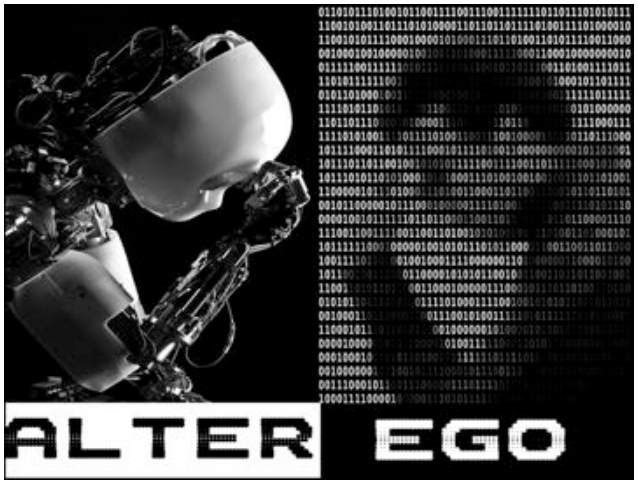
The SMART summer school, Paris, October 7 2016

The embodiment of mental health in human - robot interactions



Benoît G. Bardy

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Embodiment: The third revolution in (artificial and natural) cognitive sciences and movement sciences in the 21st century

▪ Perception-Action /Affordances	(Gibson, 1977; Warren, 2006)
▪ Active psychophysics	(Flach, 1990: Rasmussen, 1990)
▪ Enaction	(Varela et al., 1993)
▪ Sensori-Motor Contingencies	(O'Regan & Noe, 2001)
▪ Embodied Perception	(Profitt, 2006)
▪ Embodied Cognition	(Wilson, 2002)
▪ Embodied Psychiatry	AlterEgo project
▪ Embodied Music Cognition	(Leman, 2007; Dalla-Bella et al., 2007)
▪ Embodied Language	(Tomasello, 2008; Everett, 2012)
▪ Embodied Health	(Varoqui et al., 2010)
▪ Timing and time perception	(Torre et al., 2011)
▪ Mirror Neurons / Motor Resonance	(Rizzolatti et al., 1992, 1996, 1998)
▪ Theory of Mind	Multiple
▪ Motor Imagery	(Decety, 1996)
▪ Comput. /Dynamic. Motor Control	(Wolpert, 1997; Kelso, 1992)
▪ Embodied robotics	(Brooks, 1991; Pfeifer, 2001, 2007)

What is interpersonal motor coordination?

- Motor coordination between two (or more) people

- Bodily movements = hand gestures, postures, facial expressions, synchronization and so on (Schmidt & Richardson, 2008)

- Unavoidable (Issartel et al., 2007; Schmidt & O'Brien, 1997)

- Acting in synchrony with others increase cooperation by strengthening affiliation (Wiltermuth & Heath, 2009)

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Deficits in social motor coordination

Schizophrenia is characterized by:
- Attentional deficits
- Social withdrawal (avoid social situations)
- Apathy (lack of motivation)

- Co-verbal communication deficits (Del-Monte, et al., 2013):
  - Less co-verbal gestures
  - Less smile

- Synchronization deficits (Varlet et al., 2012)
  - Less stable in synchronization
  - Never lead the synchronization (always behind)

