasure of inhabiting fertile land. In one study, tree density, tree placement and level of grass maintenance were manipulated on images of neighbourhood outdoor space that were shown to one hundred American inner-city residents living adjacent to that space (Kuo et al. 1998). Preferences went for densely wooded space independent of tree placement, which can be interpreted as cueing high land fertility. Second, we like safe landscapes. Safe landscapes are those we can control: we enjoy nature, but not complete wildness. In the same study, residents preferred well maintained over tall grass; and when residents were asked to score the expected safety of space in addition to their preference, the two scores were highly correlated. The importance of safety is further supported by several studies showing that we tend to prefer landscapes that can be monitored easily from a sheltered viewpoint (e.g., Appleton 1975). Third, landscape should contain water. Indeed, adding water dramatically increases the aesthetic appeal of landscapes (Ulrich 1981). In sum, there is a reasonably large body of evidence that the preferred landscapes are those that are expected to provide refuge and resources, and thus facilitate survival and reproduction.

Faces

According to the quality indicator model, our ancestors' minds have been selected to see beauty in good-quality people who can afford either direct benefit by providing resources or safety, or indirect benefit by transmitting good genes to offspring. In evolutionary psychology, and more generally in research on sexual selection in humans and animals, the model of quality indicator is the most popular model explaining why individuals tend to share the same preferences for sexual partners.

There is indeed a shared, universal component to face preferences. New-borns presented with face pictures spent a longer time gazing at faces that have been rated as attractive by adults, independently of the gender, ethnical origin (white versus black people) and age (infant versus adult) of the displayed faces (Langlois et al. 1991). It is assumed that, in humans at least, face preference is congenital and is reshaped during postnatal development to integrate individual experience and cultural standards. Nevertheless, a number of cross-cultural studies have shown that adults continue to share face preferences (Jones and Hill 1993; Zebrowitz et al. 1993, 2012), which suggests a genetic influence in the determination of this preference (Jones and Hill 1993).

Three facial attributes in particular seem to drive commonalities in face preference in humans (for a review, see Rhodes 2006). The first one is symmetry. Preference for symmetrical faces has been found for both men's and women's faces (Grammer and Thornhill 1994), from different cultures and in cross-cultural experiments (Pisanski and Feinberg 2013). The second attribute that seems to drive commonalities in face preference is sexual dimorphism. Heterosexual men over the world are attracted by feminine women (Buss 1989). Women similarly tend to find masculine men more attractive, even though the effect is weaker than for feminine women (Rhodes 2006). The third facial attribute is averageness. Early evidence that an average face is appealing came from studies using computer-generated averaged composites of faces (Langlois and Roggman 1990). However, because blending makes averaged face looking more symmetrical and smoother, it was soon thought that these attributes, not averageness per se, were driving attractiveness. Further studies therefore replicated analyses while controlling for symmetry and smoothness, and confirmed previous findings (Rhodes et al. 1999). In addition, preference for average faces has been documented by studies on natural, non-manipulated faces (e.g., Light et al. 1981), and in one meta-analysis (Rhodes 2006).

The model of quality indicator supposes that we evolved to find averaged, sexually dimorphic and symmetrical faces beautiful because they cue beneficial mates. The link between symmetry and mate quality in particular has been the focus of a wealth of studies over the last three decades. Several authors proposed that symmetry reflects developmental stability, which depends on the genetic background and on external factors such as parasite load, nutrition, pollution (Møller 1992; Palmer and Strobeck 1986; Parsons 1990). Yet both the link between degree of symmetry and developmental stability, and between developmental stability and mate quality seem more complex and idiosyncratic than previously thought (Dongen 2006; Polak et al. 2003). Most likely, symmetry is related to quality in some animals and for certain traits, but it is not for some others. Regarding human face specifically, one study showed that perceived health cancelled the effect of both symmetry and averageness in a statistical model explaining variation in attractive faces (Rhodes et al. 2007). This study supports the idea that the appeal of symmetric and averaged faces is largely due to their healthy appearance. Furthermore, genetic diversity within the major histocompatibility complex (MHC), which are proteins coding for immune response, positively predicted male attractiveness, with face averageness mediating the relationship (Lie et al. 2008). The relationship between health or genetic quality, and masculinity in men or femininity in women, is not as strongly supported (Rhodes 2006). However, men with higher levels of circulating testosterone, that is, stronger men that are more likely to provide direct benefits, are rated more masculine (Penton-Voak and Chen 2004), and women with higher levels of circulating oestrogen, that is, more fertile women, are rated more feminine (Law-Smith et al. 2006). Overall, the huge literature on face preference made convincing the hypothesis that attractive face partly indicates good-quality mates.

Cues, Indices and Honest Signalling

Landscapes and sexual partners both vary in how good they are to the perceiver. Landscapes with fertile lands, refuges, viewpoints and water are preferred because they are expected to be beneficial, and so are fertile and healthy women, and strong and healthy men. There is nevertheless a fundamental difference between landscapes and sexual partners. Being a biological organism the latter but not the former can evolve autonomously in response to selection by the beholder. Naturally, the quality of a landscape may change with time due to the action of humans or of any other ecosystem engineers, but a landscape cannot evolve autonomously. This means that a landscape will never evolve *signals*, which are adaptations influencing the behaviour of other organisms, and which evolved specifically because of that effect (Stevens 2013). The appraisal of landscape quality will always rely on cues, and on cues only, which are incidental sources of information (Stevens 2013). In contrast to signals, cue for example could never evolve a strategy that lures the beholder by purposely advertising a false level of quality.

A strong correlation between signals and quality characterises honest signalling. It is generally assumed that a communication system needs to be reliable on average to maintain over time. Indicating quality is always costly: sexual displays, gametes, but also flower nectar, fruit pulp or amphibian toxins all need energy to be produced. If the strategy of signalling these “quality” without effectively affording them were as efficient as honest signalling, it would spread and become the dominant strategy, eventually making the whole communication system unreliable and useless.[3]

A contentious question in evolutionary biology is how the correlation between signals and quality is achieved. The most frequently cited mechanism is the “handicap principle” (Zahavi 1975; Zahavi and Zahavi 1997). All textbooks in psychology, evolutionary aesthetics and neuroaesthetics I could read cite this mechanism, and most of them only cite this one. In short, the handicap principle proposes that honest signals are maintained because they incur extra-costs that only truly good-quality individuals can bear. A classical example is the peacock tail. According to the handicap principle, the long tail of peacocks signals mate quality to peahens, and honesty is maintained because only those males that are in truly good health state can afford wasting energy or handicapping themselves (for example for fighting against rivals or escaping predators) by producing such long tails.

The theoretical conditions that make the handicap principle operative are quite restrictive, and several authors expressed concern that the mechanism has been abusively proposed to explain the maintenance of signal honesty (Számado 2011), in particular in the sociological and psychological literature (Grose 2011). It should

[3]Naturally, deceptive signalling does exist, and the system can maintain with traces of unreliability if the cost of cheating is low, explaining for example why women continue to put makeup on and men to wear epaulets.

be clear that the handicap principle relies on the existence of variation in the *extra-cost* of signal production, that this cost should be differentially higher for the lower quality individuals, and that the variation is correlated with heritable genetic variation in quality. Simply arguing, for instance, that making art is costly is far from being sufficient to fuel the idea that art is a handicapping sexual signal. As it turned out, very few, if any, studies in evolutionary biology succeeded in collecting all the empirical evidences necessary to unambiguously favour the handicap principle over alternative mechanisms, to a point that several authors doubt that the handicap principle is relevant to organic evolution (Számado 2011; Getty 2006; Cotton et al. 2004).

Alternative mechanisms that can explain the maintenance of reliable communication are numerous (Schaefer and Ruxton 2015). The most obvious one concerns signals that are reliable because they physically cannot be produced by low-quality individuals. Such signals are termed *indices* (Maynard-Smith and Harper 1995). An example of index is loud call, which is preferred by females in several animal species. Because call loudness is determined by the size of the sounding board, call loudness is an honest indicator of caller's vigour independently of the cost of calling (Stevens 2013). Another mechanism is based on public information, where cheaters are avoided because they have been previously observed cheating when interacting with a third party, or when the third party directly communicates about his bad experience (Danchin et al. 2004). Yet another mechanism relies on learning from past experience, which typically occurs in communication systems based on repeated, small-effect interactions (Schaefer and Ruxton 2015). For example, you may loose a few dollars going to the movie theatre to watch *Dude, Where's my car?* but it is unlikely you go again to watch another movie by Danny Leiner.

What about faces? It has been often suggested that feminine and masculine facial traits are honest indicators of positive quality because they indicate levels of circulating hormones during growth, which metabolisms are costly (Thornhill and Grammer 1999). Indeed, high level of oestrogen promotes certain hereditary diseases (Liang and Shang 2013) and high level of testosterone lowers immunocompetence (Folstad and Karter 1992). However, oestrogen and testosterone also and firstly have several beneficial effects, on follicle and sperm production, muscle development and strength, bone density, to name just a few (Burrows 2013). Thus, rather than signalling handicapping level of hormones, it seems more rational to interpret sexual dimorphic traits as (inevitably) honest cues of strength and fertility (see also Skamel 2003).

