Master's Programme in Sciences and Techniques of Sport and Physical Activities

Sciences and technologies in sports coaching UE3 E2

Physical Conditioning and sportive rehabilitation

Les liens dynamiques entre production motrice et efforts

Julien Lagarde

Rappels

Force, accélération

Energie mécanique

Travail

Rendement

Le mouvement pluri-articulé ?

-Coordination: Patrons sensorimoteurs (Lecture : Lagarde et al. Skills Review)

-Lagarde J., Mottet D., Bardy B. (2007). Coordination and human perceptuo-motor skills. First review of the IP SKILLS, December 2007. Sant'Anna Scool for Adanced Studies, Pisa, Italy.

- Origine

Perception-action, couplages, apprentissage, mémoire, réseaux

- Propriétés

Stabilité

Multistabilité

Redondance, équivalence motrice

Synergies musculaires

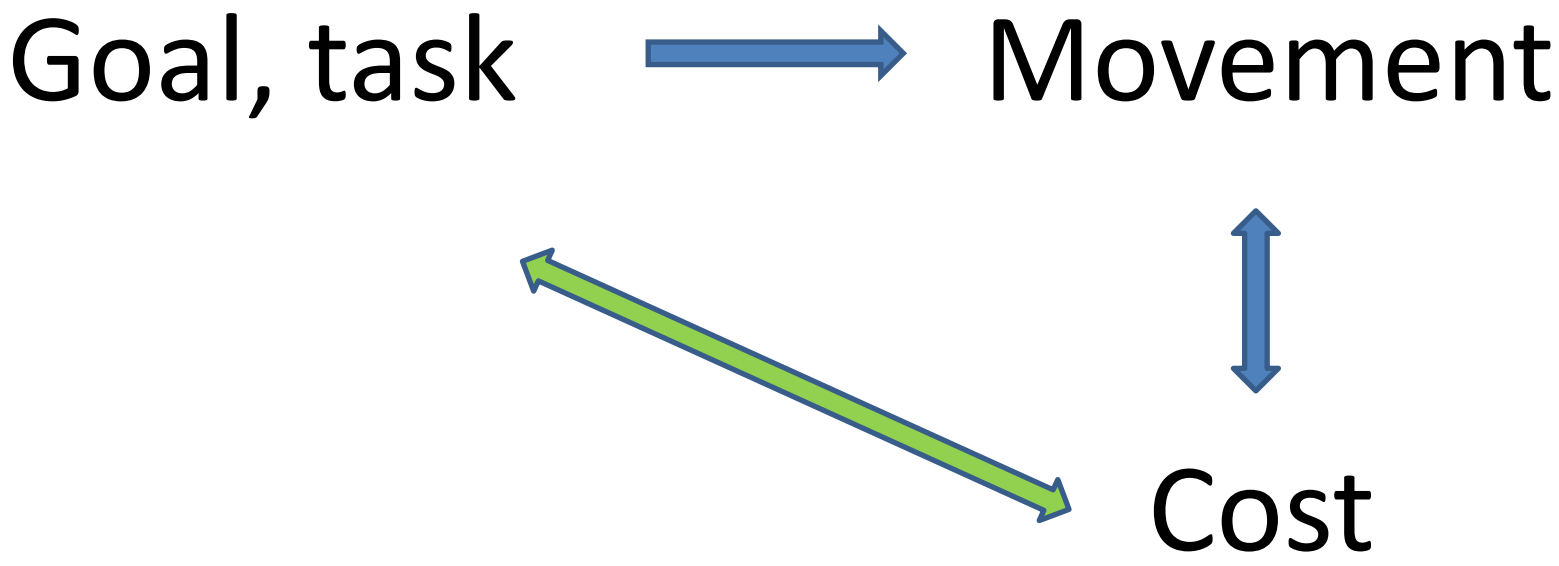
- « Efforts »?

Economie

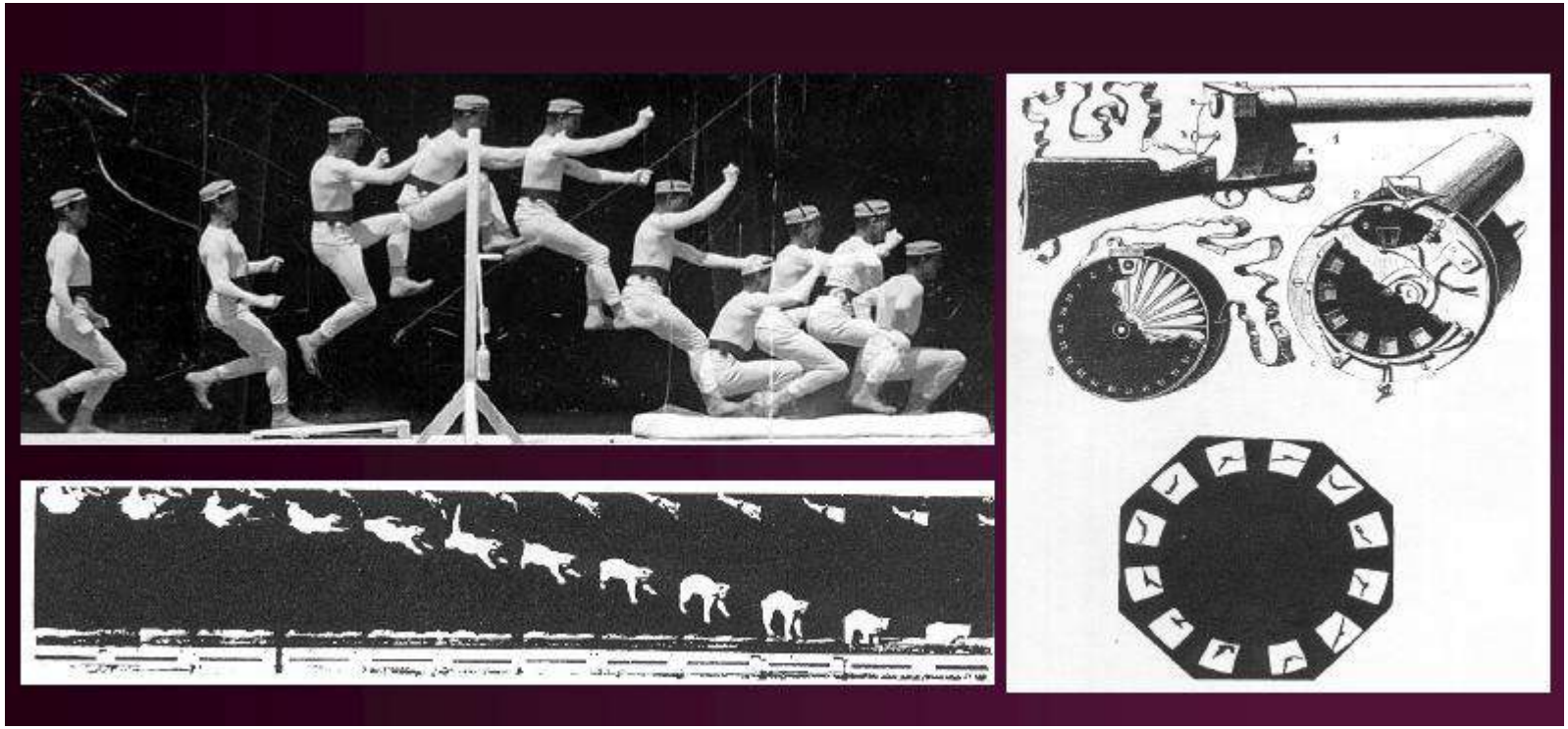
Optimalité/ Minimisation de fonction de coût

Principe de moindre action

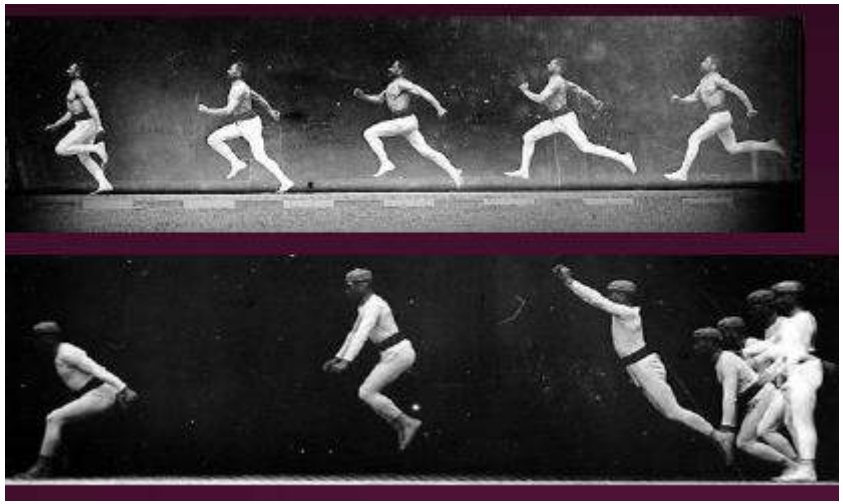
Vicariance/ *Variabilité*

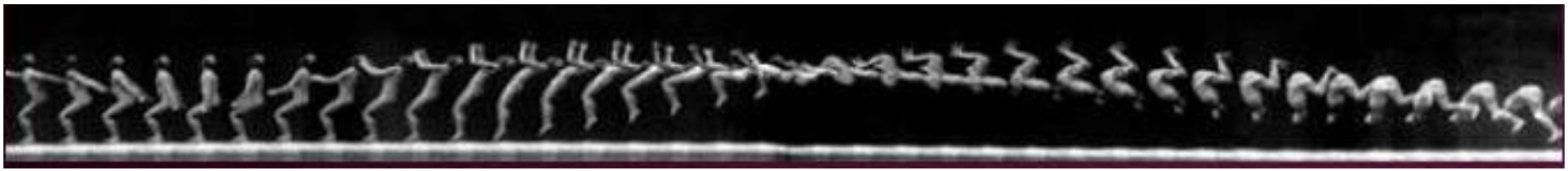

Goal, task
Movement
Cost

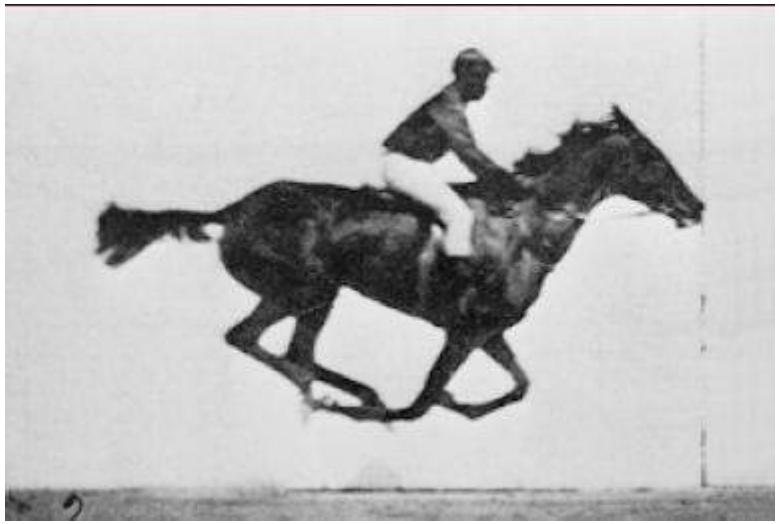
Muybridge, E. (1831-1904)
& Marey, J. (1830-1904)