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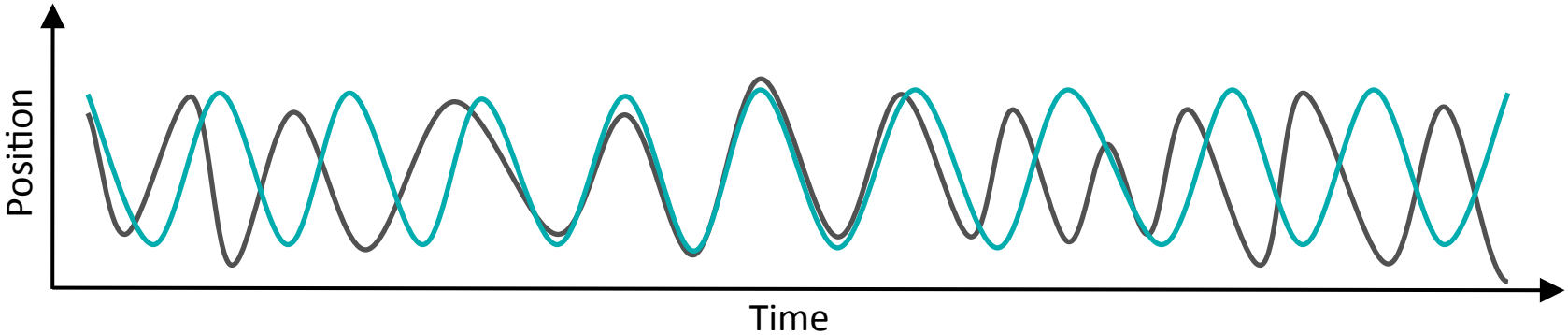
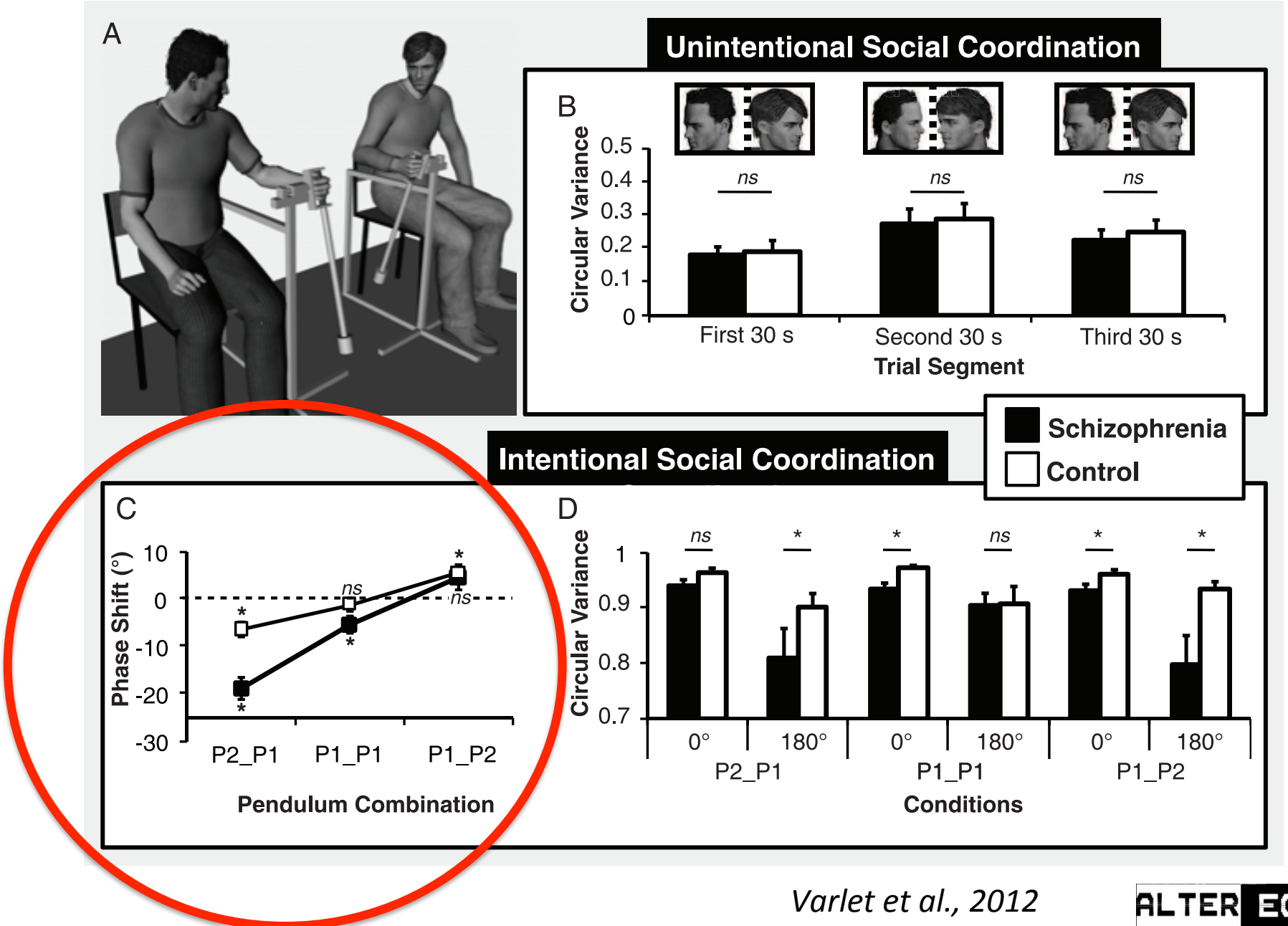
Cognitive deficits in perception-action cycles
(*Mental disorders embodied in socio-motor coordination*)





Varlet et al., 2012

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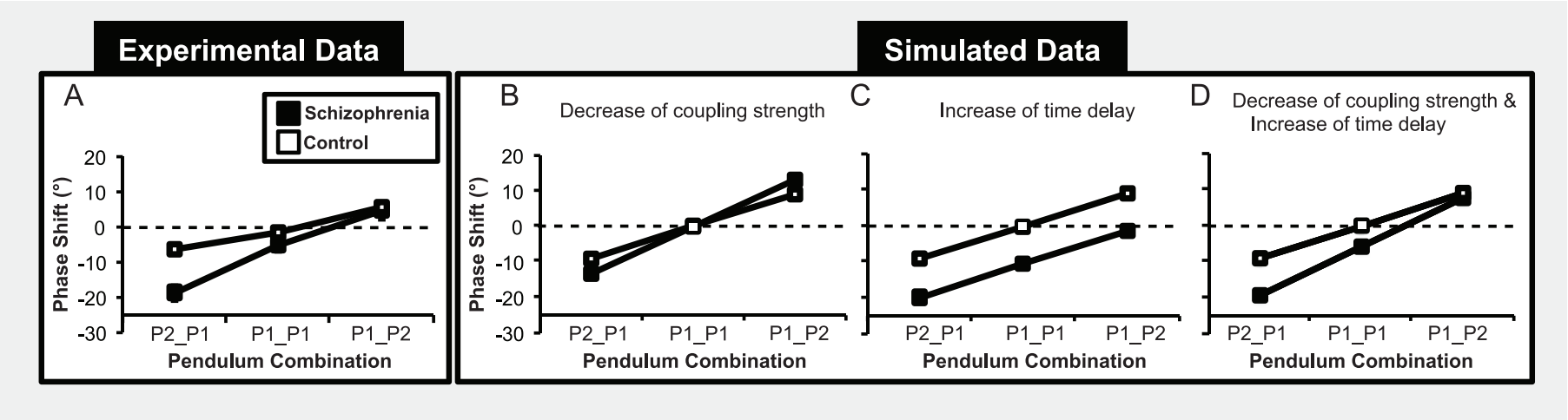
Simulation: A coupled oscillator model

Limit cycle dynamics | *Coupling function*

$$\ddot{x}_1 + \delta\dot{x}_1 + \lambda\dot{x}_1^3 + \gamma x_1^2\dot{x}_1 + \omega^2 x_1 = K_1\left(\dot{x}_1 - \dot{x}_{2\tau_1}\right)\left[a + b(x_1 - x_{2\tau_1})^2\right]$$

$$\ddot{x}_2 + \delta\dot{x}_2 + \lambda\dot{x}_2^3 + \gamma x_2^2\dot{x}_2 + \omega^2 x_2 = K_2\left(\dot{x}_2 - \dot{x}_{1\tau_2}\right)\left[a + b(x_2 - x_{1\tau_2})^2\right]$$



Movement signatures of schizoprenia (embodiment)

Varlet et al., 2012

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Therapies

Although clinicians have developed several interventions and training sessions for these patients, paradoxically, these interventions are never not focused on social motor interaction