In sum, the quality indicator model of aesthetic evolution assumes that aesthetics valuation has evolved through the course of human's evolution to appraise the qualities of its environment in terms of survival and reproduction. The model seems to correctly explain which landscapes and human's faces people across cultures agree to prefer. It could similarly explain preferences for many other items if these can be related to our vital needs. For example, according to this model we would find roe deers and strawberries aesthetically pleasing because they afford proteins and sugar, respectively, bird songs because they cue productive habitats, social scenarios provided by literature, theatre, movie, TV and music because they give us solutions to solve real social problems, poems with alexandrine lines because they signal an agile mind that can be useful for other more vital operations, or that is genetically correlated with other, heritable phenotypic traits (Thornhill 2003).

We further discussed that a reliable communication system is needed to maintain the usefulness of aesthetic valuations. The handicap principle is the most frequently cited mechanism to keep signals of quality honest. However, very often signals can be reinterpreted as cues or indices, which by essence cannot be cheated because they are physically linked with the advertised quality. Furthermore, for real signals previous interactions with the stimulus, either experienced by the beholder himself or by third parties, can be sufficient to avoid cheaters. Overall, the validity of the handicap principle remains to be supported empirically.

The handicap principle is nevertheless the only known mechanism controlling reliability that can explain evolution of extravagant ornaments such as the peacock tail. But as we will discuss in the next section, here again there is a more parsimonious explanation to evolution of such ornaments and of their associated preferences, provided that reliability is not assumed to be essential for communication systems.

Fisher's Model of Aesthetic Preferences

Sexual Selection Without Natural Selection

Sir Ronald Fisher was one of the greatest scientists of the twentieth century. In his history of mathematical statistics, Anders Hald called Fisher «a genius who almost single-handedly created the foundations for modern statistical science» (Hald 1998). His legacy deeply influenced various research areas such as agronomy, psychology, economics and evolutionary biology. In research on sexual selection, he is notably famous for the discovery of a particular mechanism explaining the co-evolution between sexual signals and the preference for these signals (Fisher 1915). Fisher observed that, once sexual signals and preferences have been paired, that is, once females start to prefer one particular trait in males, if the male trait and the corresponding female preference are both coded genetically then the corresponding genes will occur together in the chromosomes of offspring. At the population scale, the correlation between genetic variations for sexual signals and preferences will increase over generations.

Fisher thereby realised that traits and preferences would coevolve under the mere effect of their reciprocal action (Fisher 1915). Fisherian sexual selection is in marked contrast with the model of quality indicator, in which natural selection plays a preeminent role. Natural selection can be described as the sorting of individuals based on their match with their environment. For example, the ability of a male to resist parasites, to find preys or to escape predators, in sum, the ability to cope with its environment, signals the extent of direct and indirect benefits the male can provide to the female. In the model of quality indicator, sexual preferences are thus controlled by natural selection. In Fisher's model, sexual preferences are independent of natural selection.

Fisher's verbal assessment of signal-preference coevolution without natural selection had been covered with forgetfulness until Lande (1981) and Kirkpatrick (1982) formalised it mathematically in the eighties. These authors further documented the complexity and richness of the coevolutionary dynamics of signals and preferences. They showed that this dynamics depends on the relative strength of the genetic correlation between signals and preferences and the amount of genetic variations for those traits. Without entering into details, at the beginning of the coevolutionary process, the correlation is weak relative to the variation and both signals and preferences within a population converge to equilibrium. But as the correlation increases, the equilibrium becomes unstable and signals and preferences will coevolve away from it, in an arbitrary direction. This coevolution in an arbitrary direction is known as the "Fisherian runaway".

Like the quality indicator model, the Fisherian runaway can explain evolution of extravagant forms of signals and preferences that could reduce the survival of individuals. Proponents of the model of quality indicator view the peacock's tail as a handicap signalling masculine vigour. For those defending Fisher's model the peacock's tail epitomizes the outcome of a runaway process without natural selection. The model does *not* entail that natural selection is *not* influencing evolution of signals and preferences; it simply states that natural selection is not the mechanism fuelling extravagancy.

The strength of Fisher's model further lies in its ability to explain the tremendous diversity of sexual displays that occur in many species groups. Let's consider drakes. Drakes are highly colourful animals compared to female ducks, but even more stunningly they are very different from one species to another. The genus *Aix*, for example, includes two species, the Mandarin duck (*A. galericulata*) and the Wood duck (*A. sponsa*). In contrast to females, which are almost non-differentiable, males of these two species are very different, having in common only the fact to harbour multi-coloured patterns and modified feathers that have been selected for their beauty certainly more than for flight or thermoregulation. Natural selection can hardly explain such a diversification of signals. If the mechanisms producing pigments or shaping feathers were genetically linked to other vigour-related traits—a necessary condition for feather colours and shape to indicate quality—diversification of colours and shape would signify in-depth remodelling of the whole genetic make-up, which is unlikely to occur during the short evolutionary time that typically separates two sister-species.

Recently, it has been argued that Fisher's model is more than an alternative to the quality indicator model; it is the null model of evolution of sexual signals and preferences (Prum 2010). It is a null because it is the intersexual selection model that makes the minimum assumptions about evolutionary processes (Kirkpatrick and Ryan 1991). The quality indicator model is a complexification of this null model, which is not necessary to explain to most fundamental aspects of signal and preference coevolution (Prum 2010). As for any null model, if one cannot reject Fisher's model there is no good scientific reason to invoke alternative models.

Fisher's Model and Darwinian Aesthetics

In 2003 a highly cited review article was published entitled "Darwinian aesthetics: sexual selection and the biology of beauty" (Grammer et al. 2003). By cataloguing supports to the preeminent role of health assessment in mate choice, the review actually is a plea for the quality indicator model of aesthetics. The fact that this review was written by four leading evolutionary biologists illustrate how deeply rooted in the mind of evolutionists the misinterpretation of Darwin's original view of sexual selection is.

In his book on sexual selection, Darwin wrote he knew "of no fact in natural history more wonderful than that the female Argus pheasant should be able to appreciate the exquisite shading of the ball-and-socket ornaments and the elegant patterns on the wing-feather of the male" (Darwin 1871, p. 400). Darwin was more puzzled by the extreme refinements on feathers in this pheasant than by the length of its tail, which as in peacocks outrageously exceeds any functional requirement. Darwin hypothesized that these refinements are the evolutionary product of a selection for "agreeable partners" (Darwin 1871, p. 398) by females using their "taste for the beautiful" (Darwin 1871, pp. 39, 233). But Darwin was explicit that the "taste for the beautiful" serves no other functions than evaluating the intrinsic beauty of the partner: "The case of the male Argus Pheasant is eminently interesting, because it affords good evidence that the most refined beauty may serve as a sexual charm, and for no other purpose" (Darwin 1871, p. 516). By contrast, for Alfred Russell Wallace, a contemporary to Darwin who contributed to the birth of evolutionary biology, when sexual selection occurs «the only way in which we can account for the observed facts is by supposing that colour and ornament are strictly correlated with health, vigour, and general fitness to survive» (Wallace 1895). According to Helena Cronin, Darwin's view of mate choice as «a pure aesthetic experience, a selection and celebration of beauty for its own sake» (Cronin 1991) was one of the main points of disagreement between these two scientific eminences. She also highlighted that, although the scientific community has largely overlooked it, the model of quality indicator is entirely Wallacean, and anti-Darwinian.

Even though Darwin was the main discoverer of the process of natural selection, like Fisher he rejected its role of driver in evolution of sexual signals and preferences (Fisher 1915). According to Richard O. Prum, Fisher's model of coevolution between signals and preferences lays the groundwork for a genetic theory of true Darwinian aesthetics (Prum 2012). Interestingly, a recent model of quantitative genetics showed that the influence of the social environment on preferences (e.g., mate choice copying) could facilitate the initiation of the runaway process and increase the rate of trait elaboration (Bailey and Moore 2012). The importance of the social environment would be such that selection could occur in the absence of any genetic correlation between male signals and female preferences. This result broadens the scope of applications of the Fisher's model to many types of interactions between biological organisms. In the same vein, Prum suggested that Darwinian aesthetics could occur whenever a signal coevolves with its own evaluation independently of the effect of other evolutionary forces (Prum 2013). He argued that the coevolution of flower colours with pollinator preferences, of bird songs with female acoustic preferences, of artworks with the artistic sensibility of art dealers and museum visitors are all instances of aesthetic evolution. Similarly, for the neuroscientist Anjan Chatterjee art evolves autonomously (Chatterjee 2013). Art is varied and unpredictable when environmental pressures are relaxed. In oppressive regimes, or during periods of starvation, the diversification of art is constrained. For Chatterjee, if art were signalling something, this would be our freedom. This view of art evolution is entirely Fisherian.

To sum up, Fisher's model of coevolution between signals and preferences offers a parsimonious explanation to both evolution of extravagant ornaments and the diversity of signals and associated preferences. Fisher's model elaborates on original Darwin's view of a sexual selection independent of natural selection. Fisherian signals do not indicate any quality of the emitter. Fisherian signals merely indicate that they exist and that a preference for these signals has coevolved with them. Consequently, Fisherian signals cannot be honest or unreliable, and thus no mechanism to maintain reliability is required in the evolutionary model of Fisherian aesthetics (Prum 2010, 2012).