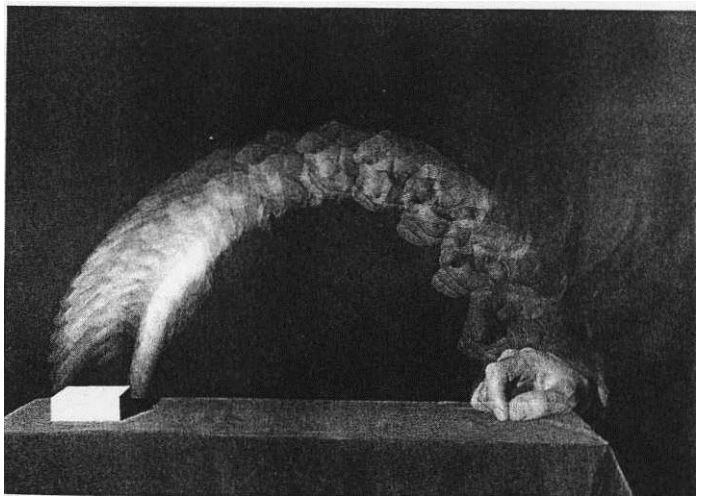


Coordination of movements









Rappels

Mouvement ?

✓Force externes (appuis) → accélération → vitesse ≠ 0 m/sec.
✓Inertie : masse, résiste aux changements de mouvement

✓Forces externes générées par des forces internes : Moments

✓Forces externes qui « travaillent » : utiles au déplacement

✓Moment force = Moment inertie x accélération angulaire
✓Moment inertie = masse x r^2
✓Moment force = masse x r^2 x accélération angulaire

Energie mécanique

Énergie potentielle + énergie cinétique = constante

(champ gravitaire : force/ poids, vitesse)

/Chaleur : frottements, processus exothermiques…

Organisation du mouvement

• Génétique, développement, apprentissage, expertise

✓La biologie, le système nerveux, soumis aux lois de la mécanique

✓Redondance articulaire

M degrés de liberté tâche < N degrés de liberté articulaires

✓Redondance musculaire

Multiples activations produisent les même forces

Grand nombre de solutions
Quels déterminismes (facteurs, mécanismes, contraintes) ?

Organisation du mouvement

Conception 1)

✓Plan, programme, du mouvement (séquence d'impulsions musculaire)

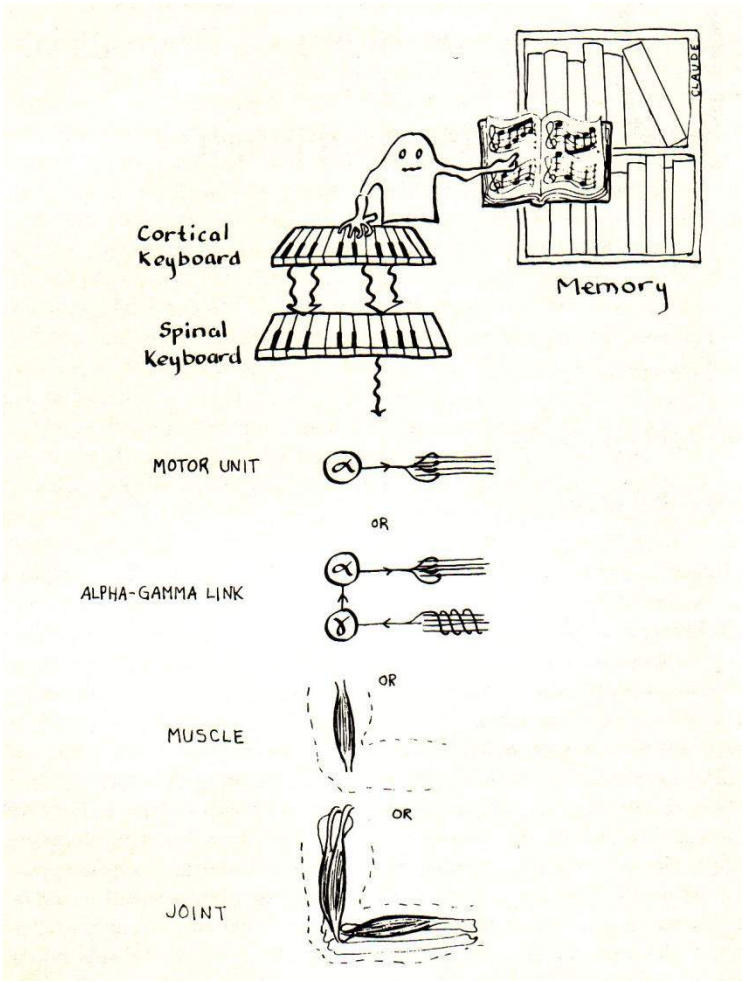
✓Modèle interne des propriétés cinématiques, géométriques, dynamique

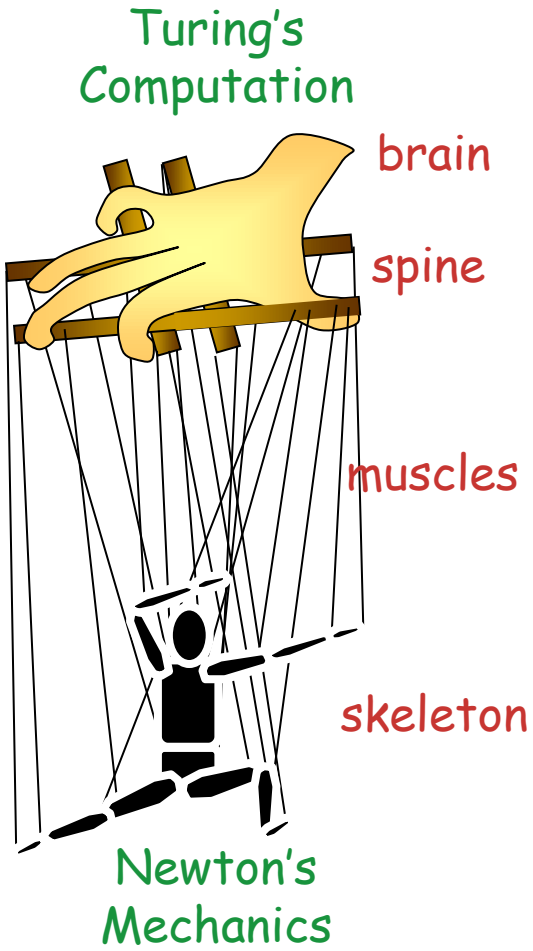
✓Cybernétique : but, commande (action), mesure des résultats, correction
→ feedback, retro-contrôle

Conception 2)

✓**Patrons de coordination**

Production of movements

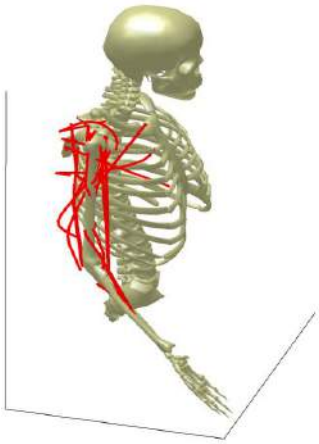




Pas de programmes « moteurs » !!

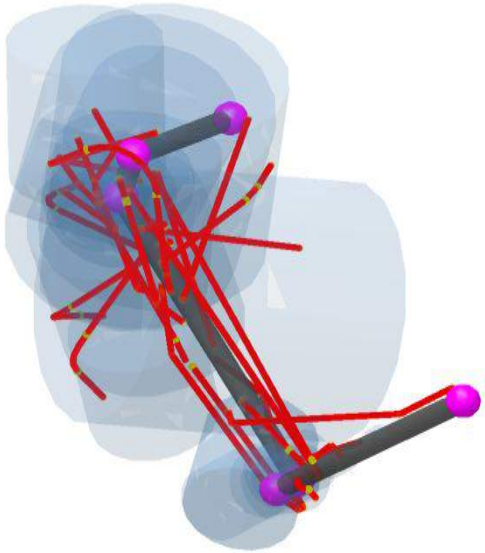
Le mouvement humain :

Un système complexe



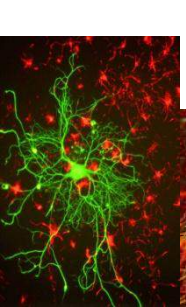
Des éléments très nombreux :

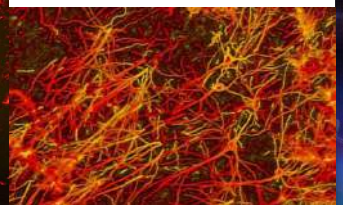
- 148 os mobiles (244 ddl / « degrés de liberté »)
- 600 muscles
- 100 milliards de neurones
- un million de milliards de synapses

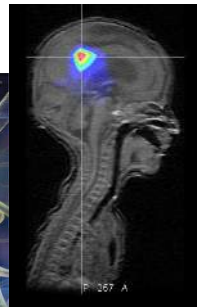


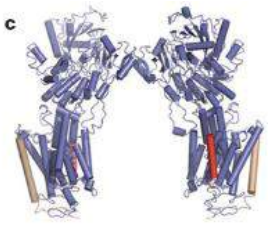
→ Nombre de circuits neuronaux possibles
= 10 suivi d'un million de zéros