All therapies are only focused on cognitive and emotional aspects, movement (almost) never observed

Our approach:

Enhance socio motor competences in schizophrenia

We propose a (new) concept that comes from various branches of sciences:

The concept of similarity

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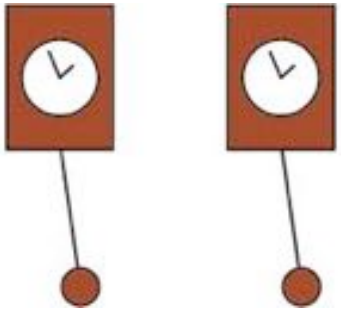
Similarity and Synchronization

- **In physics**
  -> two systems possessing the same frequency tend to synchronize better (Huygens, 1666)



- **In physiology**
  -> two biological systems possessing the same intrinsic properties tend to synchronize (von Holst, 1939, Bardy et al., 2015)

- **In motor control**
  -> two individuals coordinate better when they exchange more similar information (Schmidt & Richardson, 2008)

- **In social psychology**

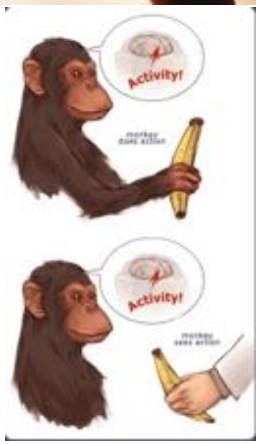
  -> people tend to like more someone that reproduces the same behavioral components (such as mimicry) as their owns (Chameleon effect; Chartrand & Bargh, 1999)

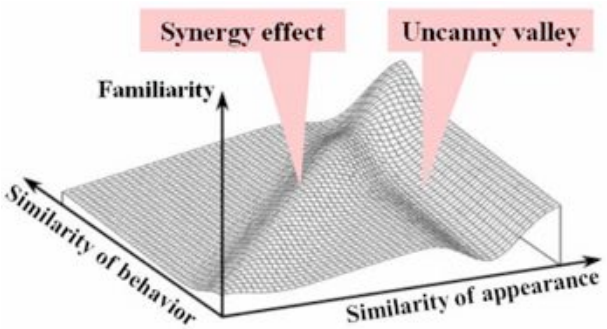
  - **In social neuroscience**

    -> Motor Resonance (Gallese, 2003) Mirror Neurons (Rizzolatti et al., 1996) – Motor theories of perception – ToM etc.

- **In social robotics**

  -> Uncanny valley (e.g., Ishiguro, 2005) and Learning by demonstration (e.g., Billard et al., 2008)

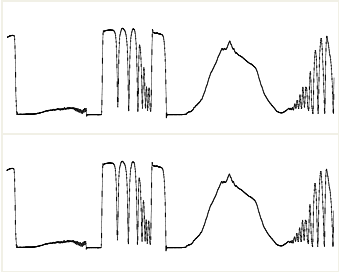




If similar systems are more synchronized, why not when a patient interact with someone like him/her?

Different levels of similarity

- Kinematics



- Morphology

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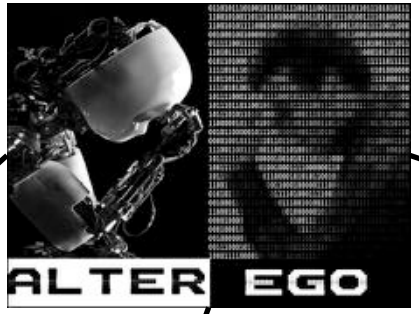
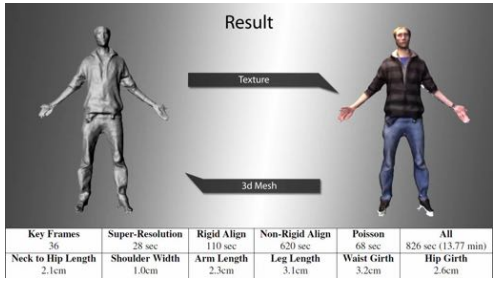
From Similarity…

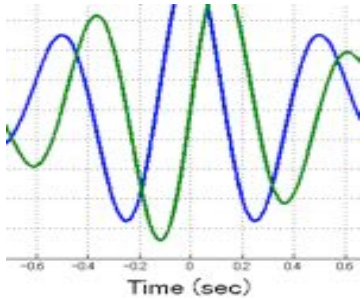


Morphological



Behavioural

Temporal



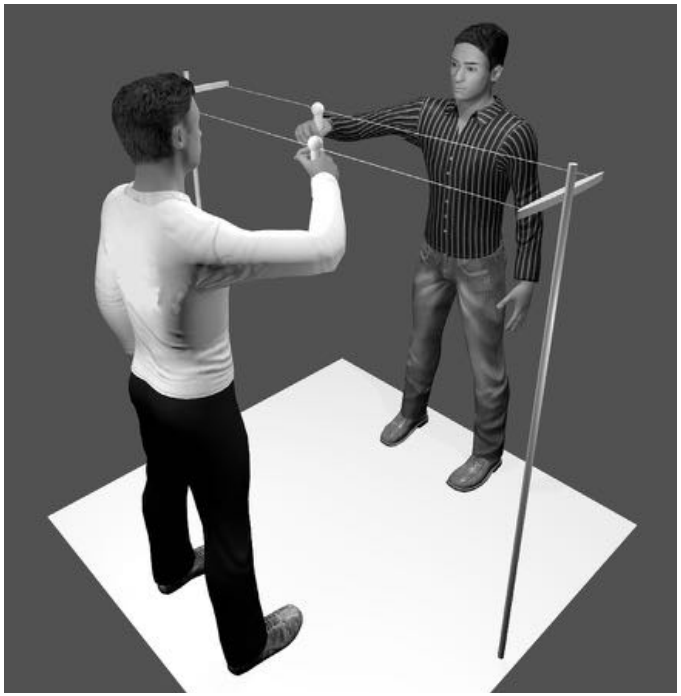
- ❑ Similarity triggers social interaction
- ❑ A bridge toward interacting with others