Proponents of the Fisher's model of aesthetic evolution made a great step forward by recognizing that preferences are not all aesthetical. Signals coevolve with their own evaluations, but at the same time they can indicate a quality, which also influences their evolution (Prum 2010). Yet only the component of the preference that has evolved through a Fisherian mechanism would qualify aesthetical.

In spite of its importance for sexual selection theory, I think that Fisher's model falls short in offering an encompassing explanation to evolution of aesthetics. As a coevolutionary model, it cannot account for the aesthetic experiences encountered with abiotic stimuli, such as beautiful landscapes. It may well be that the variety of aesthetic experiences springs from multiple and distinct evolutionary mechanisms. Or could it be otherwise? Maybe one can find an evolutionary model that can simultaneously encompass the universality and proteiformous nature of aesthetic preferences and beautiful stimuli, the diversity of situations generating aesthetic experiences, and the distinction between preferences and aesthetic preferences. But first, let's have a look at what cognitive sciences have learned about aesthetics.

Exploitative Beauty

Universal Beauty

In order to support their claim that aesthetics could be investigated scientifically, all along the twentieth century empirical psychologists have looked for regularities in people's aesthetic responses to various kinds of stimuli. In a series of studies, Irvin Child and his colleagues presented people from different cultures (Americans, Central African, Japanese) with photos of various artworks (pictures of African masks and occidental sculptures, colour reproductions of abstract paintings; Child and Siroto 1965; Iwao et al. 1969). Importantly, Japanese and Central African people originated from remote places and were questioned to certify they had no knowledge of any sort on occidental art. Participants were asked to rank pictures according to the aesthetic value of artworks. Overall, these studies showed high correlations between rankings, in support to some universality in aesthetic preferences. Furthermore, they showed that the strength of correlations was increased when participants were art experts (art students for Americans, sculptors and other craftspeople for Africans and Japanese), thereby illustrating how familiarity with aesthetics promotes congruency rather than divergence in aesthetic preferences. It is likely that the shared component of aesthetic preferences is innate, grounded deeply within the biology of humans rather than being an acquired analogy. Many subsequent studies have concurred with this view that aesthetic preferences and beauty are, at least in part, universal and innate. We cited previously one study demonstrating that new-borns unanimously seem to prefer pretty-looking faces of all origins (Langlois et al. 1991). In the same vein, several studies have shown that infants from over the world share the same musical tastes, and that differences in adult's preferences are acquired culturally (Trehub 2000).

Empirical psychologists and visual scientists have conducted an impressive number of studies to identify which basic properties of stimuli, for example lines, colours, patterns, orientations and layouts, contribute to elicit a universally shared aesthetic response (for reviews, see for example Palmer et al. 2013). The first and foremost of such basic properties is symmetry. The link between symmetry and beauty can be traced back as far as Plato and Aristotle, but it is the mathematician George David Birkhoff who first formalized this link in its famous formulae $M = O/C$, where M is the aesthetic measure, O refers to order (mostly driven by symmetry for Birkhoff) and C to complexity (Birkhoff 1933). According to the formulae, for a given level of complexity the more symmetrical a stimulus, the higher the aesthetic measure is. Later, several psychological experiments confirmed the general importance of symmetry in aesthetic appreciation (Jacobsen and Hofel 2002; Palmer and Griscom 2013). People also tend to prefer shapes with curved contour more than similar shapes with sharp contours (Silvia and Barona 2009). For colours, vertical gradients with lighter and less saturated colours placed above darker and more saturated colours are rated more beautiful than the reversed gradients or than vertical patterns with randomly ordered colours (Valentine 1962).

Higher-order spatial statistics of visual displays, which describe the general spatial organization of the display, also influence aesthetic preferences. In particular, scale-invariance usually increases the aesthetic appeal of visual displays (Redies et al. 2015). Scale-invariance means that similar patterns recur on finer and finer scales. By calculating Fourier spectral slopes on photos to estimate their scale-invariance, Christoph Redies and his colleagues found that artworks are more invariant than laboratory and household objects, parts of plants and scientific illustrations (Redies et al. 2007b). In accordance, faces represented in paintings and drawings from various cultures and periods typically are scale-invariant, while faces on ID-photos are not (Redies et al. 2007a). Regarding the representation of stimuli, people tend to prefer displays to the extent that they conform a categorical prototype (Rosch 1975). Preference for prototypes have been evidenced with all kinds of stimuli, ranging from simple abstract geometric forms (Winkielman et al. 2006) to surrealist paintings (Farkas 2002) and furniture (Whitfield and Slatter 1979).

It is noteworthy that, when investigated, these preferences that appear in humans independently of their culture have been found in other animals too. For beauty in general, Stefano Ghirlanda and his colleagues showed a shared preference for beautiful faces between chickens and humans (Ghirlanda et al. 2002). They trained chickens to peck at the picture of an average human face of one sex but not of that of the other sex. Then, they counted the number of pecks to images of new faces of both sexes. The authors found a very strong correlation between the number of pecks by chickens and rates of attractiveness for the corresponding faces obtained from university students. Regarding the characteristics of stimuli that are preferred, a number of studies have documented that, as in humans, symmetry increases the attraction of sexual partners (Swaddle and Cuthill 1994; Morris 1998), and that pollinating insects also prefer symmetric flowers (Møller and Sorci 1998; Rodríguez et al. 2004). But preference for symmetry also occurs for non-representational stimuli. In chickens, for example, naïve individuals (24–48 h old) innately prefer asymmetric geometric forms, but a spontaneous preference for symmetric forms appears in normal rearing conditions within a few days (Clara et al. 2007). In another study, newly dark-hatched chicks consistently pecked more at round than at angular objects among 40 varied stimulus objects presented (Fantz 1957). Preference for prototypicality also is well documented in animals, notably by studies interested in the 'peak shift effect'. If a rat presented to a square and to rectangle with a 4:3 aspect ratio is taught to be attracted to the rectangle, in testing trials it will respond even more strongly to a rectangle with a 3:2 ratio. This peak shift effect occurs because the rat learns to respond not to the rectangle itself but to rectangularity, that is, to what allows telling apart a rectangle and a square. The 3:2 is eventually preferred because it is more a prototype of rectangularity than a 4:3 rectangle is. Various examples of peak shift effects in animals have been reviewed by ten Cate and Rowe (2007).

Overall, the evidences presented hereinbefore unambiguously show that there exist preferences for particular characteristics of stimuli that are not specific to one domain.[4] Importantly, they also suggest that an aesthetic preference may not be a specific adaptation but it can be a by-product of adaptations in other domains. With the framework of the quality indicator model one would interpret preference for prototypical furniture as a by-product of adaptation to prefer feminine women and masculine men, and preference for round shapes as a by-product of preferences for round, energetic fruits, or round women breast, or any other good-quality round stimulus to which our ancestors have adapted. But from the quality indicator model these by-product preferences would not qualify aesthetical. Furthermore, this framework would not easily explain why aesthetical preferences are shared among species having very distinct reproduction systems or ecology such as among birds, primates and fishes. According to Darwin, the same stimuli "are often pleasing to widely different animals, owing to the similarity of their nervous systems" (Darwin 1872, p. 91). Darwin also thought that the diversity of aesthetic preferences could have a unique origin, a "fundamental cause in the constitution of the nervous system" (Darwin 1859, p. 255). In the next sections, I will present an evolutionary mechanism grounded in the neurobiology of organisms that can overarchingly explain both the universality and diversity of aesthetic preferences.

The Efficient Processing Theory of Aesthetics

One of the most important findings in psychology of aesthetics is that fluent processing of stimuli is hedonically marked and experienced as aesthetically pleasing (Reber et al. 2004). Besides, image statisticians and visual scientists have accumulated evidences that aesthetical visual stimuli such as artworks are coded more efficiently (i.e. both easily and precisely) than non-aesthetical ones (Redies 2007). Actually, the fluent processing theory and the efficient coding theory of aesthetics are two faces of the same coin: efficient coding is one neurobiological mechanism underlying the psychological phenomenon of fluent processing. In the following, I will use the expression Efficient Processing (EP) to designate both theories indistinctly. I will review a tiny fraction of the vast literature supporting the EP theory of aesthetics, starting with signal processing by low-level visual mechanisms and ending with cognitive mechanisms.

Form Processing

Perception—the internal representation of the external world—primarily relies on sensory systems, which recode information contained in external physical stimuli into neuronal signals. The sensory systems of animals have adapted to process

[4]In cognitive sciences, a domain describes a category of problems that are repeatedly encountered throughout the life of an individual, e.g., finding mates, foraging, escaping predators.

information efficiently, notably by removing the many redundancies that occur in natural stimuli (Barlow 1961; Simoncelli and Olshausen 2001). Colours, for example, are physically described by reflectance spectra, which indicate the proportion (relative to a white standard) of light reflected by the object surface at any wavelength. Within the range of visible light, reflectance spectra of natural surfaces are invariably characterised by a smooth shape indicating that spectral information at adjacent wavelengths is highly redundant (Cohen 1964). Theoretical models showed that the use of only three types of photoreceptors and the recombination of their outputs into two opponent channels, as they occur in humans, are optimal to efficiently encode spectral information (Buchsbaum and Gottschalk 1983). The sensitivity of retinal ganglion cells (the neurons that receive signals from photoreceptors) to light contrasts is another mechanism reducing redundancy, this time in the small (pixel) scale information of visual scenes (Barlow 2001). Indeed, it is more efficient to only encode the contour of a homogeneously coloured shape than to encode the very same information about the stimulus at every pixel within that shape. Further up in the visual system of primates, the retinal ganglion cells project to the Lateral Geniculate Nucleus (LGN), whose function is thought to reduce redundant information contained at a larger spatial scale, for example scale-invariance. Next, neurons from the LGN project in the brain to the primary visual cortex. Here, it was found that the neuronal network has adopted a sparse coding strategy: among the hundreds of thousands of neurons constituting this brain area, at any moment only a tiny fraction of them are simultaneously active (Olshausen and Field 2004).