* nombre de particules de l'univers connu
= 10 suivi de 79 zéros



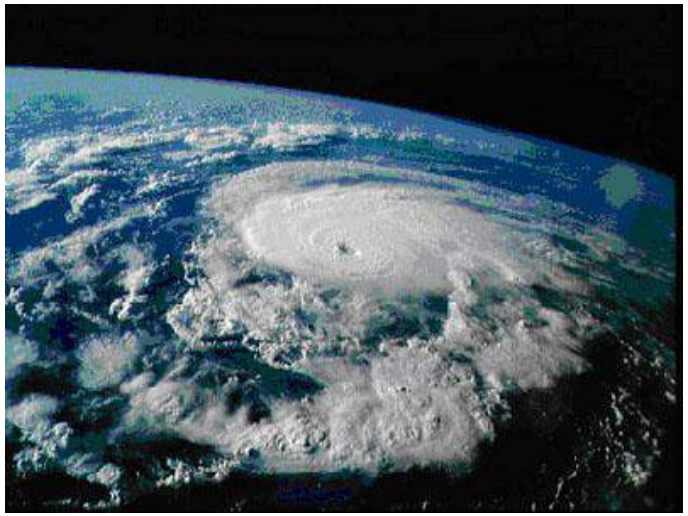


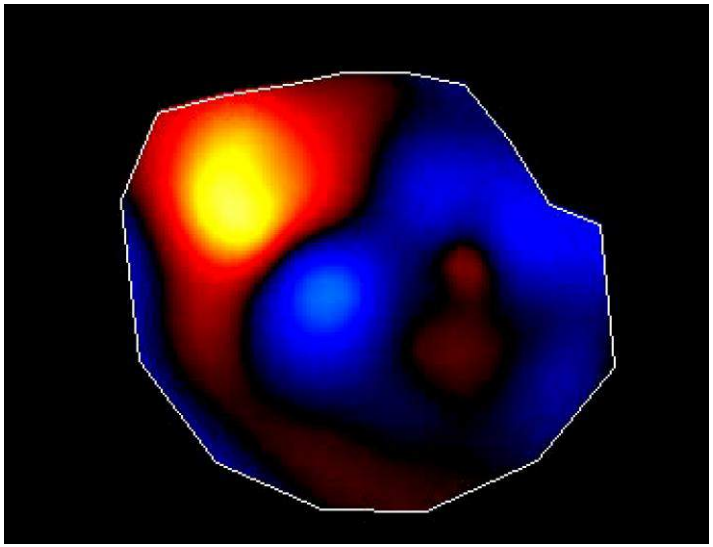




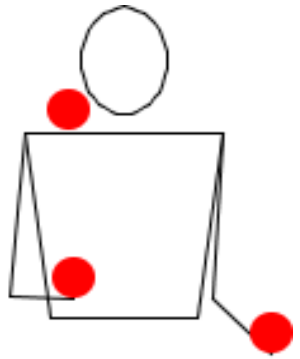
Pattern formation:

Cooperation among components; Equilibrium between opposing tendencies (grow vs. decay)