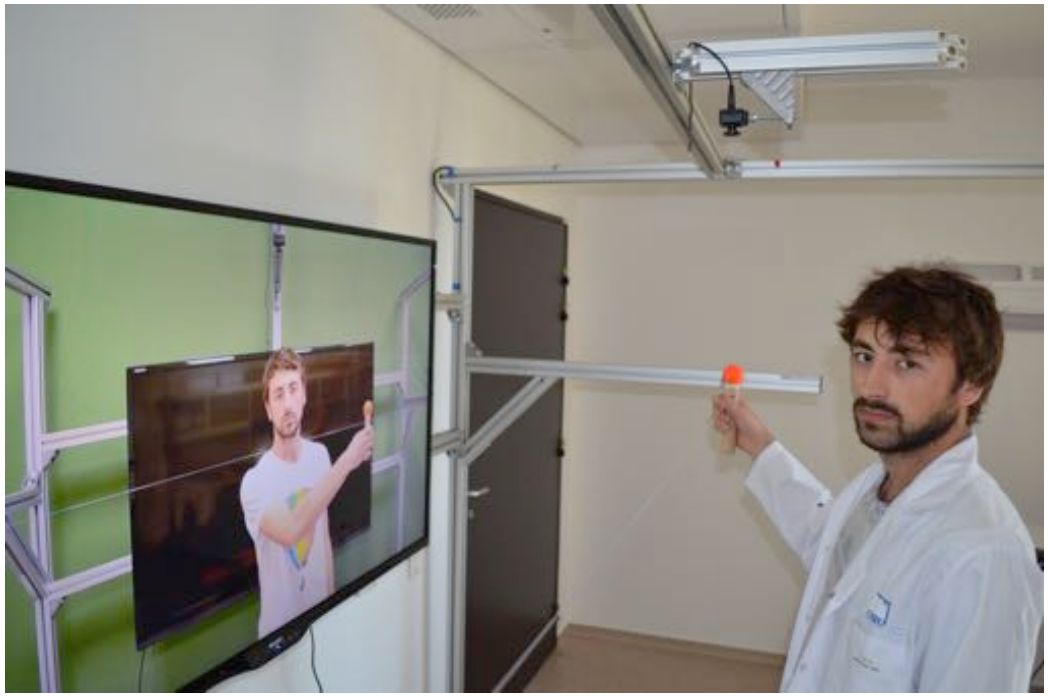
To Difference !

How to build an experiment to test the theory ?

Method

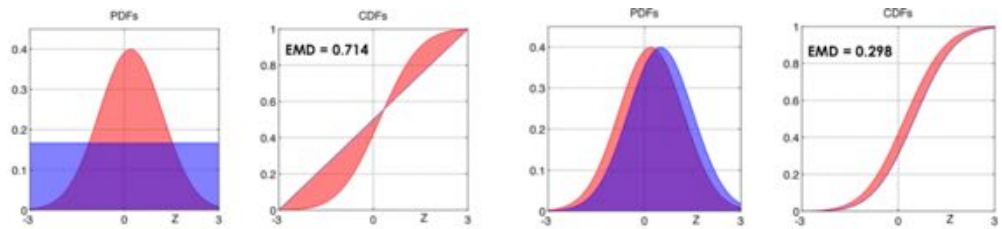
- 1 group of patients suffering from schizophrenia
- 1 group of controls (matched in terms of age, level of education, gender, etc.)
- The mirror game task (e.g. Noy et al., 2011)
- **Manipulate similarity (morphology)**





- **Manipulate similarity (kinematics)**
- Individual Motor Signature (IMS, Slowinski et al., 2016)

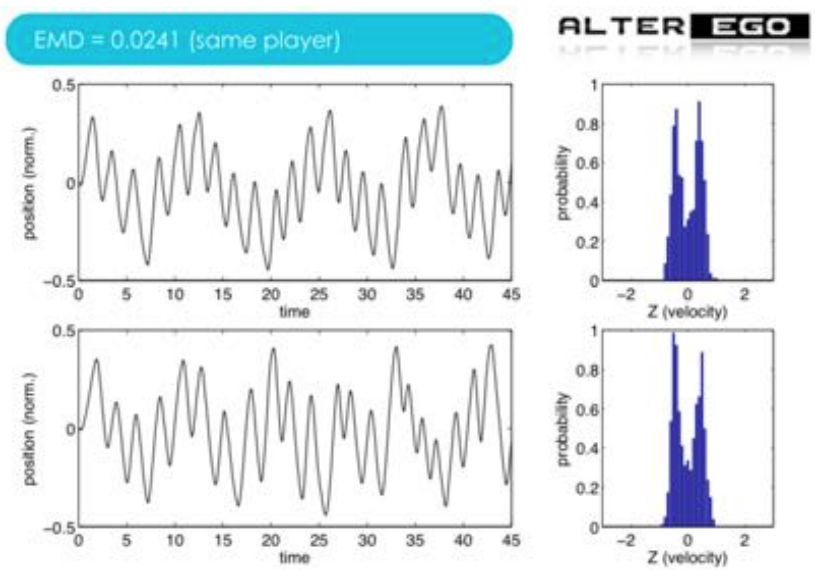
PDF : Probability Density Functions of players' velocity
EMD : Earth Mover's Distance