These various adaptations to reduce or remove redundancies are not limited to the visual system of primates but also occur in other sensory systems, of nearly all organisms investigated so far, including invertebrates (e.g., Clemens et al. 2011; Zaslaver et al. 2015). In sum, visual scenes of natural environments, such as forested and grassy landscapes for primates, have large patches of homogeneous colours, are highly scale-invariant, have sparse distribution of light intensities throughout the scenes, and these characteristics have contributed to shape the visual system of humans and other animals (Simoncelli 2003; Field 1987).

A first series of evidence supporting the EP theory of aesthetics comes from studies conducted by two independent teams showing that artworks and natural visual scenes have similar statistical regularities (Graham and Redies 2010; Redies et al. 2007b; Graham and Field 2007). We cited previously that painted and drawn portraits are typically scale-invariant. More precisely, portraitists from all cultures represent faces with the degree of scale-invariance that is characteristic of natural scenes, which differs from the typical scale invariance of faces (Redies et al. 2007a). In general, artworks match more closely the level of scale-invariance of natural scenes than other man-made objects do (Redies et al. 2007b). Similarly, artists appear to approximate the sparse statistics of natural scenes (Graham and Field 2007; though in this case the luminance range of natural scenes had to be compressed to match that of art). Collectively, these results have been interpreted as evidences that stimuli mimicking the redundancies in visual representations of nature are more efficiently processed by the visual system, which increases their aesthetic appeal (Redies 2007; Graham and Redies 2010).

More direct evidence comes from psychological studies comparing aesthetic preference with ease of information processing. Symmetric and rounded shapes are spatially more autocorrelated than asymmetric and angular shapes, and as such they should be more efficiently processed by visual systems. This has been objectified in a study showing that people responded quicker to symmetric and rounded shapes and subjectively qualified them easier to process (Reber and Schwarz 2006). In another study, thousands of people from ten countries were administered a questionnaire on fine art preferences (Komar and Melamid, cited in Mather 2014, p. 128). The study confirmed that people over the world are highly consistent in terms of fine art preferences. Among other shared responses, people overwhelmingly agreed that art should be "relaxing to look at".

Content and Context Processing

Besides redundancy reduction, another way visual systems have adapted to process information efficiently is by making expectations about the content of visual scenes, a phenomenon known as "predictive coding" (Rao and Ballard 1999). Predictive coding means that higher levels in the brain constantly send predictions about what to expect next in the flow of information processing. Predictions are compared with current input to establish prediction errors, which are sent back to higher levels that revaluate their predictions, and so on. Predictive coding increases processing fluency by adapting low-level perception to the statistics of the perceived visual scene (e.g., top-down control of retinal receptive fields; Friston and Kiebel 2009).

In accordance with the EP model of aesthetics, psychological experiments revealed that the aesthetics of visual scenes with predictable content is valued positively. We already illustrated this with prototypes, which facilitate object categorisation. Furthermore, people prefer repeatedly presented stimuli to new stimuli they have never been exposed to before (Zajonc 1968). This co-called "mere exposure effect" is arguably the most studied phenomenon in empirical aesthetics, being supported by experiments with photographs, paintings, music, simple sounds, nonsense words or shapes (Bornstein 1989). The extent to which the layout of an object, beyond its mere identity, matches predictions also influences aesthetic preferences. For example, photographers know well that the vertical placement of an object should fit to its ecology for the whole scene to be aesthetically pleasing. Palmer et al. (2012) demonstrated this by showing that people tend to prefer photos of flying eagles and of swimming sting rays where eagles and rays where placed at the top and at the bottom of images, respectively.

Benefits and Rewards of Efficiently Processed Stimuli

An important question for evolutionary aesthetics is *Why stimuli that are efficiently processed should be preferred?* It has been argued that such stimuli are selected because they are beneficial to the perceiver. Efficiently processed stimuli can provide the perceiver with direct benefits in at least three ways. First, EP enhances memory storing and retrieving. Both theoretical and empirical studies showed that sparse representations are more effective for storing patterns (Willshaw et al. 1969) and are advantageous for learning associations (Palm 2013). In the same vein, it was found that symmetrical patterns are remembered better than asymmetrical ones (Garner and Clement 1963). Second, EP increases speed of detection and recognition. High figure-ground contrasts, which have been shown to be aesthetically attractive in psychological experiments with humans, are also more efficiently coded than low figure-ground contrasts (Reber et al. 1998). In animals, there are numerous studies showing that conspicuous stimuli are advantageous to the perceiver (Renoult et al. 2016a, b). For example, Spaethe et al. (2001) analysed the correlation between the colour contrast of artificial flowers displayed on a green background and the time spent by bumblebees (*Bombus terrestris*) to visit three flowers of the same colour. The authors tested seven different colours and found that colour contrasts are linearly correlated with search time. Third, efficiently processed stimuli could save energy. Neural processing is extremely costly: in humans neural activity in the visual system alone accounts for 2.5–3.5 % of a resting body's overall energy requirements (Attwell and Laughlin 2001; Laughlin 2001). Simply opening the eyes onto an animated visual scene increases glucose consumption in the visual cortex by 50 % (Lennie 2003), which may explain why we expect to think more deeply when closing one's eyes. By minimizing the number of simultaneously active neurons, sparse coding allows metabolic savings (Olshausen and Field 2004). By shortcutting mid-level perceptual stages because lower level and higher levels are matching well, predictive coding is economical too (Friston and Kiebel 2009). Yet evidence that EP is metabolically beneficial is not evidence that efficiently processed stimuli allows significant energy savings. Indeed, whether or not energy savings have driven evolution of preference of efficient stimuli depends on how high is the differential cost between efficient and inefficient stimuli relative to the overall energy consumption of the aesthetic valuation. To my knowledge, such a differential cost remains to be evaluated.

Alternatively, efficiently processed stimuli may not provide the perceiver with direct benefits, but they could merely inform him that things and events are familiar and that interaction with the environment is going smoothly (Reber et al. 2004). As mentioned previously, EP is hedonically marked. This means that EP elicits a positive affective response; it is intrinsically pleasurable (Winkielman et al. 2003). In one study (Winkielman and Cacioppo 2001), participants were presented with pictures for which processing ease was manipulated by a subliminally presented contour prime that either matched or mismatched the target. Meanwhile, the affective response was monitored using facial electromyography. The authors found that easy-to-process pictures elicited higher activity over the region of *Zygomaticus* *major*, indicating positive affect. The hedonic marking of EP is consistent with the so-called affect-as-information theory (Clore et al. 2001; Schwarz 1990), where people unconsciously ask themselves "how do I feel about it" to decide whether processing should continue to complete recognition, scene evaluation and conscious decision making, whether a different perceptual strategy is required (for example attentional perception; Bradley 2009), or a motor response is urgently needed (for example escape; Ekman 1992). Pleasure is rewarding because it is triggered by a stimulus that is expected to be beneficial. As long as a stimulus is processed fluently, our brain is rewarded with pleasure, which drives us to behave positively with that stimulus.

Eventually, processing efficiency both directly benefits the perceiver and informs him about the potential benefits of the stimulus. Importantly, the pleasure generated by efficient processing is in itself rewarding. Thus formulated, the EP model of aesthetics does not seem to differ markedly from the quality-indicator model of aesthetics. There is one fundamental point, however, that puts apart these two models: while in the former the adaptation is the specific preference, in the later the adaptation is the general processing strategy. Because of that difference, EP stimuli can undergo a completely different evolutionary dynamics compared to quality-indicator stimuli.

The Exploitation of Efficient Processing

In sexual selection theory, besides the models of quality indicator and of Fisherian runaway, there is a third model of preference and signal evolution that has gained popularity over the last two decades: the exploitation of sensory biases (Ryan et al. 1990; Ryan and Rand 1993; Endler and Basolo 1998). The model assumes that adaptations of sensory systems to various tasks, such as foraging, escaping predators or finding mates, generate preference biases, and that sexual signals exploit these biases to increase the attractiveness of the signaller. Generally, low-level mechanisms of sensory systems are tuned to the dominant physico-chemical characteristics of that environment. In aquatic habitats, for example, lighting is highly variable, depending on water depth and bank vegetation. Different studies on fishes independently reported an adaptive tuning of photoreceptor sensitivities to the specific lighting environment of the studied species (e.g., Cummings and Partridge 2001; Bowmaker et al. 1994; Carleton 2009). Sexual signals can then adapt to the specific photoreceptor sensitivities to increase conspicuousness or distinctiveness (e.g., Cummings 2007). Some preference biases can originate from higher-level perceptual mechanisms than those of the sensory systems. Males in several species of Goodeinae fishes, for example, display a terminal yellow band on their tail, which attracts females by mimicking a worm on which these fishes feed (Garcia and Ramirez 2005). Here, the exploitation of a preferential bias requires at least configural perception for the female's brain to identify a worm, and possibly cognitive recognition. In order to account for preference-biases originating from high-level perceptual mechanisms, several authors have renamed the expression “sensory bias” as “perceptual bias” (Ryan and Cummings 2013; Schaefer and Ruxton 2009).

