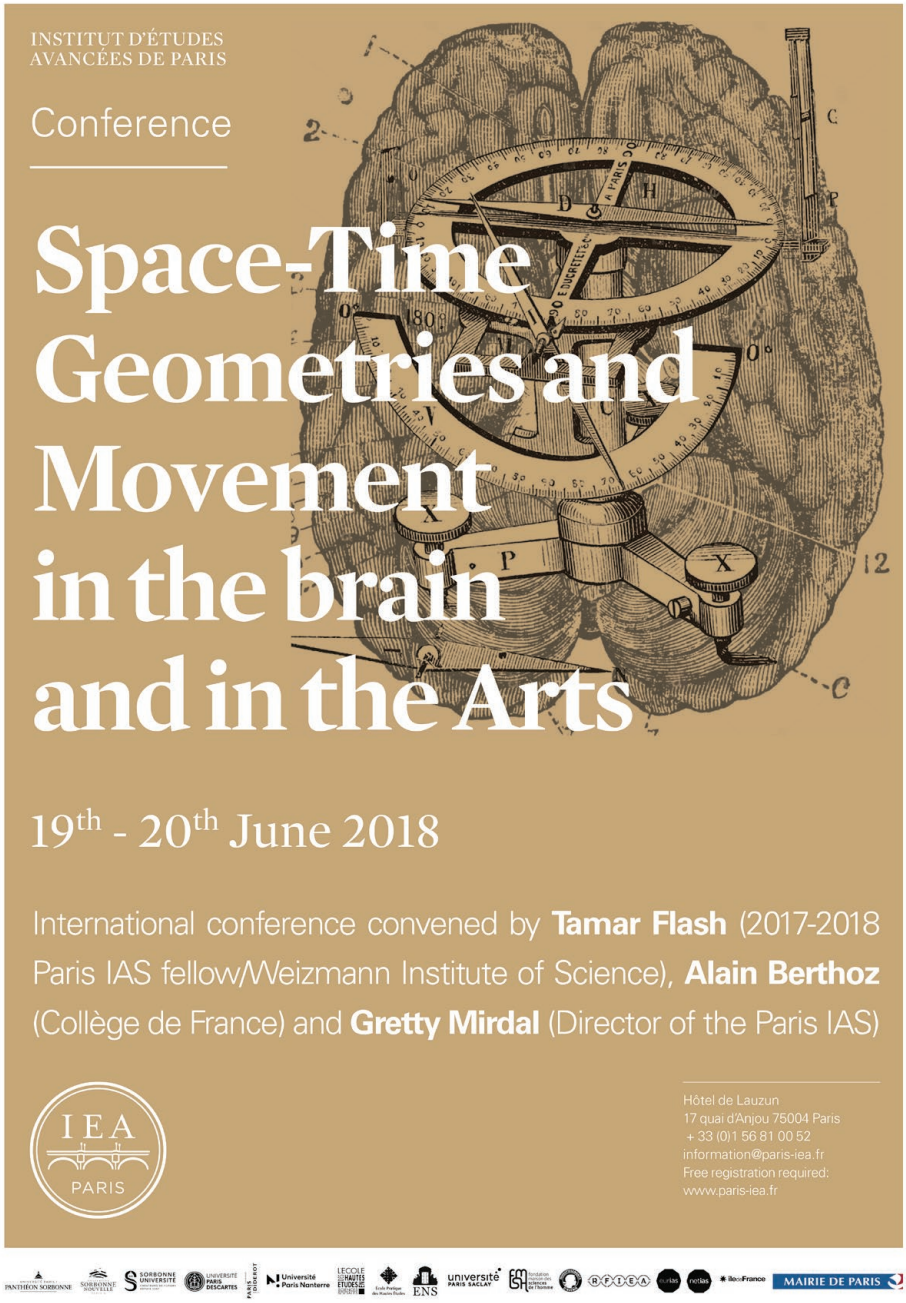

Presentation

Space and time are of fundamental importance to understand human perception, action, memory and cognition. Movement, which describes the changes in the locations of physical objects and human bodies with the passage of time, is equally important in physics, biology, neuroscience, psychology, as well as the arts. Our bodies and minds shape the way we perceive space and time and the scientific theories we formulate about physical laws. Hence the importance of understanding how the brain perceives and represents space, time and movement, and how it plans and controls our bodily movement and actions.