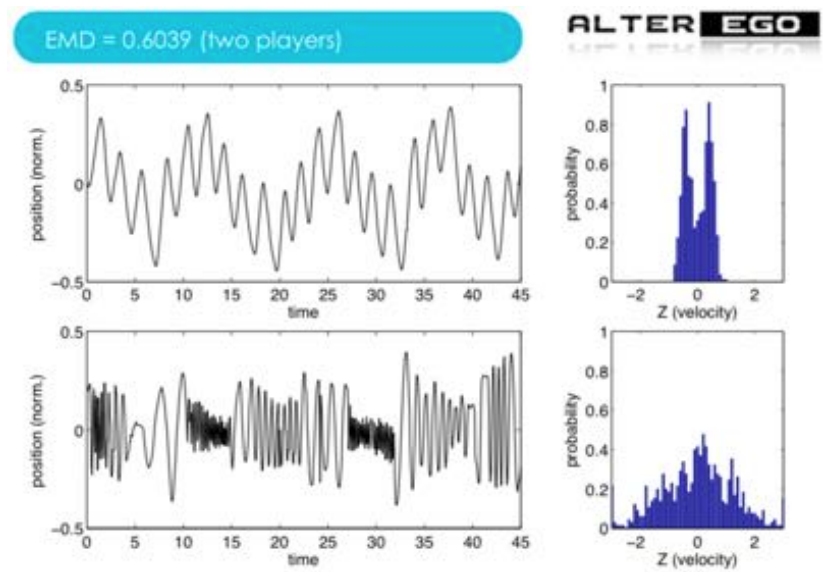


$$EMD(p_1, p_2) = \int_Z |CDF_{p1}(z) - CDF_{p2}(z)| dz$$

- Solution of optimal transportation problem
- Has a closed form for PDFs in 1D

- EMD represents a metric on the set of PDFs:
  - Positive definiteness, $d(P_1,P_1)=0$, $d(P_1,P_2)>0$ if $P_1 \neq P_2$
  - Symmetry, $d(P_1,P_2)=d(P_2,P_1)$
  - Triangle inequality, $d(P_1,P_2) \leq d(P_1,P_3)+d(P_2,P_3)$





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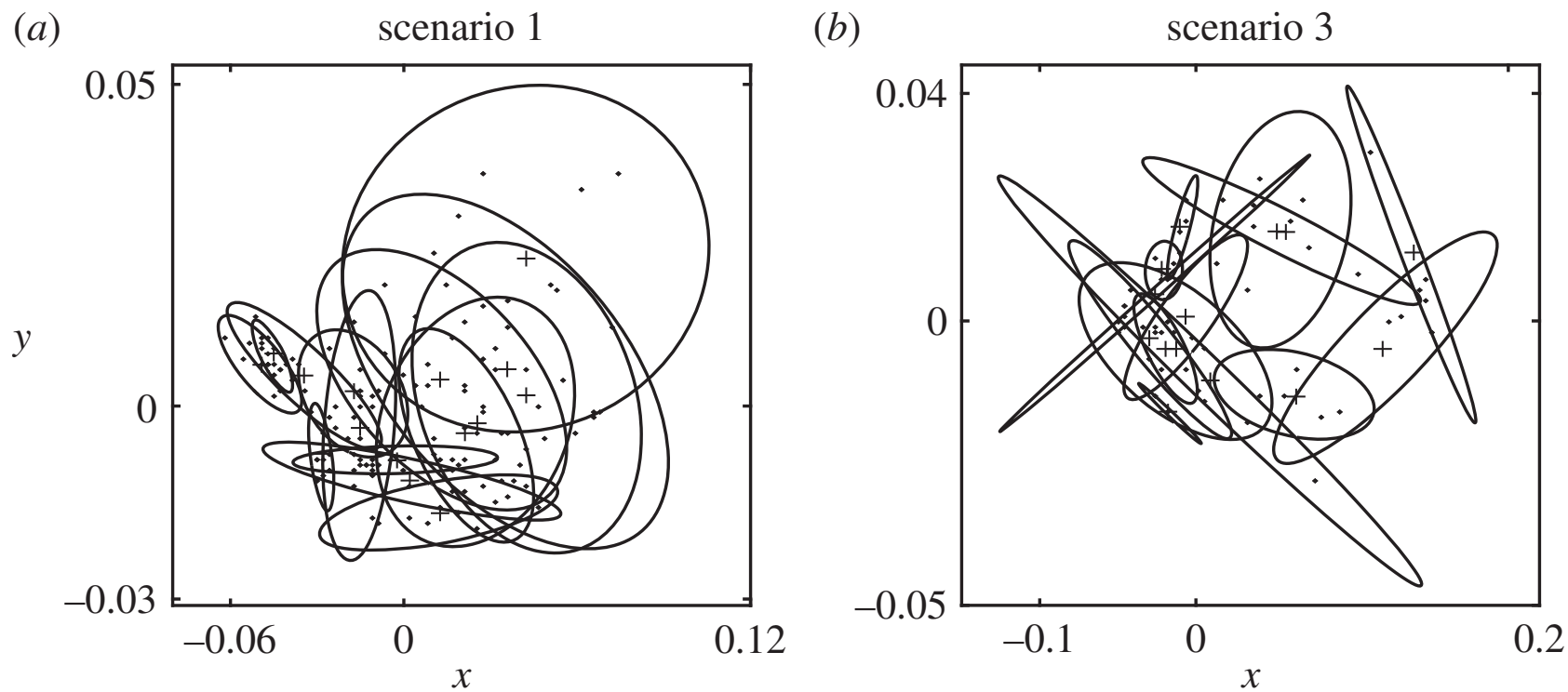
Individual Motor Signature (IMS) and the similarity space



Slowinski et al., 2016

x: First dimension of MDS (average velocity)
y: Second dimension of MDS (kurtosis)