The exploitation of EP model of aesthetic evolution proposes that aesthetic stimuli exploit receiver’s innate attraction driven by EP. Painted portraits that are aesthetically valued owing to their spatial statistics mimicking those of natural scenes are like tail yellow bands exploiting female’s attraction to yellow worms in Goodeinae fishes. Crucially, the exploitation of EP simultaneously fits to models of sensory, perceptual and cognitive bias[5] since EP influences any stage in information processing, from perception to cognition. Because of this, EP-driven preferences can be highly diversified. The exploitation of EP model thus predicts a very dynamic “landscape” of aesthetic preferences, which is likely to vary among species, populations, individuals and also with time for a given individual. In return, such a dynamic landscape would promote diversification of signals (Arnold et al. 2001). In addition, the model predict a rugged landscape of aesthetical preferences: by combining different aspects of form, patterning, colouration, layout, symbolic meaning and contextual presentation, there are multiple ways a signal can be efficiently processed, and thus multiple opportunities to bypass any ecological, phylogenetic or physiological constraint to signal diversification. This is noteworthy because a recurring criticism to the model of sensory bias refers to its inability to explain the diversity of sexual signals. Richard O. Prum wrote “sensory bias seems to me unlikely to explain the bulk of secondary sexual trait and preference radiation in groups of closely related species” (Prum 2012). While this is likely correct for most sensory biases, the exploitation of EP model predicts the exact opposite pattern: an extreme diversification of both signals and preferences.

By essence, the exploitation of EP cannot be co-evolutionary. However, according to the EP theory of aesthetics, the positive aesthetic value of a stimulus can sprout from the co-evolution between this stimulus and its associated preference. Let’s consider a stimulus that coevolves with its preference following quality-indicator and Fisherian mechanisms. From a brain perceptive, this stimulus would trigger pleasure, which would activate desire, which may eventually drive the perceiver to interact with the stimulus. According to the exploitation of EP model, this pleasure and the associated preference initially have no aesthetic value. But the coevolutionary loop allows perception and cognition to adapt to efficiently process the stimulus. Because it is hedonically marked, EP would then add pleasure to pleasure, thereby reinforcing preference for the stimulus. Here, the added pleasure is aesthetical. But it is only if the stimulus further mimics the form, colour, pattern or any other characteristic of other important stimuli that have also shaped perception and cognition, that the stimulus will be exploitative and would become beautiful. The EP theory of aesthetics thus identifies the aesthetic preference as one component of the overall preference for a stimulus. The evolutionary model of

[5]In Ryan and Cummings (2013), perception encompasses cognitive mechanisms. I added the expression «cognitive bias» to follow the distinction between perception and cognition I made throughout the review, in accordance with the dominant view in empirical aesthetics.

exploitation of EP interacts with other models of stimulus evolution to increase further the relative contribution of aesthetics in preference.

The exploitation of EP extends previous suggestions that aesthetic preference is a by-product of evolution and development of sensory systems. Modelling the evolution of artificial neuronal networks, Arak and Enquist (1993) showed that preference for exaggerated stimuli could emerge from the mere adaptation of sensory systems to recognize signals, and the authors already qualified such by-product preference as aesthetical. In chickens, it was found that preference for symmetry arises early during development as a by-product of the improvement of pecking sensorimotor skills that occurs during active food manipulation (Clara et al. 2007). This result confirms predictions from another theoretical work by Enquist and Arak (1994) showing that symmetry preferences is a by-product of the need to recognize objects irrespective of their position and orientation in the visual field. The EP theory of aesthetics offers a functional explanation to these results and recasts them into a more general paradigm that also accounts for other universal and domain-independent preferences.

The model of exploitation of EP proposes a dynamic of aesthetic evolution that can uniquely explain most if not all of the often-observed correlations between exploitative stimuli and quality. It is usually assumed that preference biases pre-date preference for quality indicators (Kokko et al. 2003). In the case of the Goodeinae fishes, for example, the appearance of feeding responsiveness during evolution likely predated that of sexual responsiveness (Garcia and Ramirez 2005). Yet the observation that feeding responsiveness decreases in species with more elaborated yellow band tails suggests that the originally exploitative band tails subsequently evolved into honest signals (Garcia and Ramirez 2005). Such a transition between models is nevertheless permitted only if mechanisms underlying exploitative stimuli are functionally linked with mechanisms determining quality (e.g., an increase in saturation of the yellow band simultaneously increases resemblance with worms and indicates ability of males to find food-derived yellow carotenoids in their environment). Unfortunately, such functional links are often speculative and sometimes physiologically unsupported. By contrast, the exploitation of EP model does not require any functional link to explain correlations between stimuli and quality. In red-legged partridge (*Alectoris rufa*), for example, a higher fractal dimension of bib predicted better body condition and immune responsiveness (Pérez-Rodríguez et al. 2013). This result is puzzling if one thinks fractal dimension as an indicator of quality because there is no obvious functional link between the studied qualities and the mechanism regulating the spatial structuring of melanin deposition in feathers. However, it is easily explained by EP exploitation: high bib fractality would have evolved secondarily to increase female preference by exploiting the hedonic marking of fractal patterns, which is a by-product of the general adaptation of bird visual system to the spatial statistics of natural environments.

Pleasure, Desire and Disinterestedness

The EP theory of aesthetics and the evolutionary model of EP exploitation echo a prominent concept in philosophy of aesthetics: disinterestedness. Although it can be tracked down to the writings of many philosophers including Schopenhauer ("pure, will-less contemplation"), Croce or Bergson, the concept of disinterestedness culminated in Kant's aesthetics (Kant 1790/1987) to a point that the experience of feeling a pleasure free from any utilitarian strings usually refers to "Kantian" aesthetics. For those philosophers, then, aesthetics is linked to pleasure and not to any form of desire. It is an entirely hedonic experience. In colloquial parlance, the aesthetic experience could be described as "liking without wanting" (Chatterjee 2003).

The disinterestedness of aesthetics has been germane to many works and theories in experimental aesthetics (e.g., Palmer et al. 2013). In turn, the neurosciences gave scientific credit to the philosophical concept by revealing distinct neurophysiological bases to pleasure and to desire (Berridge et al. 2009). In mammals, pleasure engages an ensemble of brain regions collectively labelled the limbic system. Crucially, the neural circuitry of pleasure is the same for the different stimuli and sensory modalities: the view of good food, the taste of a thirst-quenching drink, the listening of a charming voice, or any other advertisement of potential benefits are all regulated by the same opioid and cannabinoid neurotransmitters in the limbic system (Chatterjee 2013). The limbic system is also the place that gives birth to desire. However, desire is mediated by a different chemistry: the dopamine system. Usually, pleasure motivates us to act through the effect of desire. Both affects are tightly linked and are thus shaped conjointly through evolution and development (Chatterjee 2013). Yet because they are regulated by different neurochemical mechanisms, in some cases they may activate disjointedly. Dopamine-activating drugs, like amphetamine, for example, amplify desire but not liking. In extreme cases, the disjunction may lead to addiction (Robinson and Berridge 2008). According to Chatterjee, amplification of pleasure without desire, that is, brain flooding with opioids and cannabinoids but not with dopamine is the neurophysiological mechanism underlying a true, disinterested aesthetic experience (Chatterjee 2013). It is thus a quest for pure pleasure that drives people to art exhibitions, motivates us singing alone in the shower, makes us doodling friezes on the corner of a sheet during boring meetings.

It is noteworthy that Darwin had already envisioned this link between pleasure and beauty: "… the sense of beauty in its simplest form—that is, the reception of a peculiar kind of pleasure from certain colours, forms […]" (Darwin 1859; p. 255). As emphasized by Michel Kreutzer, "taste" in the expression "taste for the beautiful", which is repeatedly used by Darwin to characterise the main motivation in mate choice, was referring back to a eighteenth century concept of beauty linked to immediacy and disinterestedness (Kreutzer and Aebischer 2015). Darwin's view of mate choice as a selection for beauty for the sake of pleasure in beauty was thus fully consistent with a modern mechanistic definition of aesthetics.

Crucially, the evidences supporting the core role of pleasure and the lack of utilitarian goal in human aesthetics have been recently found in animal brains too. Firstly, researches on the neurobiology of aesthetics are not restricted to humans: pioneering studies on the dissociation between pleasure and desire, for example, were conducted on rats (Berridge et al. 2009). Secondly, the underlying limbic neural mechanisms for generating affective reactions are similar in the brains of most mammals (Berridge and Kringelbach 2008), and the general architecture of the limbic system is relatively conserved among tetrapod, at least (Bruce and Neary 1995). The biological grounds to aesthetics described previously are thus likely common to mammals, birds, reptiles and amphibians. Last, a recent study with fruit flies *Drosophila melanogaster* showed that, in these organisms too, liking and wanting can be uncoupled and are controlled by different neural circuitries (Lin et al. 2014). From a biological perspective, there is therefore no good reason to expect the aesthetic experience to be unique to humans.