Our interest in the use of movement, space and time in different artistic fields - fine and digital arts, performance arts and music - is mainly inspired by the notion that knowledge about the general organizing principles and simplifying strategies used by the brain in perception action and memory, in movement generation and representation, and in action-perception coupling, can lead to new insights regarding the ways artists make use of movement, space and time in their artistic creations and how humans are affected and perceive works of art (aesthetic experiences).

IEA PARIS

Hôtel de Lauzun
17 quai d'Anjou 75004 Paris
+ 33 (0)1 56 81 00 52
information@paris-iea.fr

Program

Tuesday 19 June

Introduction

9.00 - 9.05 Introduction and welcome
Gretty Mirdal, Director of the Paris Institute for Advanced Study

9.00 - 9.05 Scientific presentation
Tamar Flash, 2017-2018 Paris IAS fellow / Weizmann Institute of Science and **Alain Berthoz**, Collège de France

Perception and Memory

9.15 - 9.45 *Variety of brains geometries for action/ perception*
Daniel Bennequin, Université Paris Diderot

9.45 - 10.15 *Neurogeometry and perception*
Giovanna Citti, Università de Bologna, and **Alessandro Sarti**, CNRS – EHESS

10.15 - 10.45 *Perceiving and modelling performers' movements qualities*
Frederic Bevilacqua, IRCAM - Centre Pompidou

10.45 - 11.10 Break

11.10 - 12.00 *TBA*
John O'Keefe, University College London, Nobel Prize of Medicine and Physiology 2016

12.00 - 12.30 *Dimensionality reduction in touch*
Vincent Hayward, Sorbonne Université

12.30 - 13.00 *The multiplicity and coherence of brain reference frames, geometries and cognitive strategies for movement*
Alain Berhoz, Collège de France

13.00 - 14.00 Lunch Break

Perception and Memory

14.00 - 14.30 *The role of Neural Circuitry in Skilled Drawings*
Emilio Bizzi, Massachusetts Institute of Technology

14.30 - 15.00 *Traces of life*
Thierry Pozzo, Université de Bourgogne

15.00 - 15.30 *Brain space-time representations and action-perception coupling in movement and the arts*
Tamar Flash, 2017-2018 Paris IAS fellow / Weizmann Institute of Science

15.30 - 16.00 *On what moves us*
Beatrice de Gelder, Maastricht University / University College London

16.00 - 16.20 Break

Music

16.20 - 16.50 *Cortical Dynamics while Following Musical Meters*
Moshe Abeles, The Hebrew University and Bar-Ilan University

16.50 - 17.20 *The EEG dynamics signature of flow sensation during movement in music*
Guy Cheron, Université Libre de Bruxelles

17.20 - 17.50 *Space and timing in musical expression: lessons from conducting*
Eitan Globerson, The Jerusalem Academy of Music and Dance

17.50 - 18.30 *Interaction, Cooperation and Entrainment in Music: Experience and Perspectives*
Luciano Fadiga, Università degli Studi di Ferrara and **Sera Tokay**

Program

Wednesday 20 June

Drawing and Painting

9.10 - 9.40 *Motor coordination, cerebellar predictions, and cognitive processing*

Chris Miall, University of Birmingham

9.40 - 10.10 *The epistemological role of drawing*

Renaud Chabrier, Author, draughtsman and film director, Institut Curie, PSL

10.10 - 10.40 *Measuring and understanding the geometry of pictorial shape*

Johan Wagemans, KU Leuven

10.40 - 11.10 *Geometry in artistic knowledge and the understanding of fundamental visual processes*