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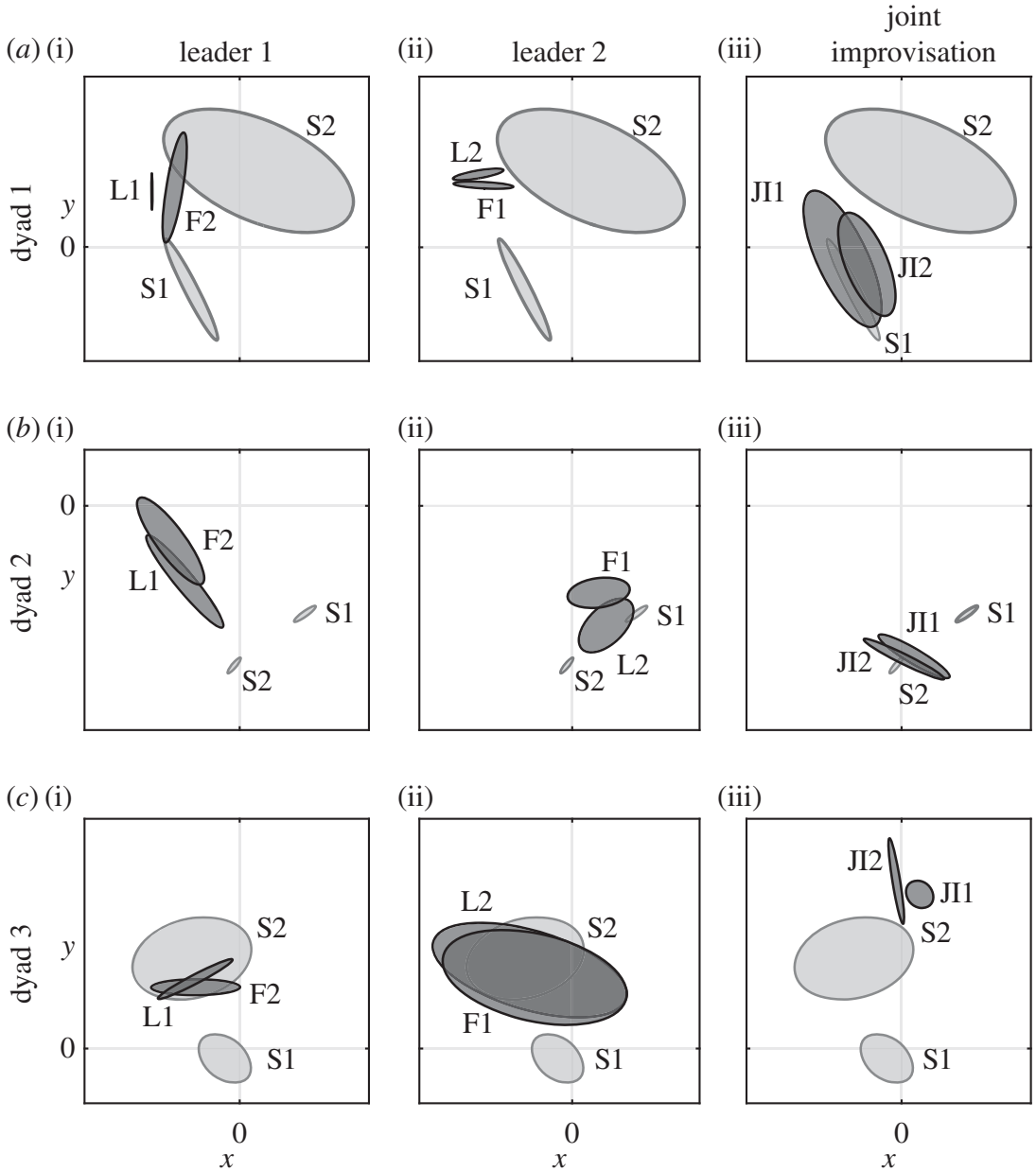
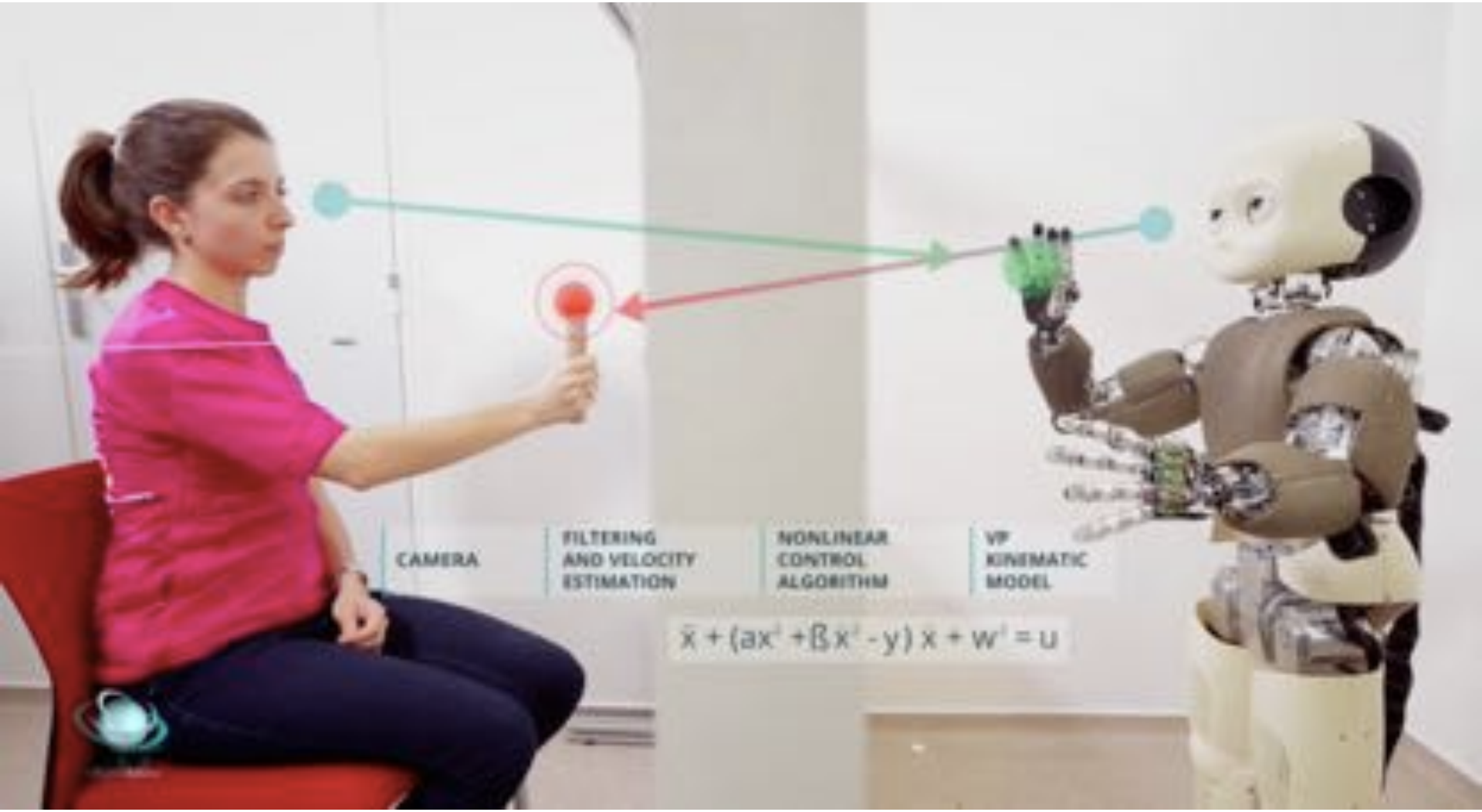