Efficient processing is only one of the many mechanisms in which liking can occur without wanting. Rolf Reber emphasized that, "although the fluency theory covers some interesting phenomena, it does not cover all kind of aesthetic experience" (Reber 2012). For example, solving conceptually challenging tasks, like understanding how a porcelain urinal (*Fountain,* Duchamp, 1917) has become one of the most important pieces in 20th-century art, can also generate pleasure in the form of aesthetic experience (Redies 2015). Aesthetic experience also accompanies solving of processing tasks early in the visual system, for example when the shape of an object in a noisy image suddenly appears (Topolinski et al. 2015). These two types of aesthetic experiences are not entirely explained by efficient processing: although pleasure is triggered precisely when information processing becomes fluent, here the ambiguous, challenging nature of the stimulus is also determining. I suggest that the exploitation of EP is one particular case of a more general mechanism of aesthetic evolution through exploitation of pleasure mediated by the dynamics of information processing. Nevertheless, because EP can be modelled or approximated (see paragraphs on image statistics) for a diversity of stimuli and animal species, in my eyes the exploitation of EP offers a highly promising and workable model for evolutionary aesthetics.

Conclusions

Few topics can take pride in transcending the traditional frontiers between disciplines from the humanities and the sciences as much as aesthetics. It is only recently, however, that cognitive sciences have realised how much they could gain in recognizing two millennia of thoughts about aesthetics in philosophy and the arts (Shimamura and Palmer 2012). Now that evolutionary biology is getting involved in the topic too, it is vital that the discipline builds on existing knowledge, both for its credibility and for the quality of its contribution.

In an attempt to broadly define the contours of aesthetics I first listed some necessary (but not sufficient) criteria that could characterize this concept: (1) the aesthetic experience is ubiquitous: it can be caused by a variety of stimuli, both biotic and abiotic, from different domains; (2) beautiful stimuli in a given domain are highly diversified; (3) they are also often extravagant; (4) yet it seems that individuals within and even across species share a common taste for the beautiful. I then reviewed three main models of aesthetic evolution, discussing how they could address these criteria. The most widely cited model of quality indicators could easily explain the ubiquity and the shared component of aesthetic experiences, as well as the extravagancy of some beautiful stimuli. However, it hardly explains the huge diversity of beautiful stimuli within a domain. Fisher's coevolutionary model of aesthetics can account for both the diversity and the excessive elaboration of beautiful stimuli. However, it is difficult to understand how this model alone could maintain shared aesthetic preferences. Moreover, Fisher's model being exclusively coevolutionary, it does not explain temporal changes in abiotic beautiful stimuli.

The third model I reviewed assumes that aesthetics is a by-product of adaptations to process and to be attracted by certain stimuli in the brain of the perceiver. Throughout their evolution, the perception and cognition of animals have evolved to efficiently process and to find beneficial stimuli pleasurable. Efficient processing and the associated pleasure are adaptations determining attraction or preference (in choice situation) that could evolve following quality indicator or Fisherian models. But being attracted by or preferring a stimulus does not signify we find this stimulus beautiful. Beauty arises if the stimulus exploits efficient processing and pleasure, if it taps into these adaptations to amplify their effect. The exploitative phenomenon occurs when stimuli have formal and contextual presentation and meaning that can simultaneously activate several of such adaptations. This model of exploitation of efficient processing, and more generally of processing-driven pleasure, can successfully explain the ubiquity and universality of aesthetic experiences, and the diversity and extravagancy of beautiful stimuli.

In evolutionary biology, aesthetics has been traditionally defined a posteriori from the putative mechanisms of its evolution. I fully acknowledge that definitions should emerge from results rather than merely stick to postulates. But it is an epistemological fallacy to try to understand the evolution of something that has been defined as the result of its evolution. It is like trying to understand how the wings of birds have evolved while defining wings as adaptations to flight. Surely this approach would strongly narrow the spectrum of possible mechanisms influencing wing evolution. Arguably a better approach would define wing from scientific results on empirical, proximate mechanisms making a avian wing what it is, for example its lift and the presence of feathers. Listing necessary but not sufficient criteria as I did in the introduction crudely followed this empiric approach to definition. And as we could see, it already permitted to highlight some limitations of major models of aesthetic evolution. The exploitation of EP model not only fits to the listed criteria; it is also soundly grounded into a bulk of empirical works on aesthetics. The model naturally emerged from results showing that beautiful stimuli are processed efficiently (the EP theory of aesthetics) and activate the pleasure circuitry independently of the desire circuitry. When applied to sexual selection, the exploitation of EP also recognizes that aesthetic preference is different from (and nested within) sexual preference. This difference is critical to understand evolution of aesthetics and its role in evolution of communication, but unfortunately it could not but be ignored by presupposedly defining aesthetics as an adaptation. Last, the EP exploitation model of aesthetic evolution has no ambition of durability. Empirical aesthetics has become a very active field of research, and it will be a necessity for evolutionary biologists to adapt and refine models of aesthetic evolution as knowledge in this field progresses.

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Philosophical Aesthetics and Neuroaesthetics: A Common Future?

Bruno Trentini

Abstract The future of the art/science relationship does not only concern the field of artistic creation, but also the field of aesthetic experience. In fact, whereas aesthetics has existed as a philosophical discipline since the 18th century, more and more scientific experimental works study aesthetic experience. Philosophical aesthetics now shares its object of study with what is often called neuroaesthetics. The aim of this chapter is to shape a common vision enabling philosophical aesthetics and neuroaesthetics to pool their results and their tools so that the research world does not suffer from a regrettable scission in the field of theory of artistic theory. Indeed, aesthetics seems to have a lot to gain from physiological studies dealing, on the one hand, with the capacity of cognitive processes to adapt to non-routine situations and, on the other hand, with the capacity of these adaptations to be felt by individuals.

It does not seem possible to isolate cognitive processes that are specific to aesthetic experiences. For instance, perception processes are very frequently involved in the experience of a work of art, and are systematically involved in the reception of an anamorphosis by Felice Varini or an immersive work by Ann Veronica Janssens. Premotor and motor processes seem necessary to mentally reconstruct the poietic gesture in front of a work by Jackson Pollock, or to interact with a work by Maurice Benayoun. The list could go on and on. It would besides be very surprising to find a kind of cognitive process that works of art cannot activate and it is easy to think about works of art that each mobilizes many kinds of cognitive processes. The understanding of each process in isolation is not yet sufficient to understand what aesthetic experience is.

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These observations highlight the fact that aesthetic experience is integrative, that is to say that it involves many levels of cognition, and that it cannot be reduced to an atomic behavior; in other words: it is complex. Regarding the issue of naturalization of aesthetics, this complexity can be interpreted in two different ways: either we consider that the aesthetician cannot dispense with the understanding of the cognitive processes involved in aesthetic experience, or we consider that any attempt at naturalization is detrimental to aesthetics, because the mere fact of trying to naturalize experiences that are so complex would inevitably lead to a harmful reduction of the field. Besides, regardless of whether naturalization is desirable or not, we can first wonder if this approach is even possible. Yet, if we define naturalization as a scientific approach aiming at finding observables that can give account for issues that were initially not related with physiology—that were not embodied—, the complexity of aesthetic experience makes it almost impossible to find relevant observables. This chapter notably aims at defining the observables which would be interesting to study in order to naturalize aesthetics. Of course, the choice of the observables and the choice of the concepts of philosophical aesthetics to be naturalized will impact the progression of the field: do we aim at naturalizing an aesthetic category like the beautiful or the sublime, or at naturalizing the specificity of any aesthetic experience? Of course, various possibilities exist and the mere fact of making a choice will necessarily tend to freeze and narrow the field down. However, in order to undertake the most relevant naturalization, it would be better if the naturalization of aesthetic experience did not shift the key issues of the field. As a consequence, the question of knowing if naturalization is desirable and the question of knowing if it is possible can be dealt with together. We should besides not forget that aesthetics was at the origin anchored in a physiological and even a psychophysical framework, and that contemporary aesthetics has developed from this framework of scientific naturalism. If the question of naturalization is now once again taking center stage, it is above all as a result of the emergence of cognitive science, which have modified the way we comprehend the relationship between human beings and their environment. Cognitive science notably enable us to think about sensitivity and intelligibility in another way, to think about the relationships between these two notions, and even to think without using these labels that arbitrarily create a distinction where maybe none is required. One main difficulty of the aesthetician indeed lies in the articulation of sensation and knowledge, perception and intellection.

Since naturalist investigations are de facto being carried out, the most important point to tackle the issue of the naturalization of aesthetics seems to be to figure out which naturalization is possible for the aesthetics that we wish. Thus, this chapter is intended both for the supporters of naturalization and for its firmest opponents, both for philosophers and for scientists. If choosing a specific label for the aesthetics proposed in this chapter was required, embodied aesthetics would best fit. Embodied aesthetics is the extension of embodied cognition, a philosophical trend proposed by Francisco Varela notably following the reading of the phenomenology of Merleau-Ponty: sensations, perceptions but also body and physiology are thus thought to be the main actors of aesthetic experience.