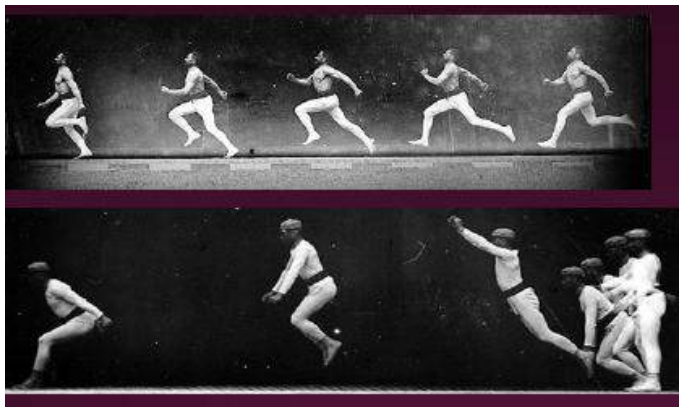


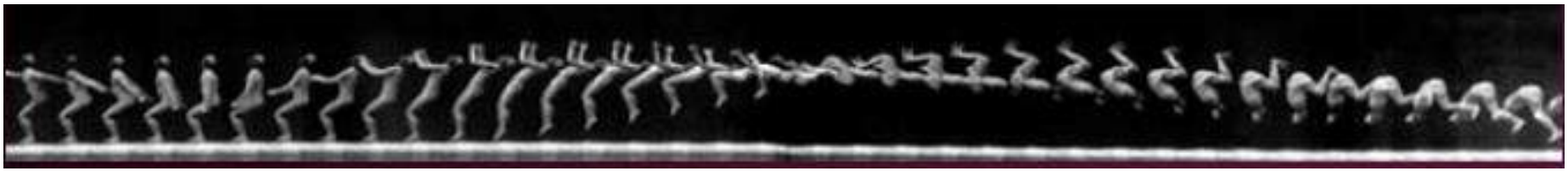
Emergence in living systems

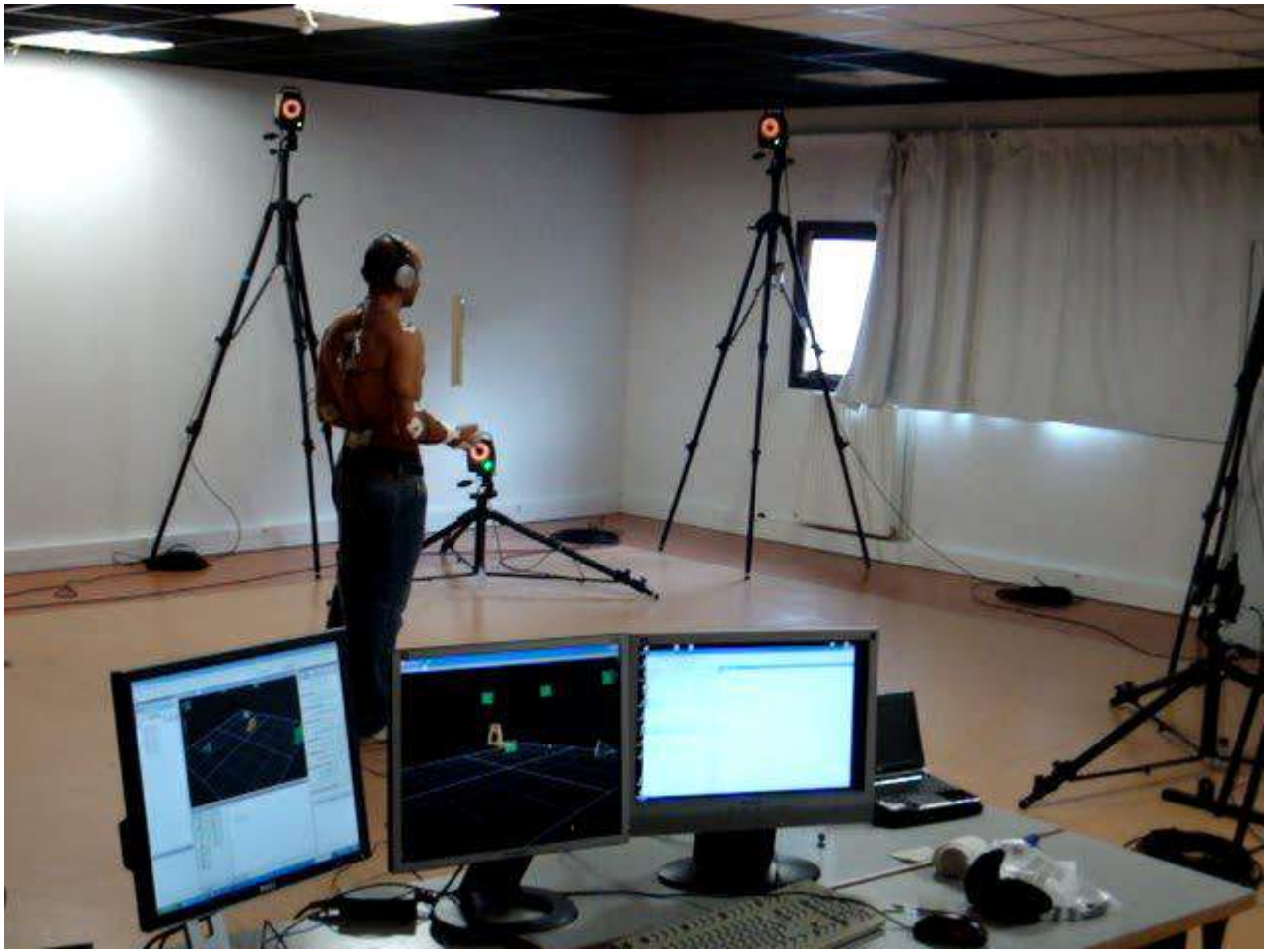


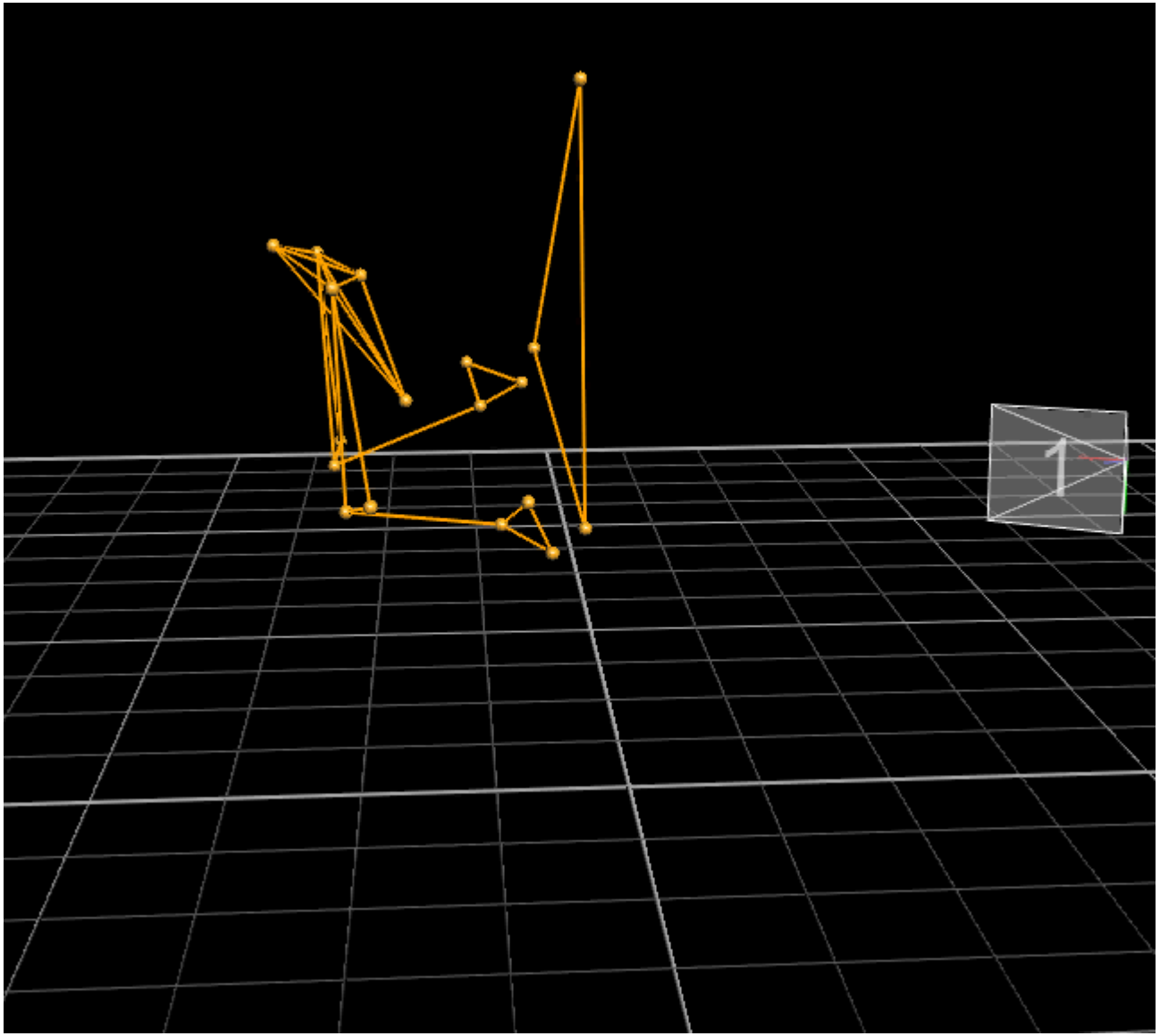
Mains en anti- phase

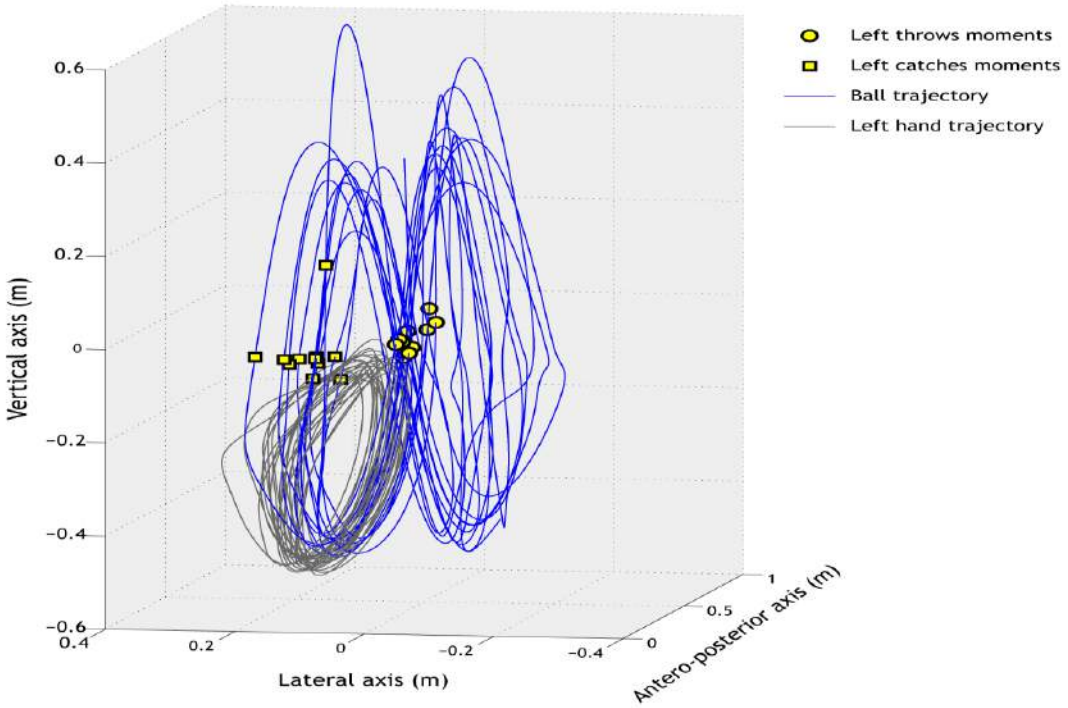
Mesurer le mouvement du jongleur

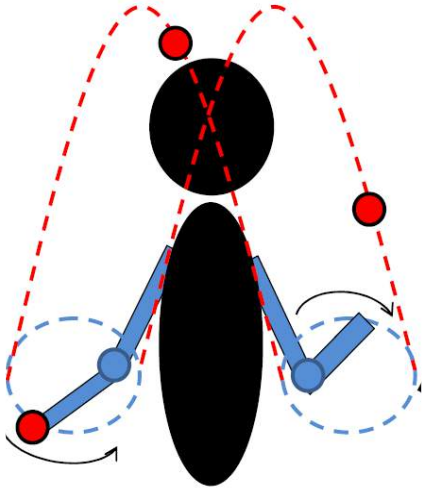




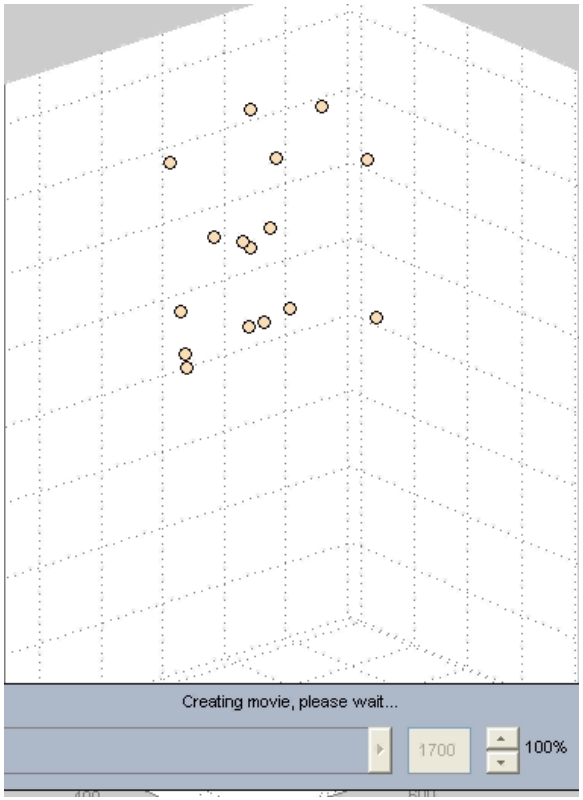


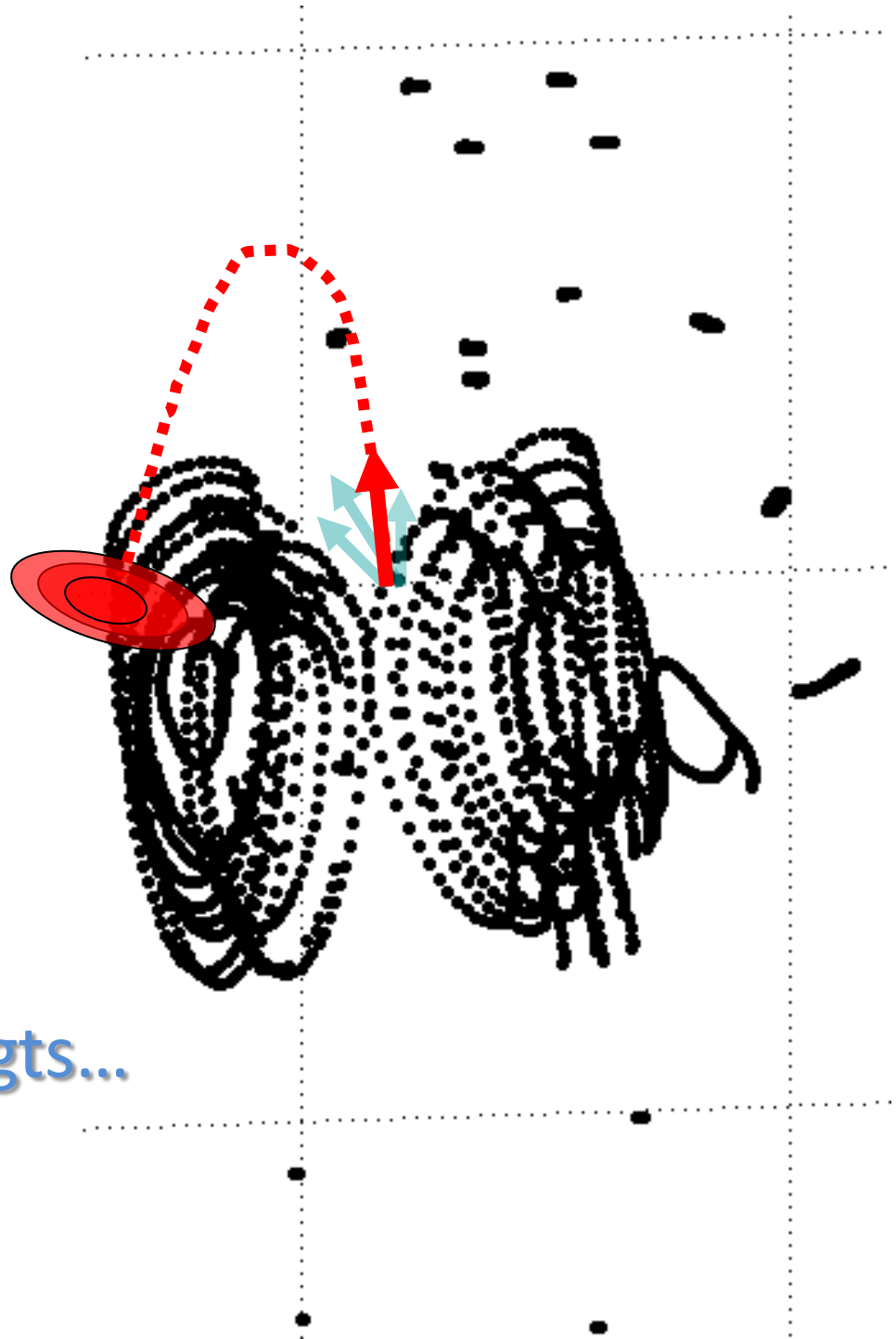






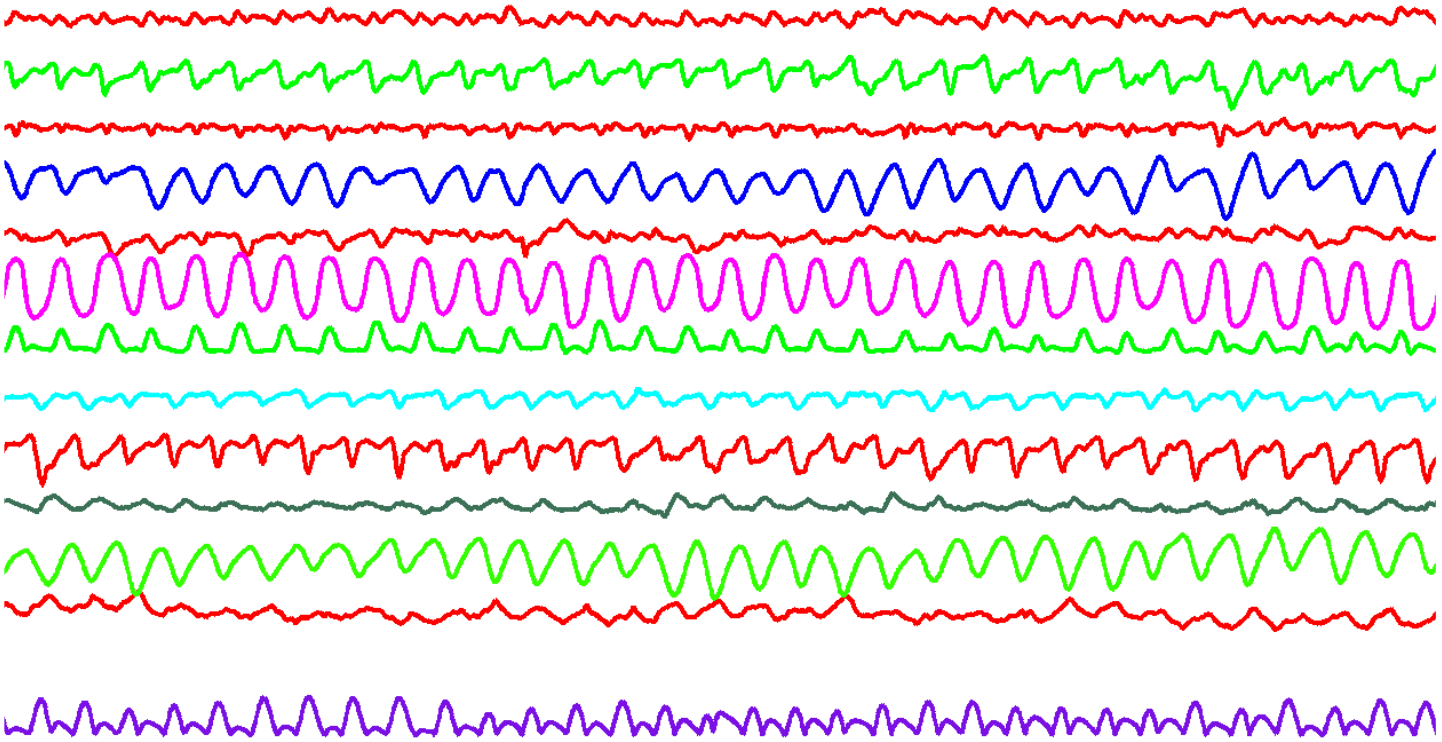
Niveau de la tâche





Les mains, les doigts…