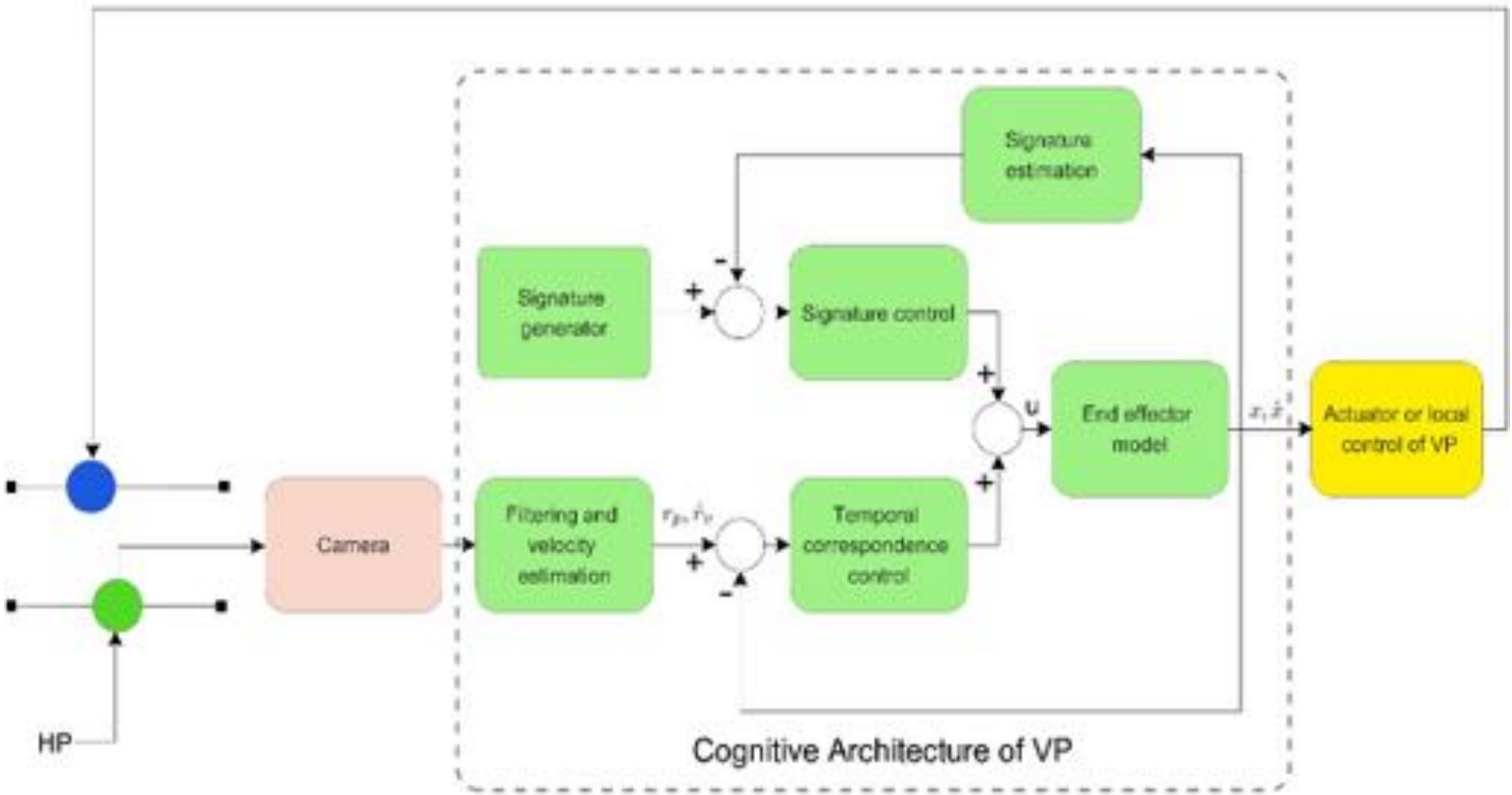
- IMS
- Morpho. Similarity
- Mov. Similarity
- Role (L / F / JI)
- Behavioural plasticity
- Social Penetrability
- Various pathology
- Rehabilitation

Slowinski et al., 2016

The AlterEgo cognitive architecture



The AlterEgo cognitive architecture



Manipulating social roles

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Manipulating social roles

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Example of a protocol

1. TEST with conditions counterbalanced across participants (4 x 30s = 2mn)

2. EXPOSURE period 3 x 1 minute for condition 1

3. TEST same 4 conditions counterbalanced across participants (2mn)

Likewise with the other conditions counterbalanced

4. EXPOSURE condition 2.
5. TEST
6. EXPOSURE condition 3.
7. TEST
8. EXPOSURE condition 4.
9. TEST
10. EXPOSURE condition 5

11. TEST

Analysis of each condition for the first test: spontaneous effect of similarity

Total time= 27 min

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Example of a protocol

Was there any evolution of the similarity/dissimilarity effect on participants' motor behavior?

Comparison of the pre and post tests for each exposure.