Robert Pepperell, Cardiff Metropolitan University

11.10 - 11.30 Break

Performing Arts

11.30 - 12.00 *Individual and collective movement dynamics in performing dance*

Guido Orgs, Goldsmiths, University of London

12.00 - 12.30 *The Score of the Dance. Virtual and Actual Spatiality*

Einav Katan-Schmid, Humboldt Universität zu Berlin

12.30 - 13.00 *Automated analysis and interactive sonification of expressive qualities of movement and non-verbal social interaction: a case study on dance*

Antonio Camurri, Università degli Studi di Genova

13.00 - 14.30 Lunch Break

Digital Arts

14.30 - 15.00 *New artistic practices in digital space: an art of movement in space-time geometries?*

François Garnier, ENSAD

15.00 - 15.30 *Dance notation and robot motion: geometries?*

Jean-Paul Laumond, LAAS-CNRS

15.30 - 16.00 *Spectator and virtual actor movement interactions. From child gestures to interactive digital creation*

Marie-Hélène Tramus and **Dominique Boutet**, Université Paris 8 Saint-Denis

16.00 - 16.45 General Discussion

Beatrice de Gelder, Maastricht University / University College London

16.45 Concluding Remarks

Tamar Flash, **Alain Berthoz** and **Gretty Mirdal**

Abstracts

Variety of brains geometries for action/perception

Daniel Bennequin, Université Paris Diderot

As said by Rodolfo Llinas (cf. I of the vortex), animals brains appeared in evolution for controlling movements of displacement in space, and brains are "geometric machines". This last assertion concerns the manners the elements, regions and dynamics of the brains are organized, but also the manners external world is internalized and transformed for successful actions in the world, interlaced with perceptions. As Alain Berthoz suggested, several geometrical spaces and modules are necessary for managing several kinds of actions (cf. Le sens du mouvement, and Movements Geometries), for instance grasping, standing, walking, navigating, imagining. The main reason underlying this variety of geometries is adaptation. In this talk we will show that many levels of geometrical spaces invented by mathematicians, from Euclidian figures to Topos theory, going through affine and projective transformations, may organize different (interacting) systems of the brain. The presentation will be mainly based on works made in collaboration with Tamar Flash and Alain Berthoz, and many other researchers, on movement timing, action/perception control, eye movements, visuo-vestibular information, pre-conscious folds and consciousness.

Neurogeometry and perception

Giovanna Citti, Università de Bologna, and **Alessandro Sarti**, CNRS – EHESS

In this talk we present a joint work where we show how perceptual phenomena are related to neurogeometry, that is the intrinsic geometry of neural connectivity. The talk will be organized in two parts, showing two different aspects: 1) Functional geometry and perceptual completion (G. Citti).
In the first part we describe different families of cells in terms of Lie groups, focusing on the action of the cortical connectivity, responsible for local aspects of perception as for example perceptual completion. 2) Emergence of perceptual units (A. Sarti). In the second part we will see how the neuromathematical approach together with instruments of spectral analysis can explain the constitution of perceptual units, as well as geometrical illusions and hallucinations.

Perceiving and modelling performers' movements qualities

Frederic Bevilacqua, IRCAM - Centre Pompidou

While the concept of «movement qualities» (i.e. how the movement is performed) is widely used in dance, the modelling of such concepts remains difficult. Moreover, the perception of movement qualities has been only partially studied.
I will present some possible approaches in modelling such movement qualities, and argue that movement qualities could be seen as specific properties of space-time trajectories.

Dimensionality reduction in touch

Vincent Hayward, Sorbonne Université

The dimensionality of the raw physics in touch is enormous and mechanical interactions are very messy. We will comment on how our somatosensory system could to sort out this mess to arrive at a high degree of constancy.