Coordonner les bras… *14 angles* (sans compter les doigts !)



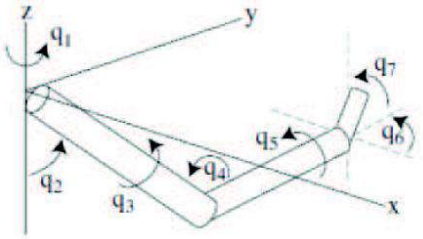


Figure 2 : 7-Degrees of freedom, 3-link chain in 3D space

+

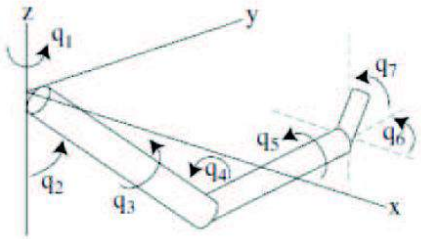
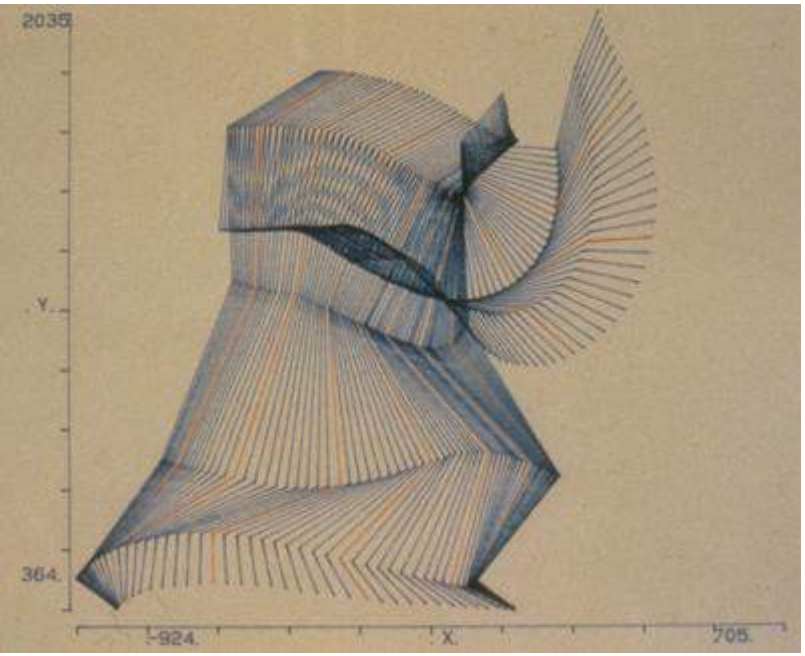


Figure 2 : 7-Degrees of freedom, 3-link chain in 3D space

Stability of ***patterns***



Maintain, persistence of order between *limbs* (e.g. timing)

And *in relation to external events*

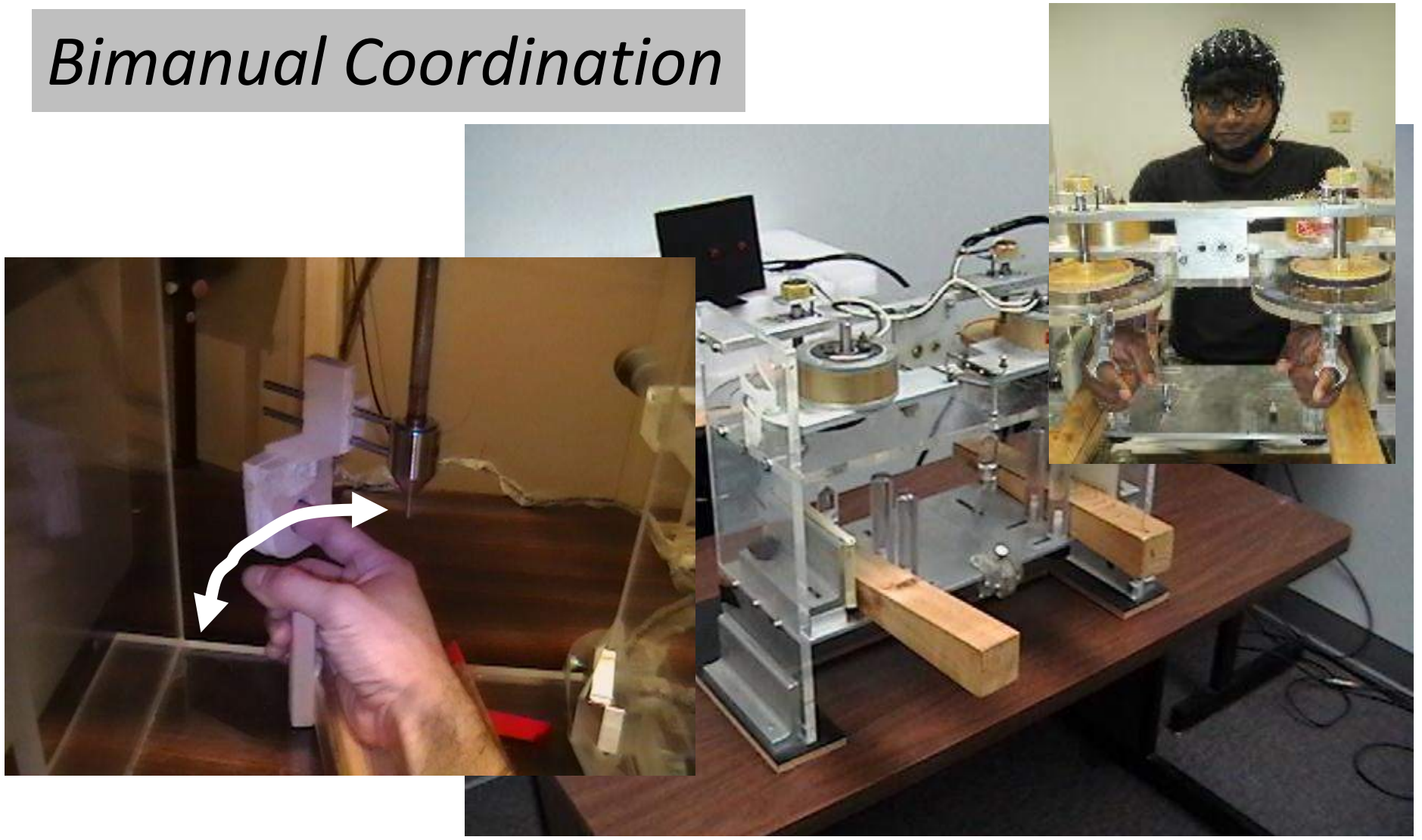
- Walking
- Speaking
- Reaching
- Catching

Dynamics:

Formation and change of coordination patterns

H Haken, S Kelso, G Schöner, M Turvey…

Bimanual Coordination

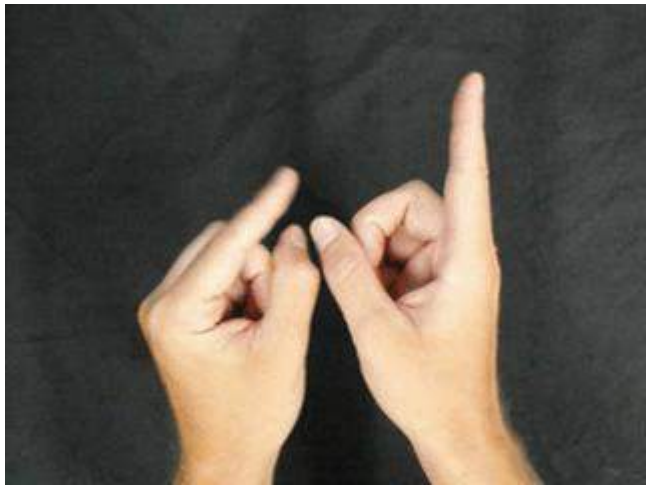


Oscillatory movements of 2 joints

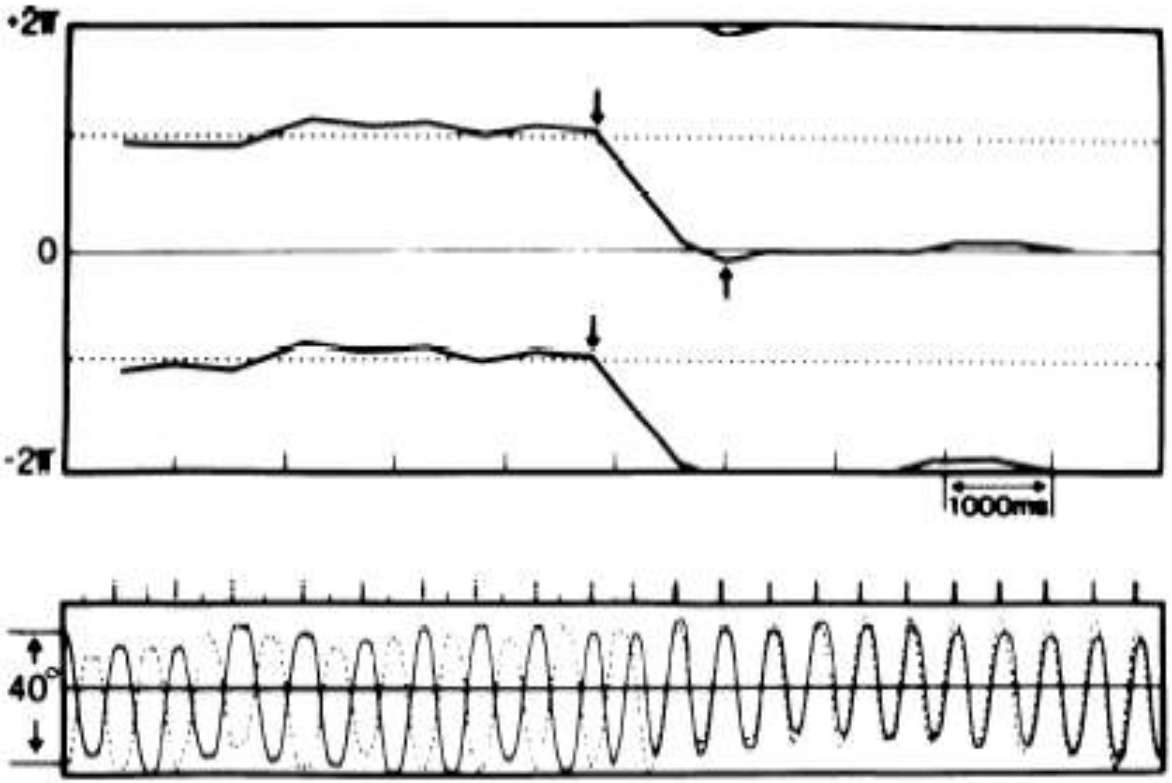
Lower frequency, two stable behaviors

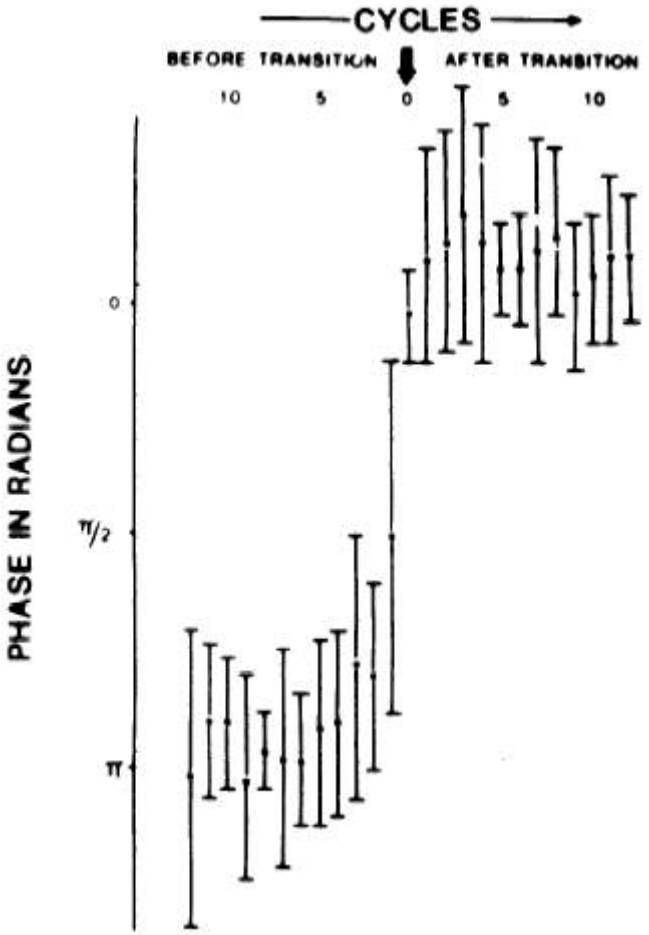
- en phase

- antiphase



(Control parameter (Ω) < 2 Hz)

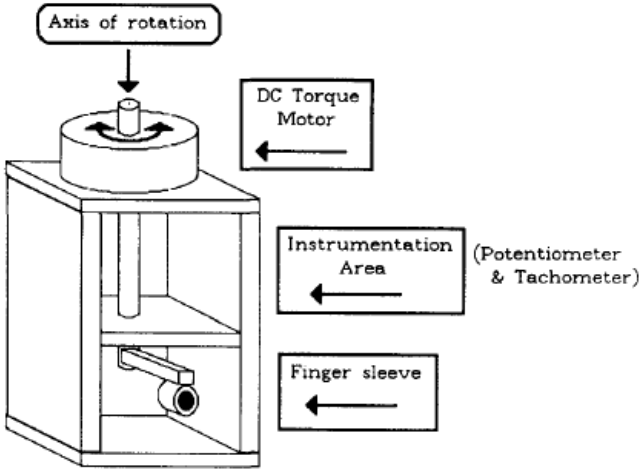


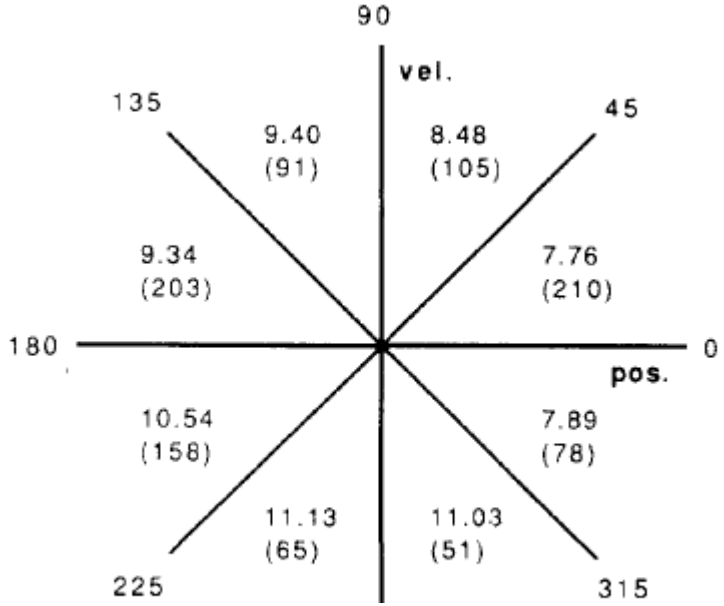


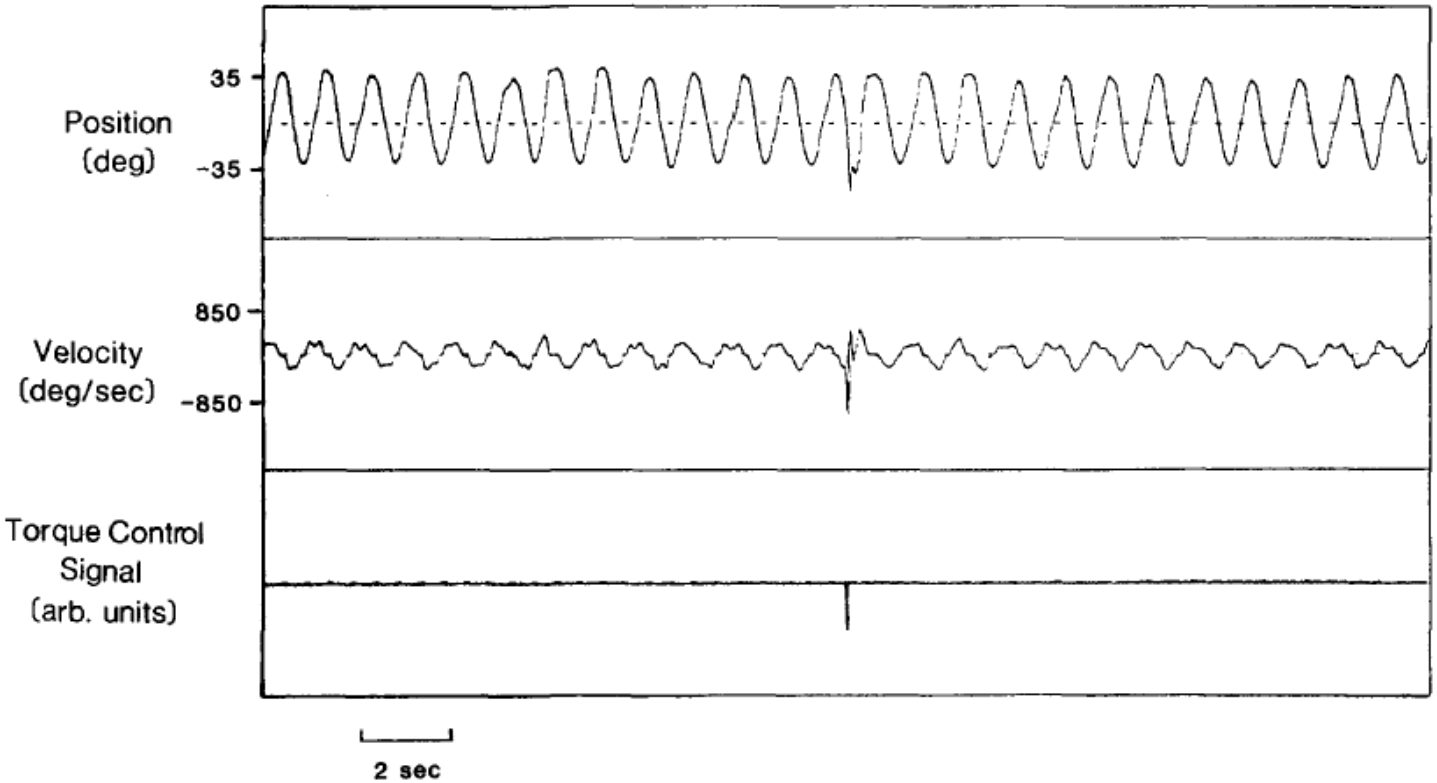
Phase transitions and critical behavior in human bimanual coordination