The first part of this article provides a presentation of the main experimental and epistemological pitfalls encountered in neuroaesthetical studies on the beautiful and pleasure. Not only is the study of the beautiful cut off from a considerable part of the artistic reality—which could be a conjectural and accidental problem—but it also presents difficulties that are not encountered in the study of the other aesthetic category defined in the 18th century, the sublime. The second part of this article puts emphasis on the sublime, showing that even though very few neuroaestheticians have worked on it until now, its naturalization is far more advanced. One of the best advantages of the sublime is that it involves cognitive processes that are quite well understood or at least much studied. We will finally discuss the resulting question of knowing whether it would be better to naturalize aesthetics or to encourage philosophical aestheticians to seize naturalized studies which do not necessarily deal with aesthetics.

Naturalization of the Experience of the Beautiful: Methodological and Epistemological Pitfalls

Even if the first studies carried out by Plato and Aristotle about artistic creation did not tackle the question of art by focusing on the beautiful but by focusing on imitation, the beautiful has prevailed as an artistic value, to such an extent that Hegel defined aesthetics as the science of fine art. If the beautiful has become the category which is the most (widely) studied by neuroaestheticians, this is of course because it is the most common and classical label. But this may also be because it seems easy to justify this aesthetic approach with respect to the Neo-Darwinist theories. For example, sexual attraction can be thought to be the substrate on which the beautiful has developed. Surprising as it may seem, this hypothesis was more or less already formulated in *The Symposium* by Plato, was put forward two millennia later by Nietzsche (Nietzsche 1889), and is nowadays defended by some researchers (Grammer et al. 2003). In other studies, a link between aesthetic experience and the prey/predator relationship is proposed (Smith 2005). These studies bet on a behavior that has increased the fitness of the individual. This hypothesis is deemed questionable since it explains aesthetic behavior only by the pleasure that is generated, without any consideration about the processes that generate this pleasure: according to Denis Dutton, this idea is as simplistic as thinking that a pleasure pill would be equivalent to aesthetic experience (Dutton 2009).

It is yet important not to confuse, on the one hand, the rooting of aesthetic behavior in the theory of evolution with, on the other hand, the naturalization of aesthetics, which consists in defining relevant observables. While the first is for the moment purely speculative, the second is an approach giving rise to practical experiments, which we can precisely discuss. There seems to be an epistemological problem which is inherent to the works dealing with the beautiful in art. This problem comes from the term “the beautiful” itself, which suffers from a strong socio-cultural bias. However, while he was aware of the subjectivity of the judgment of taste, the father of neuroaesthetics, Semir Zeki, chose to work on the beautiful. He is in that way consistent with a major philosophical tradition, since his more precise goal is to manage to naturalize the free play of faculties, which Kant supposed to be the major characteristic of the beautiful

(Kant 1790). Naturalization thus consists in finding an invariant that would systematically come into play when individuals feel a pleasure generated by an object that they find beautiful, and which would not or almost not hardly occur otherwise, in order to be able to *observe* the free play of faculties. Zeki searched for this invariant in cerebral activity, in a given cerebral area. In that sense, he assumed the existence of a "module"[1] of the beautiful. We will not discuss this hypothesis, but we will discuss some experiments aiming at testing it, more precisely the experiments described in the paper of Ishizu and Zeki (2011). It is worth noting that when Zeki and Ishizu studied individuals who are confronted with a work of art, they took care not to impose to the subjects an object that they, the experimenters, would found beautiful. They indeed asked the subjects to evaluate the beauty of the objects that were submitted on a scale from 1 to 9, in order to correct the bias due to differences in taste. Afterwards, Ishizu and Zeki tried to identify the specificity of the cerebral activity of the individuals while they were apprehending the objects that they, the subjects, had themselves judged as beautiful.

We cannot deny the fact that it is necessary in the design of the experiment to ask the individuals which objects they consider as beautiful, in order to take into account the taste of each of them. Nevertheless, this caution relies on a problematic introspection. Indeed, the beautiful that Zeki aimed at subjectively describing is very precise: the will of characterizing the neural bases of the experience of the beautiful presupposes the distinction between the beautiful and other positive categories like the agreeable or the sublime. Yet, the problem is that it is not wise to consider that the subjects who are studied by this neuroaesthetics are able to distinguish between these different positive aesthetic categories: many people use the term "beautiful" to characterize a rough ocean under a threatening sky, whereas they must activate cognitive processes that are very different from the ones they activate when they look at a "beautiful" bunch of tulips. This problem remains unaddressed by neuroaesthetics. The design of the experiments which focus on the beautiful does not usually take into account the different aesthetic categories (Cela-Conde et al. 2004, 2013; Zeki 1999)—and it will probably remain difficult to take these categories into account with non-expert subjects. It would thus be preferable to carry out experiments aiming at the naturalization of aesthetics without using a socio-cultural label as complicated as "beautiful". Unfortunately, asking for an introspection about aesthetic categories which are less used—and which are thus not mastered by everyone—would equally distort the results. The same criticism applies to the studies in which individuals are asked to classify works of art according to their aesthetic preferences (Vartanian and Goel 2004); the adjective "aesthetic" has had, in the everyday language, in English as well as in French, a meaning which is very different from the philosophical and neuroscientifical meaning which is supposed to be studied in these works. Thus, not only should not art be reduced to the beautiful, but another pitfall should also be avoided: aesthetic experience should not be reduced to pleasure. Even if we accept that all every aesthetic experience gives rise to pleasure, a major stake is to understand the

[1]This hypothesis is inspired by Jerry Fodor's research on the modularity of mind.

specificity of the pleasure of aesthetic experience. Once again, focusing on the category of the beautiful proves to be problematic: it wrongly suggests that, as soon as an aesthetic experience is unpleasant at any level, it cannot bring satisfaction. Some studies thus limit aesthetics to the beautiful, to the neutral and to the ugly (de Tommaso et al. 2008), or to an opposition between positive and negative values (Munar et al. 2012; Kreplin and Fairclough 2013; Lang et al. 1993). A considerable experimental bias seems to occur here to the extent that these approaches go against many behaviors performed in front of works of art which exploit an attraction/repulsion relationship, as in the case of the category of the sublime.

The Sublime Enables a Less Problematic Naturalization

Maybe by default, or perhaps because we have the means to do so—in a nutshell, a priori without any objective reason—pleasure and the beautiful have been studied. They are important in aesthetic experience, but all pleasure is not aesthetic. It is important not to confuse the beautiful, aesthetics and art: when it comes to building a neuroaesthetics that aims at becoming a theory of art, one of the main risks is to study the beautiful as if it were a synonymous for art. Only by opening up the cognitive investigations to aesthetic values other than the beautiful can we maintain the crucial interdisciplinary dialog between neuroscientists and both classical and contemporary philosophers of art.

The works of naturalization that focus on the beautiful run the risk of shifting the principle of the field, or even of diluting it in researches that cannot give account for the diversity of aesthetic experiences. It is not possible to study a single pleasure at a hormonal, neuronal or even behavioral level, since the complexity and the integrativity of aesthetic experience makes it possible for the spectator to be satisfied with a work that is, at a physiological level, *unpleasant*. This case is the one which is described by Burke, Kant, Hegel or Schiller in their works on the sublime. The sublime implies unpleasure, fear (or representation of fear), but comes to pleasure. Reductionist naturalist researchers would tell us that it is neither possible to enjoy the sublime, nor the vertigo, nor the imbalance felt at the top of the Tower of Pisa: indeed, their studies would highlight the fact that individuals wince, that beads of sweats form on their foreheads, that they physiologically feel emotions that fall into the category of negative emotions.[2] However, despite all this, some would be satisfied. Let there be no mistake, we do not intend to say that such empirical studies would refute introspection; on the contrary we intend to say that they would lead to propose a theory that would be refuted by the studied system itself, that is to say the set of aesthetic experiences. Thus, trying to naturalize the approbation of the spectator who is confronted with a work of art not only is not a question of aesthetics anymore, but gives also rise to the risk of grafting an over-simplified

[2]This criticism can also more generally apply to studies that try to describe aesthetic experience as an ability which would be selected *for itself* by evolution.

determinism onto an experience which involves too many parameters to be modeled by a reductionist approach.

Anjan Chatterjee hypothesized that the lack of interest of research toward the sublime can be explained by the limited data available about the cognitive processes that are involved in the behavior linked with the sublime. He mentioned the metaphor of a person who would search for his dropped coin under the light of a street-lamp because it would be the only place which would be lit, even if he would not have lost it at that place (Chatterjee 2010). Indeed, the sublime is not studied enough in neuroscience, but this metaphor does not seem to bring a satisfactory explanation. In fact, even if the label "the sublime" is poorly used is neuroscience, the experiences linked with the sublime do involve many processes that are widely studied. The processes involved in the aesthetic experience of the sublime, for instance postural imbalance or vertigo, are indeed abundantly studied—because postural imbalance is also associated with many pathological behaviors. There could be an interplay between the study of pathological imbalance in a routine context and the study of the imbalance of a healthy individual in an artistic context: artistic objects indeed imply a considerable particularity in the relationship between individuals and their environment. Imbalance at the levels of posture and of the vestibular system would constitute a relevant observable to naturalize the sublime. What is more, the specificity of the sublime lies in the satisfaction that is taken in an unpleasant situation: fear, which is generally classified as a negative emotion (Ekman 1992), becomes a source of pleasure. Regarding this subject, we can also find an abundant literature about emotions, mainly about negative emotions like fear. It is also quite easy to rationalize fear in light of the theory of evolution: it acts as an alarm to draw the attention of the individual to a danger he or she should avoid. In other words, the aesthetic experiences that can be described as sublime already benefit from real scientific investigations in the field of cognitive science and in the trend of naturalization.