The multiplicity and coherence of brain reference frames, geometries and cognitive strategies for movement

Alain Berhoz, Collège de France

I will propose that Evolution has selected a remarkable variety of simplex modular brain mechanisms for movement and perception in space. I will briefly review: a) The multiple reference frames and cognitive strategies used for perception and action (retinotopic, co-variant, contravariant, force fields, egocentric, allocentric , heterocentric, geocentric etc.). They require transformations (See for example A. Pellionicz and R. Llinas pioneering work on the cerebellum as a geometrical transformer, and recent work on colliculus, retrosplenial cortex, parahippocampus); b) Lateralization between left and right brain, including hippocampus , as well as gender differences. c) The five different geometries used by the brain for coding body space, prehension space, near distant locomotor space, distant environment and navigation space . The

reason for having different geometries is that they are different action spaces requiring different properties. As proposed by Henri Poincaré and documented by the work of Jan Koenderink, Tamar Flash and Daniel Bennequin, they are Euclidian and non Euclidian geometries allowing in particular a close relation between time and space and, for example, providing general principles for executing the same movement in different spaces . d) The brain networks involve a viewpoint or a perspective change which appear progressively during child development as they have evolved during phylogeny ; d) The capacity of inhibiting non relevant reference frames or geometrical strategies;
The great challenge is still to understand how a general unity and coherence can be obtained. It is therefore not surprising that so many pathologies include deficits in the relation with space and spatial memory. My hypothesis is that artists play with this marvelous, rich, repertoire of neural modules , use or express them (For instance Eshkoll dance notation using body-wise , environment-wise and partner-wise reference frames; depth segmentation and simultaneous perspective in painting, etc.). Artists by destroying the unity and coherence of all these modules may also be free from standard heurisitics and invent new vicariant creative expressions.

The role of Neural Circuitry in Skilled Drawings

Emilio Bizzi, Massachusetts Institute of Technology

For centuries, artists have sought to create works that give viewers pleasure, an experience that summons emotions or activates the senses. The production of drawings rests upon a number of neural circuits that are organized hierarchically with feedback loops at every level of central nervous system. I will describe the neurological mechanisms underlying the formation of spatio-temporal patterns of motor activity involved in drawing and briefly touch upon the formation of motor memories that result from the intense practice that is often the daily investment of novice to skilled artists.

Traces of life

Thierry Pozzo, Université de Bourgogne

In this talk I will try to uncover the link between Art and Science of movement starting from the idea that the visual perception/reception of biological motion traces is under strong motor constraints.

Brain space-time representations and action-perception coupling in movement and the arts

Tamar Flash, 2017-2018 Paris IAS fellow / Weizmann Institute of Science

Many motor behavioral studies were aimed at inquiring what general principles underlie movement generation during multi-joint movements. Careful analysis of the observed behavior has led to the formulation of several of kinematic laws of motion describing the invariant geometric, kinematic and timing patterns of upper limb and full body movements. To account for the origin of the formulated kinematic laws of motion and the observed geometrical and temporal invariants, several theoretical approaches were developed. These included optimization theory and geometrical approaches, both types of theories aiming at accounting for the tight coupling between spatial and temporal features of natural movements. Similar coupling also characterizes visual and proprioceptive motion perception, thus suggesting strong action-perception coupling and the existence of particular neural representations and brain networks which encode space, time and movement by combining both Euclidean and non-Euclidean geometries. The hypothesized organization has also important implications with respect to motor compositionality and the notion that complex motor behaviors are constructed by composing together simpler elementary building blocks while obeying particular syntactic and sequencing rules.

On what moves us

Beatrice de Gelder, Maastricht University / University College London

In daily life perception is inherently multimodal and engages the sensory systems spread out over the whole body. Similarly a viewers' responses to art are multisensory, it is not just the case that the visual brain responds to visual images and the auditory brain to auditory ones. The notion that the body plays a role in perception of art works has a long history in the writings of artists. Yet making sense of this fundamental intuition has so far mostly eluded neuroscientists including researchers on emotion. In this talk we will review some recent views on the role of the body in artistic experience and discuss some examples from visual art perception and from dance studies.