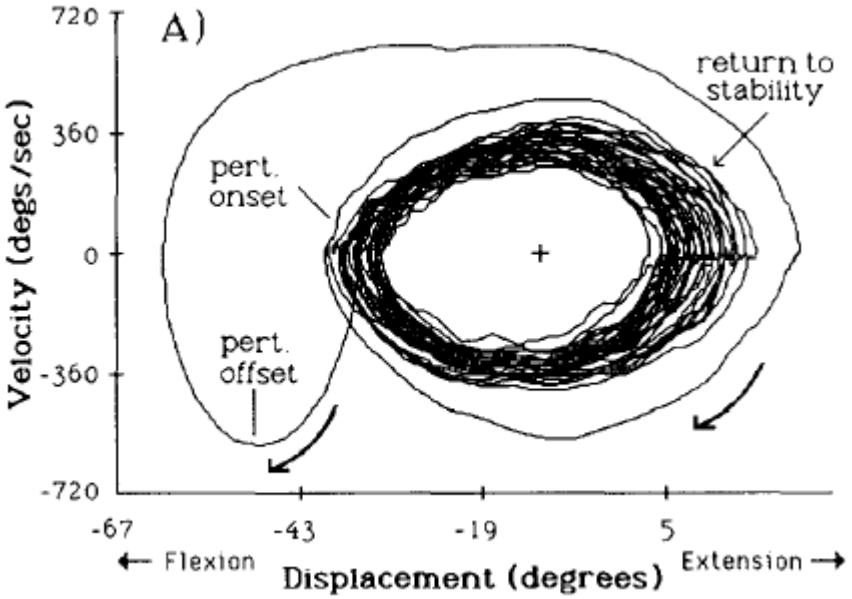
Am J Physiol Regul Integr Comp Physiol 246:1000-1004, 1984.

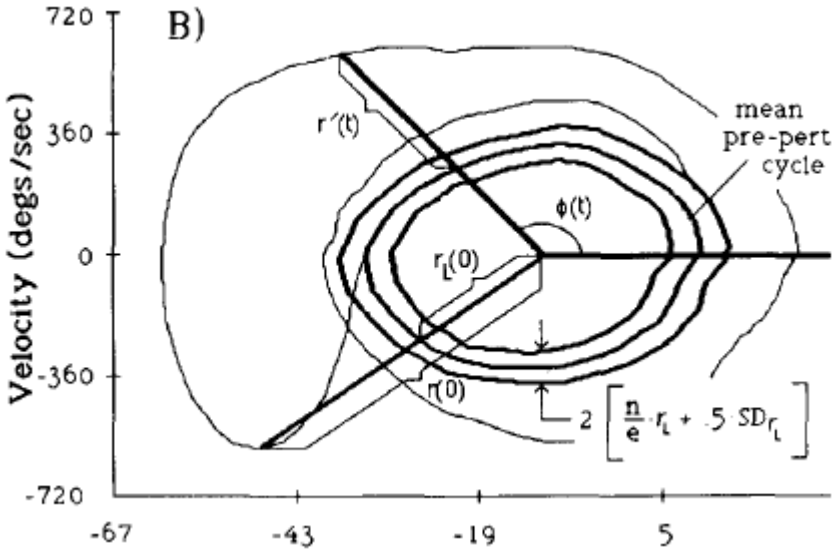
J. A. SCOTT KELSO
Haskins Laboratories, New Haven 06511, and Departments of Psychology and Biobehavioral Sciences, University of Connecticut, Storrs, Connecticut 06268


Axis of rotation
DC Torque Motor
Instrumentation Area
(Potentiometer & Tachometer)
Finger sleeve


90
vel.
135
45
9.40
(91)
8.48
(105)
9.34
(203)
7.76
(210)
180
0
pos.
10.54
(158)
7.89
(78)
11.13
(65)
11.03
(51)
225
315


35
Position
(deg)
-35
850
Velocity
(deg/sec)
-850
Torque Control
Signal
(arb. units)
2 sec





Journal of Experimental Psychology:
Human Perception and Performance
1991, Vol. 17, No. 1, 183-197

0096-1523/9

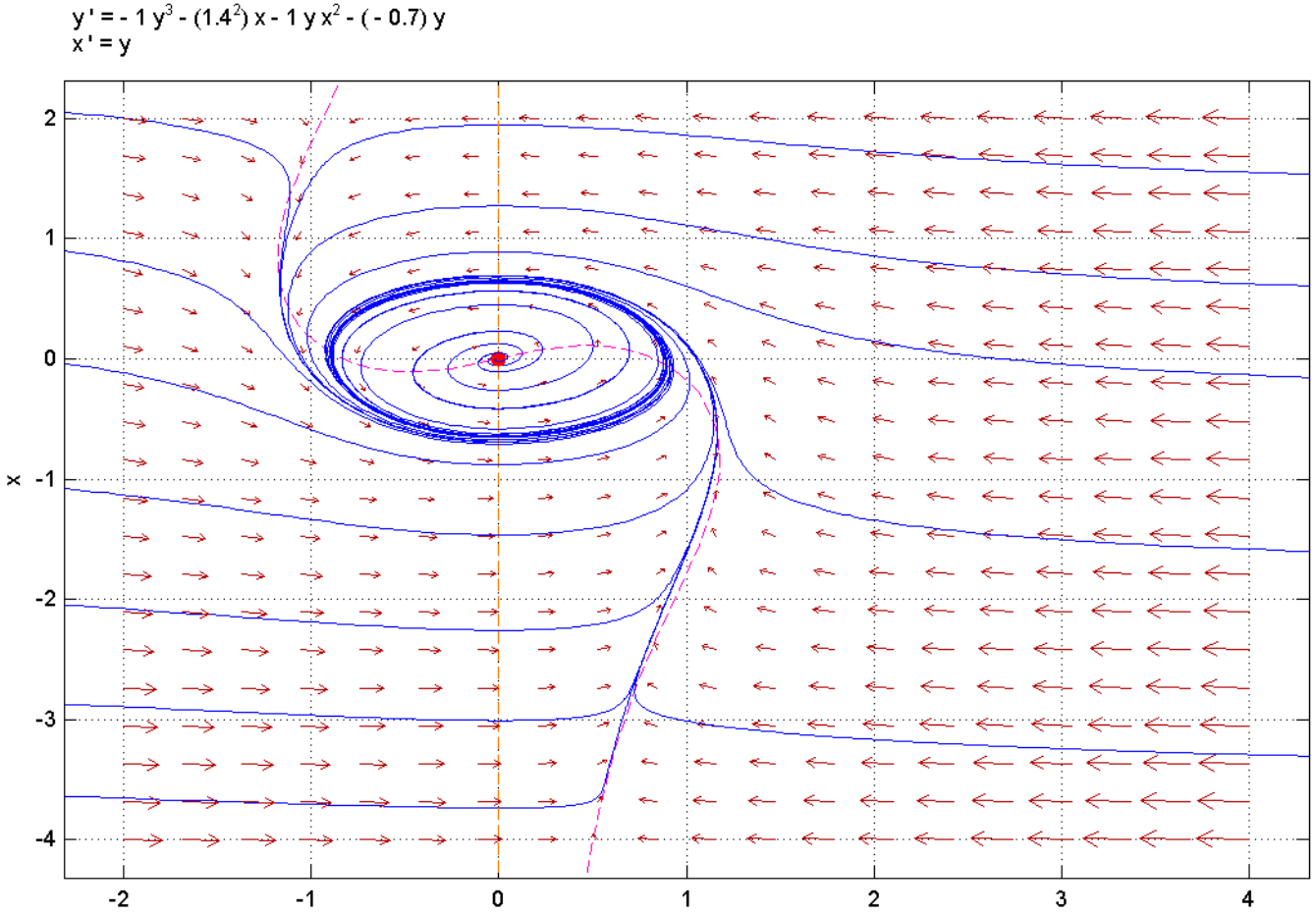
Steady-State and Perturbed Rhythmical Movements: A Dynamical Analysis

Bruce A. Kay
Department of Brain and Cognitive Sciences
Massachusetts Institute of Technology

Elliot L. Saltzman
Haskins Laboratories, New Haven, Connecticut

J. A. S. Kelso
Center for Complex Systems
Florida-Atlantic University

Champ de vecteur pour un comportement périodique stable



Chaque composant est représenté par un cycle limite

Le cycle limite « attire » les trajectoires : Attracteur.

Domaines d'utilisation scientifique des systèmes dynamiques

Physique

- Mécanique classique (le Système solaire est il stable ?)