Pre-Test → Similar Morphology / Similar Kinematic → **Post-Test**

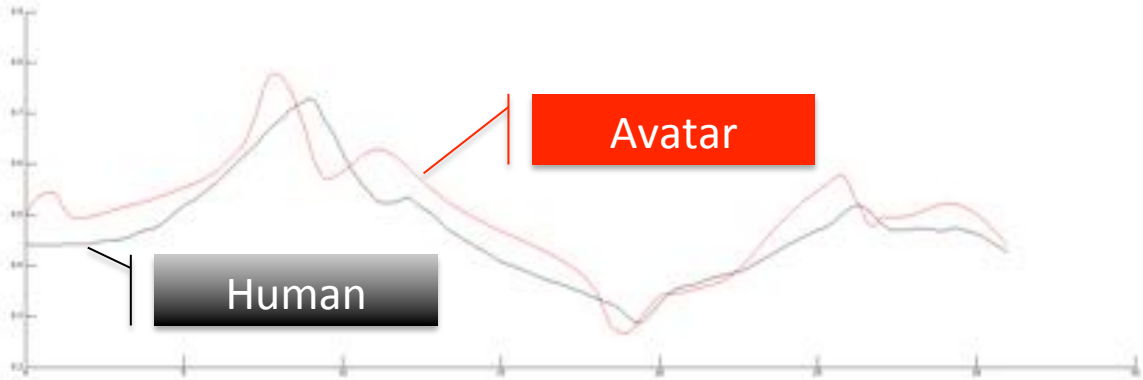
Pre-Test → Similar Morphology / Dissimilar Kinematic → **Post-Test**

Pre-Test → Dissimilar Morphology / Similar Kinematic → **Post-Test**

Pre-Test → Dissimilar Morphology / Dissimilar Kinematic → **Post-Test**

Measurement of synchronization

1. Optimal lag for cross covariance
   - Estimates participant / avatar temporal delay



2. Continuous/discrete relative phase

3. Cross-wavelet transform

New perspectives in mental rehabilitation based on the concept of similarity

Two steps

1/ similarity <-> launch a social interaction

2/dissimilarity <-> increase synchronization

6 months proof of concept in progress

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Final esults ?

Come to Montpellier !!!

THE ALTEREGO EUROPEAN WORKSHOP

« Contemporary Technologies for Mental Health »

September 29-30, 2016

Université Montpellier 3,
Paul Valery, Site Saint Charles
Rue du Professeur Henri SERRE
Montpellier, France

Thursday, 29 September 2016

13h30 -13h50 **Welcome coffee**

13h50 -14h00 Opening, **Benoît Bardy**, (Coordinator) and **Michel Brochard** (Project Officer) of the AlterEgo European Project

14h00 -15h15 **1st session**

- **Didier Striker :** 3D virtual AlterEgo: from unstructured 3D point clouds to realistic virtual humans for real-time graphics applications
- **Robin Salesse and Catherine Bortolon :** Can we trigger automatic imitation using photo realistic avatars in schizophrenia patients ?
- **Eric Brunet :** Using affective agents to train social cognition : challenges and solutions

15h15-16h00 **Posters + AlterEgo demo**

Coffee break

16h00- 17h15 **2nd session**

- **Stéphane Raffard :** The effects of an avatar therapy for social functioning in schizophrenia patients (ALTEREGO therapy) : proof of concept study
- **Aude Billard :** Designing and using a humanoid robot to support schizophrenia research
- **Krasimira Tsaneva-Atanasova and Mario di Bernardo :** Individual motor signature, virtual players and coordination in the mirror game

17h30- 18h30 **Keynote Lecture**
Richard Schmidt : Means for Understanding Social Competence in Autism

Friday, 30 September 2016

08h30 - 09h00 **Welcome**

09h00 - 10h15 **3rd session**

- **Ali Oker :** Embodied Conversational Agents : How artificial emotional intelligence can be an asset in schizophrenia research ?
- **Ghiles Mostafaoui :** Entrainment effect and unintentional synchronization in Human Robot Interactions
- **Mauraine Carlier :** Physical activity, mental health and rehabilitation, using new technologies to improve pleasure and enjoyment during a moderate practice

10h15 - 11h00 **Posters + AlterEgo demo**

Coffee break

11h00 - 12h15 **4th session**

- **Pascale Piolino :** virtual reality for ecological studies on human memory
- **Fabrizio Flacco :** Robot Control for Safe Human Robot Collaboration
- **Zhong Zhao and Mathieu Guegnon :** Improvisation and similarity : how to improve social interaction ?

12h30 - 14h00 **Lunch**

14h00 - 15h00 **Keynote lecture**
- **Tom Ziemke:** Using Social Robots in Psychotherapy for Kids with Autism : the DREAM Project

15h00 - 15h30 **Posters +demo**

Coffee break

15h30 - 16h45 **5th session**

- **Diane Purper Ouakil :** NEWROFEED : a personalized neurofeedback protocol in ADHD
- **Vincent Henry :** Eye tracking and Autism spectrum disorder
- **Stéphane Bouchard :** Overview of virtual reality in mental health care, the example of anxiety disorders

16h45 - 17h00 **Closing The AlterEgo team**

Contact : d-capdevielle@chu-montpellier.fr

The Project is funded by the European Union

Mise en page : *Service Communication - CHU de Montpellier - G. Faugier - 06/2016*

Collaborators

Motor Control

- Ludovic Marin
- Mathieu Gueugnon
- Robin Salesse
- Zhong Zhao

Virtual Reality (morphology)

- José Henriques
- Norbert Schmitz
- Didier Stricker

Psychiatry and clinical psychology

- Catherine Bortolon
- Delphine Capdevielle
- Stephane Raffard

Robotics (control)

- Aude Billard
- Madhi Khoramshahi
- Ashwini Shukla

Mathematical modeling (kinematic)

- Francesco Alderisi
- Mario Di Bernardo,
- Piotr Slowinski
- Krasimira Tsaneva-Atanasova
- Chao Zhai

www.euromov.eu/alterego