Cortical Dynamics while Following Musical Meters

Moshe Abeles, The Hebrew University and Bar-Ilan University

Brain activity was measured while subjects tapped with their fingers to drum beats structured as 2/4 or ¾ meter. The meter was flipped at random time points and the subjects were asked to adapt to the new meter every time it changed. We reconstructed the amplitude of the cortical current dipoles (CCDA) at ~550 points over the cortex and cerebellum. In the CCDAs we detected times at which a miniature evoked activity (mEA) was evident. The sequences of such mEA tend to repeat with high time precision of 1 to 5 ms. Within such repeating sequences we could identify sequences that are specific to routine tapping and to the process of readapting to a new meter.

This ability opens a whole new aspect of association between brain processes and cognitive activities.

The EEG dynamics signature of flow sensation during movement in music

Guy Cheron, Université Libre de Bruxelles

The term "flow" describes the optimal experiences (to be in the zone) that are most enjoyable in human life while fully engaging in an activity. Within artistic behaviours, the flow emerges from an action that requires specific skills and challenges. It also expands self-esteem and the individual's capabilities through learning new optimizations that increase the feelings of continuity and fluidity in attention and action. Because of the conjunction of action skill, challenge and emotion in a single flow-state, the scientific community remains confronted with the complex question of identifying its neurophysiological outcomes. In this context, the question of the space-time geometries and the relation between oscillatory brain and movement remains largely debated. In this communication my intent is to trace experimental perspectives applying tools of movement neuroscience and motor control concepts in order to characterize the physiological aspects of the brain state during flow in violin musical performance.

Space and timing in musical expression: lessons from conducting

Eitan Globerson, The Jerusalem Academy of Music and Dance

The art of conducting involves a highly structured collection of movements, which are employed in order to convey musical ideas. While the right hand of the conductor, holding the baton, delivers an analysis of the beat, the left hand compliments this information by adding more abstract, emotional musical content. Both analytical and emotional content in the art of conducting are conveyed through the usage of time and space, representing the different acoustic attributes of sound. This transformation from time and space to musical interpretation will be discussed in detail, employing many musical examples.

Interaction, Cooperation and Entrainment in Music: Experience and Perspectives

Luciano Fadiga, Università degli Studi di Ferrara and **Sera Tokay**

Cooperation is not only crucial for achieving obvious material goals such as, in the animal world, to migrate together, to get a prey or to escape from a predator. Human beings also often cooperate - in a creative and non-stereotyped way - for aesthetic reasons to produce artworks, such as in ensemble music or dance. A fundamental component of these processes, crucially requiring coordination, is entrainment. Entrainment in music performance is not the mere synchronicity among individuals. Entrainment is an active process of interpersonal tuning aiming at converging in a "place" where a synergy is built-up by a continuous process of interaction. During entraining, the feedback received by individual performers is the product of the whole ensemble.

Our presentation will be subdivided into two parts. The first part will deal with empirical evidence of interpersonal entrainment with particular regard to the phenomenon of interaction/communication in music ensembles. A group of music players form an ecological environment where sensorimotor communication is devoid of any symbolic encoding. The way by which a conductor expresses leadership does not rely on a set of codified gestures, it is the results of a continuous tuning between her gestures/expressions and the result coming from the integration of the actions of her "limbs" (the players). The results of some experiments will be presented together with new hypotheses about possible future approaches to the effect exerted by music on listeners audiences.

In the second part, some thoughts about orchestra conduction will be exposed by a musician, conductor, and also philosopher. From her perspective, artistic practice is not limited to the technical performance, but is subject to a constant self-reflection directed towards its very essence. The conductor's communication with the orchestra is essentially non-verbal and unfolds in a special space whose dimensions are: empathy (rather motor than emotional), anticipation of musical tempo and sensorimotor interaction between conductor's gestures and instrumental movements of the musicians. The perfect equilibrium of these ingredients is at the basis of excellent performances in music.