It would be a mistake to believe that neuroaesthetics focuses on the beautiful because the means that are available to study aesthetic experience would not enable to study another aesthetic category. There have besides been some works in cognitive aesthetics dealing with the sublime in general and the situation of imbalance in particular (Noë 2001). These studies have given rise to few experiments, simply because the works of art that were used were large sculptures, which made the practical implementation of the experiments challenging.[3] Yet, many bidimensional works can have an impact on the postural equilibrium of the spectator and could constitute a promising paradigmatic case study. *Contemplation irrationnelle*, a work created in 2003 by Philippe Ramette, is in that sense particularly interesting. In this photograph, we can see a person who is apparently sitting at the edge of a quite impressive precipice. We can quickly realize that this photograph is actually a quite commonplace view that has been rotated one quarter-turn, so that the great

[3]We notably think about *Clara-Clara* by Richard Serra, which is an example that Alva Noë took. Since it is a monumental sculpture, any study should only be done in situ.

skyline irremediably becomes an abyss. The road that is winding between small hills becomes a path that is almost vertical. However, the awareness that the landscape has been rotated is not sufficient to suppress the illusion of the precipice because the person that we see seems to be sitting in the correct orientation: his thighs appear horizontal, his back vertical. It would be interesting to study to what extent the perception of this photograph by an individual that would be in front of it, preferentially standing up, stimulates his or her vestibular system and (her) posture. Some studies dealing with the contagion of vertigo suggest that the fact of watching another person who is in a situation of imbalance can lead to a modification of one's own balance. We could thus speculate that imbalance could arise from perceptual processes which, under the influence of visual discordances linked with verticality, do not provide conscience with a steady perception, but with a perception that frequently oscillates between a photograph that would or would not have been rotated. Aesthetic experience thus seems stimulated by various elements, notably the tendency for empathy, vertigo—both caused by real risks or by the illusion of risks—, or the possibility of bistable perception. It could without doubt be possible to list more elements, and it could then be even more difficult to know which one would be specific to the aesthetic experience which is at stake, if we suppose that this question even has a meaning. Therefore, it may be more interesting for aesthetics to study the cognitive processes involved in aesthetic experiences without trying to give account for the particularity of one aesthetic category or another.

Upstream and Downstream Aesthetic Categories

It does not seem possible to naturalize aesthetics, but it is interesting to naturalize the routine cognitive processes that are involved, in a non-routine manner, in aesthetic experiences. If only for the comparison between the beautiful and the sublime, we realize that studying the specificity of one will not enable to understand that of the other: the beautiful and the sublime are very different as far as the cognitive processes and the link with the theory of evolution we could draw are respectively concerned. Indeed, the beautiful is often considered as a derivation of an acquired behavior, but it is harder to explain the pleasure that the individual takes in a context that stimulates a state of alarm from a physiological point of view. As we have highlighted from the introduction of this chapter, aesthetic experiences involve numerous cognitive processes. Since it does appear that one of them is not more particular than another, we could hypothesize that aesthetic experience emerges from a common way of using cognitive processes. Regarding this hypothesis, we can detect a constant in the philosophical history of aesthetics: aesthetic experience is induced by a sensitive awareness of our own cognitive processes even though our attention focus on the outside world. This statement is a contemporary and generalized rephrasing of the idea that the awareness through the sensitivity of the free play of faculties is a reflective judgment that Kant supposed to be at the basis of the beautiful (Kant 1790).[4] This hypothesis is in keeping with the integrative idea that aesthetic experience involves a split attention (focused on oneself and on the world), or involves a self-reference to one's own mental processes (Vessel et al. 2012, 2013). We adopt such a characterization of aesthetic experience as a general working hypothesis because it gives account for the possibility that aesthetic experience can involve numerous cognitive processes: aesthetic experience is a sensation induced by the way cognitive processes, whatever they may be, adapt as successfully as they can to non-routine and highly cultural situations. Thus, the most convincing way of trying to naturalize upstream aesthetic categories like the beautiful and the sublime is to find the observables that indicate the adaptability of cognitive processes, i.e. the reconfiguration of perception. Naturalizing reflective judgment would be a better way to *observe* aesthetic experience. Nevertheless, the question of knowing whether this knowledge will help the aesthetician to give a better account of artistic experiences remains open: naturalizing reflective judgment is a response to a speculative will of understanding aesthetics in its most abstract issue (Trentini 2014). On the contrary, in order to build an aesthetics that is able to give account of artistic experience downstream aesthetic categories, it would be more interesting to understand the steps leading to reflective judgment rather than reflective judgment itself. To translate the words of the introduction of *Naturaliser l'esthétique* written by Jacques Morizot: "the challenge we have to take up is to understand how routine mechanisms are able to generate a non-routine vision" (Morizot 2014).[5] It could be tempting to hypothesize that the understanding of these routine mechanisms would not bring anything new to the understanding of aesthetics, but aesthetic experience can only emerge from breaking out routine. Because the experience is non-routine, cognitive processes must adapt to a new configuration; because they must adapt in a non-routine way, a particular feeling emerges from their adaptation. In that sense, a complete rupture with the evolutionist theories is not desirable: we have to understand how cognitive processes have adapted to the environment at the scale of evolution and how they can adapt at the scale of the individual—by being flexible or plastic—, but we should not globally consider aesthetic experience as a selected or a counter-selected ability. We should consider aesthetic experience as involving abilities that are acquired both through culture and by evolution.

[4]Semir Zeki seized the concept of the free play of the faculties to make it the cornerstone of his naturalization at the neural level; it seems to us that his modularist approach—as defined by Fodor—cannot enable to understand aesthetic experience. In fact, the cognitive fluence that he studied is specific to the beauty. We thus loose the specificity of reflective judgment to only keep fluence. Not only this study cannot enable to establish a philosophy of art, but it also fails to pave the way for a generalization of the beauty on the other aesthetic experiences.

[5]"Le défi à relever est de comprendre comment des mécanismes de routine sont en mesure d'engendrer une vision qui ne l'est pas".

Conclusion

If we were to put forward a particular skill of the aesthetician—and probably of the art critic as well—we could mention the ability of making a singular experience communicable, and as a consequence the ability of conducting a good introspection, that is to say the ability of correctly grasping what is going on in their bodies, at the level of their organs, of their senses, and the ability of linking as accurately as possible these sensations to the multiple thoughts that went through their minds. This undertaking is of course not infallible, and we can suppose that the more relevant the introspection, the easier the communicability. Since we are dealing with introspection, I allow myself to speak in my name, about a personal aesthetic experience.

I discovered the works by Marcius Galan at the *White Cube*, gallery in London, in the summer of 2013, and I once again saw one of these works in the exhibition *Inside* at the *Palais de Tokyo* in Paris in the winter of 2014. Despite my research between these two moments, for instance about the way in which perception can generate the illusion of a surface where there is none, about the interpretation of the variation of colors that the presence of a glass plate would have caused, I felt an intense experience on both occasions. In other words, even if I was aware of the cognitive processes that were involved to create the illusion, the illusion still persisted. Thus, I do not think that the naturalization of aesthetics can weaken aesthetic experience—nor can it dictate aesthetic experience, since the understanding of the processes do not necessarily make a work pleasant to someone who did not like it in the first place. However, by putting forward the coupling between perception and action, I can make the wish of going through the intangible surface communicable and this is precisely what I did at the *Palais de Tokyo*: I waited for people to enter the room and I threw myself into the virtual window. Against all odds, I did not feel at ease. It may seem ridiculous, but my body was put into a state of alert: I was presumably *afraid* of hitting the glass plate. My cognitive processes apparently reacted as if the glass plate had been true. I thought that this moment was particularly interesting, and particularly promising as regards the theory of embodied aesthetics.

Sometimes, in front of a work of art, I have the intuition that one thing or another has occurred in me and that my perception has adapted in one way or another, for one reason or another. If convincing experiments that clearly refute my hypothesis have been carried out, I do not want to trust my introspection to use it to comment on the work. If on the contrary experiments of naturalization go in the same direction as my introspection, I feel comforted in my view. In other words, naturalization of cognitive processes, even apart from aesthetic experience, represent clear benchmarks in my research, which help to hold back a misleading introspection or to clarify a relevant but too confused introspection. Thus, knowing that experiments have shown that most people feel unbalanced while watching a funambulist nourishes my research on Philippe Ramette. Knowing that experiments dealing with disown (Guterstam and Ehrsson 2012)—which is the feeling of not belonging to one's own body—were put forward nourishes my research on the works by Ann Veronica Jannsens. The list could go on and on, yet, further research would still be required in order to obtain relevant data to carry out a work of embodied aesthetics dealing for example with conceptual art. I am nevertheless perfectly prone to believe that such data can be obtained.

These few elements having been established, aesthetics seems to have a lot to gain from physiological studies dealing, on the one hand, with the capacity of cognitive processes to adapt and, on the other hand, with the capacity of these adaptations to be felt by individuals. It is to our mind at these two levels that naturalization can prove to be beneficial to aesthetics.

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