Motor coordination, cerebellar predictions, and cognitive processing

Chris Miall, University of Birmingham

Drawing and painting require complex spatial transformations from visual representation to motor actions. We have explored how eye-hand coordination contributes, and also explored how the format and complexity of the images being drawn can modulate eye-hand coordination and brain activation. I will extrapolate from our data to discuss some recent attempts to measure the brain responses that might underly coordination and cognitive functions, and aim to discuss what might be the metrics of cognitive learning.

The epistemological role of drawing

Renaud Chabrier, Author, draughtsman and film director, Institut Curie, PSL

Since cave art, drawing is one of the most ancient human tools for expressing geometries and movement of living bodies, especially after a time of memorization and consolidation.
The processes underlying sketching activity remain largely unknown, but neuroscientific discoveries from the last decades indicate that "places", "grids", "waves" or "textures" may play a crucial role.
In this presentation, I will show how animation techniques such as morphing can help us reappreciate the practice of hand drawing in history and today, both as a source of information about the space-time geometries in our brains, and as a powerful tool for epistemology.

Measuring and understanding the geometry of pictorial shape

Johan Wagemans, KU Leuven

Pictorial shape is the shape we perceive in a picture. When we look at a drawing, photograph, or painting, we spontaneously organize the line segments, pixels, or pigments into surfaces and objects with a particular spatial organization. This is remarkable because the construction of a 3D spatial layout appears instantaneously and effortlessly in spite of its geometric impossibility (due to the fundamental problem of underdetermination). The geometric attributes of this spatial organization can be measured experimentally when observers are given particular tasks (e.g., adjusting a gauge figure to fit the local surface orientation). Pictorial shape turns out to share some common characteristics but it also reveals idiosyncratic properties. I will illustrate how we can try to understand the geometry of pictorial shape with two lines of experimental research: one with Picasso's line drawings of nude female figures and one with a photograph of a sculpture of a reclining female nude.

Geometry in artistic knowledge and the understanding of fundamental visual processes

Robert Pepperell, Cardiff Metropolitan University

In this talk I will summarise a large body of research undertaken with colleagues that crosses the fields of art practice and history, philosophy, vision science, neurobiology, and computer graphics technology. It concerns the nature of vision, how artists have represented vision, and how artistic knowledge can inform scientific understanding of fundamental visual processes. The research suggests that artists have consistently employed a unique non-linear geometry to describe visual space, and that this geometry can be defined, mathematically modelled, and computationally engineered to create 'dynamic images' that respond to human activity.

Individual and collective movement dynamics in performing dance

Guido Orgs, Goldsmiths, University of London

Movement is a common feature of all performing arts, including dance, theatre and music. In this talk I will present a range of studies on how movement speed, acceleration and synchrony among performers bias visual perception and predict affective responses to dance. The dynamics of individual human movement produce distinct biases in the subjective experience of time, effort and speed. In the lab, we used sequences of static body postures to study how the brain reconstructs movement dynamics from sequential static input. Using fMRI, we show that motor areas of the brain are involved in the reconstruction of perceived movement speed from static sequences of body postures. Smooth and predictable transitions between these postures are preferred to jerky transitions. In the theatre, we studied social and affective effects of performing and perceiving movement synchrony. Participants performed a set of movement tasks that were either performed as a group or individually. During execution (dancers) and observation (spectators) of these tasks, we assessed movement synchrony based on performer acceleration and spectators' psychophysiological responses using wrist sensors. Synchrony among performers was associated with group affiliation among performers and predicted spectators' heart rate and enjoyment. In a follow-up fMRI study, we used inter-subject correlations (ISCs) to link movement synchrony among performers to brain synchronization among spectators. Comparing expert and novice spectators, ISCs revealed greater synchronization in professional dancers than in novices in visual and motor areas of the brain whilst watching dance. In line with an evolutionary function of dance in group communication, individual and collective movement dynamics in dance convey social signals that are extracted by dedicated brain mechanism and predict spectator affect.

The Score of the Dance. Virtual and Actual Spatiality

Einav Katan-Schmid, Humboldt Universität zu Berlin

The presentation will deal with motility and spatiality in dancing, and with the role of time-space geometry within. Following the case studies of Forsythe's «Improvisation Technologies», «Gaga» - Ohad Naharin's movement research, the annotation project of «Motion Bank», and «Playing with Virtual Realities» - a recent research project of dancing in VR, which I directed, the presentation will explore the score of the dance as a mental-physical enactment of motility. My discussion on spatiality in dance derives from arguments and discoveries in phenomenologies of perception and enactive approaches in philosophy, as well as from the felt experience of dancing.

Automated analysis and interactive sonification of expressive qualities of movement and non-verbal social interaction: a case study on dance

Antonio Camurri, Università degli Studi di Genova

The European Horizon 2020 ICT project DANCE (dance.dibris.unige.it) focuses on two main research challenges: (i) the understanding and the automated analysis of the participation to the emotion conveyed by a sequence of movements in space, the understanding of the non-verbal language of bodies that communicate, and (ii) imagining and questioning concrete ways to "listen to a choreography", "feel a ballet", that is, to develop computational models of interactive sonification of the measured movement qualities: How affective and relational qualities of body movement can be expressed, represented, and analyzed by sound. This project aims to open new perspectives for scientific and technological research, for artistic research, and for novel human-centric media and applications.

New artistic practices in digital space: an art of movement in space-time geometries?

François Garnier, ENSAD

With digital spaces, artists get a new medium allowing them to create visual arts in time and the 3 dimensions of the space. This new dimensionality profoundly transforms their artistic practices, in terms of design, production and diffusion. Through case studies we will try to understand how digital artists manipulate, often empirically, the concept of space-time geometries and how their creations could constitute bases of experimental paradigms to understand human perception, action, memory and cognition.

Dance notation and robot motion: geometries?

Jean-Paul Laumond, LAAS-CNRS

Roboticists aim at segmenting robot actions into a sequence of motion primitives in order to simplify the robot programming phase. Choreographers aim at capturing the essence of human body movements within a sequence of symbols that can be understood by dancers. To that extent, roboticists and choregraphers pursue the same quest. This talk reports a pluridisciplinary approach combining a dance notation system (the Kinetography Laban) with a robot programming system (the Stack of Task). Motion scores are used instead of quantitative data to compare and enlighten differences in robot and human movements. The origins of these gaps come from the difference between the geometrical perspectives of both the choreographer and the roboticist to represent the body in the space.?

Spectator and virtual actor movement interactions. From child gestures to interactive digital creation

Marie-Hélène Tramus and **Dominique Boutet**, Université Paris 8 Saint-Denis

As part of the CIGALE project (Capture and Interaction with Artistic, Linguistic and Expressive Gestures) a multi-agent interaction platform has been developed, which triggers different gestural behaviors of a virtual actor who has the capacity for perception-action, within the framework of a kinematic analysis of a human interactor's movement. We will explain how our artistic modalities deal with space, time and movement in a particular way to achieve our specific artistic goal: make emerge a gestural interaction between human and virtual actor thus giving the feeling of a «living» improvisation and head towards an aesthetics of improvisation.

Our research is fundamentally interdisciplinary, intersecting digital interactive art (relationship with a virtual actor in an artistic situation) and linguistics (gesture study and its expressivity). It leads us to confront the approach of computer modeling of interaction gesture by a finite state machine (FSM) which uses, among other things, a kinematic model of motion analysis (digital art) with the study of the spectator's gesture and the virtual actor's gesture through the analysis of the rotations of their arms' joints (gesture study in linguistics) and through an aesthetic analysis.

If, according to Alain Berthoz, "What makes the human being original is precisely his ability to avoid the determinism that confines him in a reality intrinsically linked to his needs and sensory tools, through the remarkable ability of his brain to implement the vicarious processes he is provided with, in order to escape reality or his reality", could it be that these interactive artistic installations with virtual actor are expressions of vicariance?