- Transitions de phase dans des systèmes physiques (physique statistique (gds nombre de particules-atomes) et comportements macroscopiques modélisés par des champs); ex. champ magnétique; comportements collectifs)

- Mécanique des fluides (turbulence)

- Météorologie

- Réactions physico-Chimique

- Radio, laser, radar

Biologie

- Cœur

- Neurosciences
    - Modèles de neurones; réseaux de neurones
    - Synchronisation dans des populations de neurones
    - Comportement moteur (coordination bimanuelle; coordination quadrupèdes)

- Génétique

- Écologie des populations

Autres

- Trafic routier
- Finance

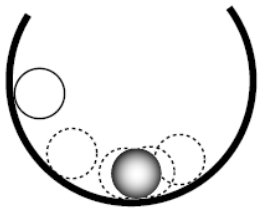
2) Repères historiques

Fin 19^{ième}, explosion 1930's, 1970, à nos jours

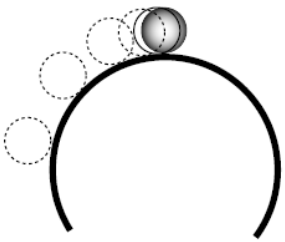
3) Objectifs du cours

- Découvrir et comprendre les éléments de base
[flot, champ de vecteurs, espace des phases]

- Les définitions et outils d'étude de la stabilité (déf. intuitive)

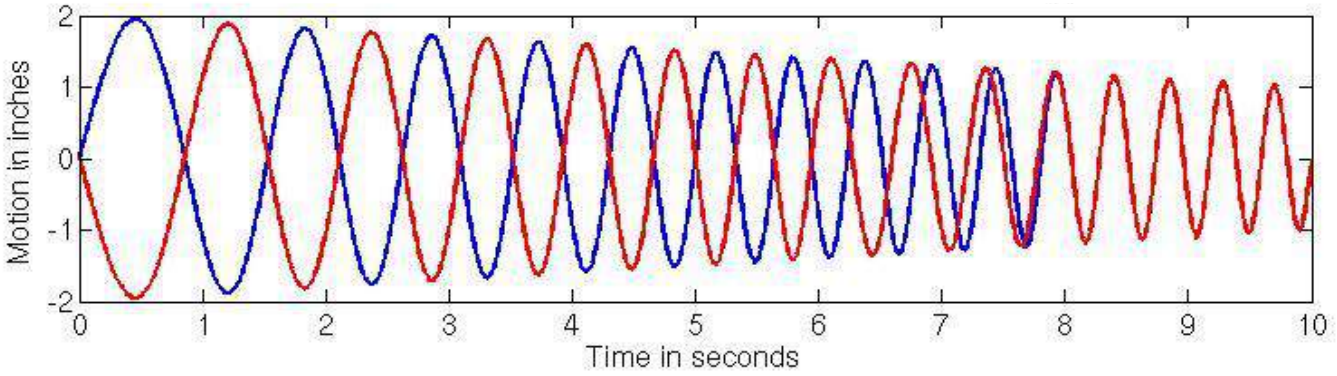


stable



instable

2) Deux états stables dans la coordination: Couplage non linéaire

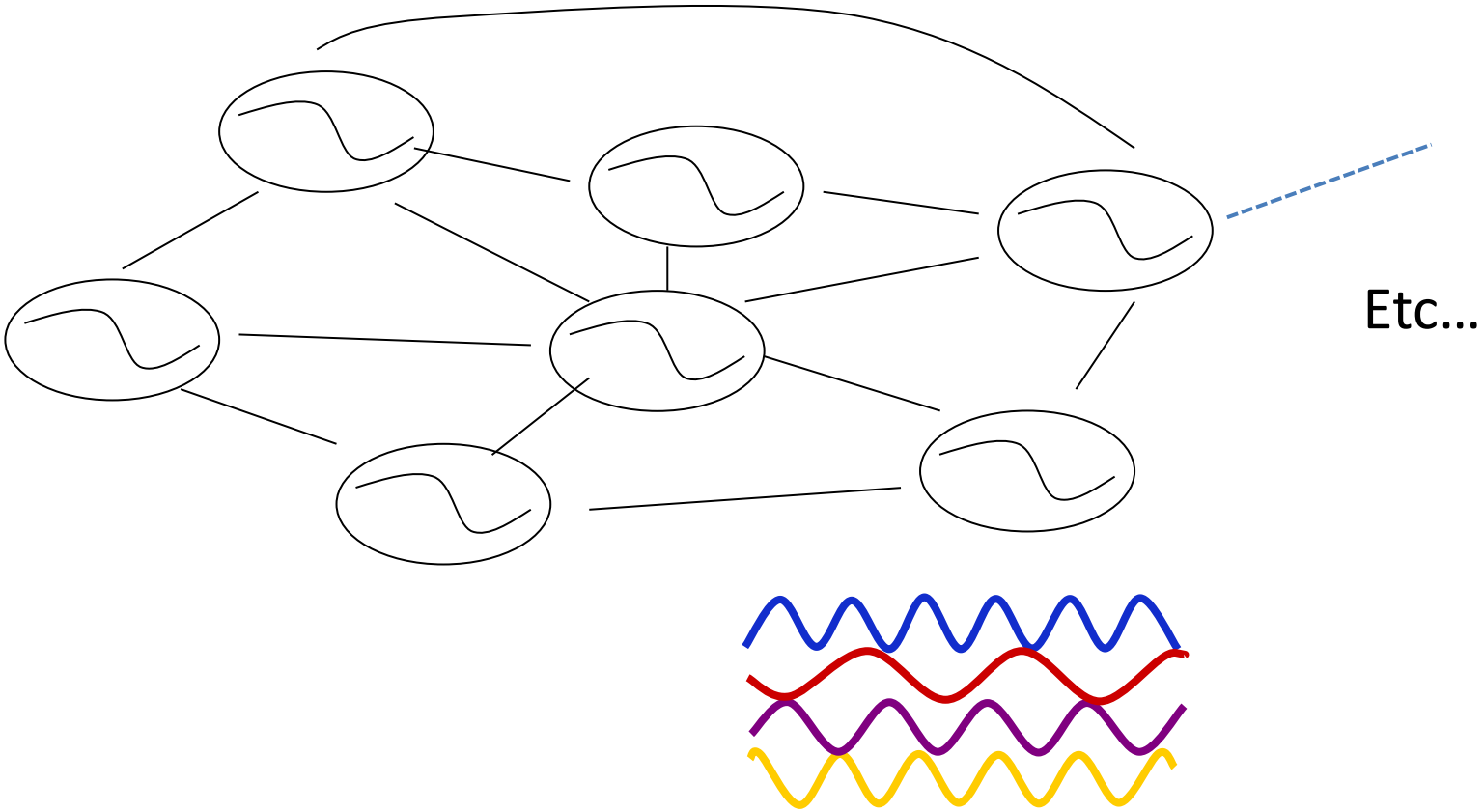


$$\ddot{x}_L - \alpha\dot{x}_L + \beta\dot{x}_L^3 + \gamma x_L^2\dot{x}_L + \omega^2 x_L = -(\dot{x}_L - \dot{x}_R)(a - b(x_L - x_R)^2)$$

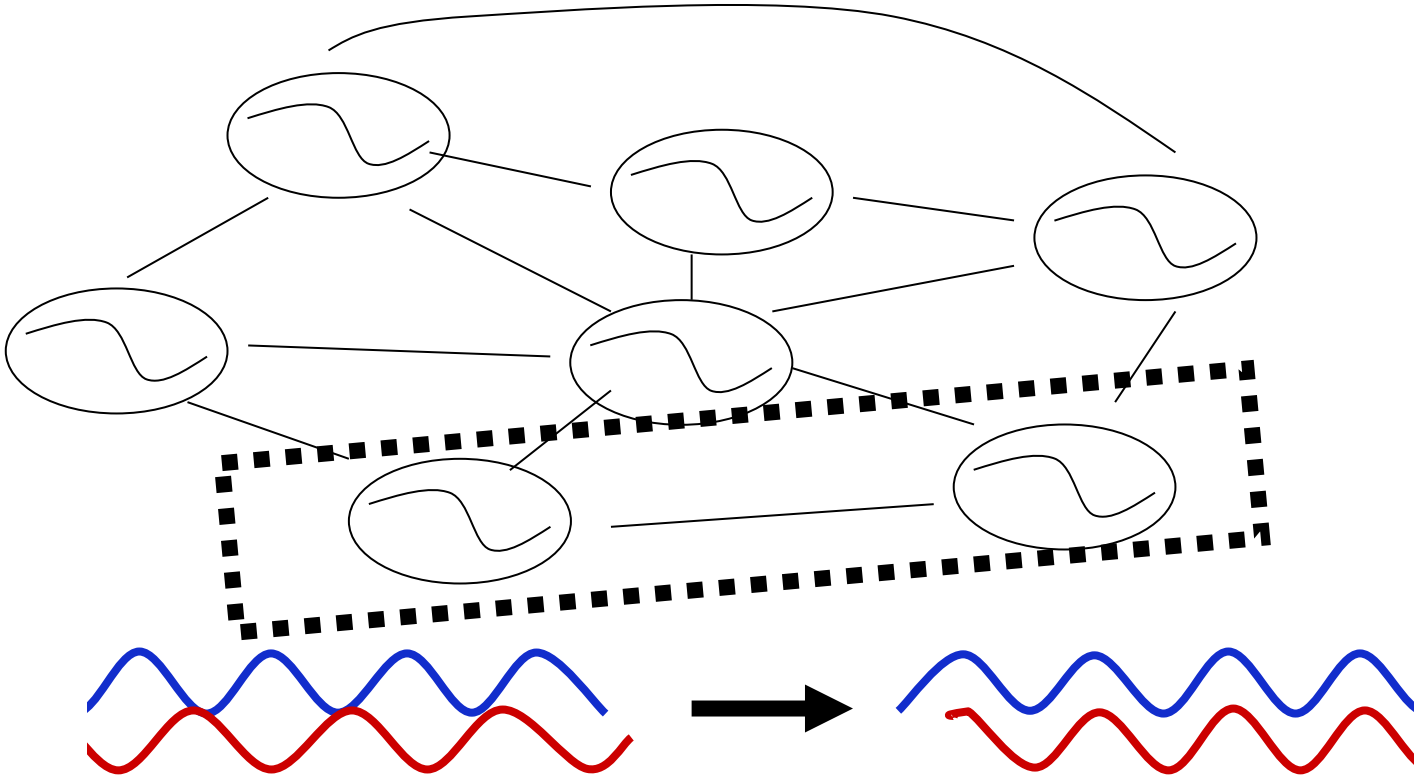
$$\ddot{x}_R - \alpha\dot{x}_R + \beta\dot{x}_R^3 + \gamma x_R^2\dot{x}_R + \omega^2 x_R = -(\dot{x}_R - \dot{x}_L)(a - b(x_R - x_L)^2)$$

couplage

Généralisation



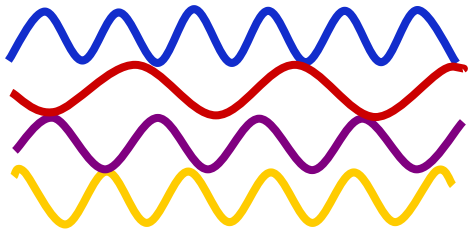
Couplings : every cell (component) exchanges with every others (all to all coupling)



2 components lock in and add up their attractive strength to attract the others toward their common rhythm (frequency and phase)

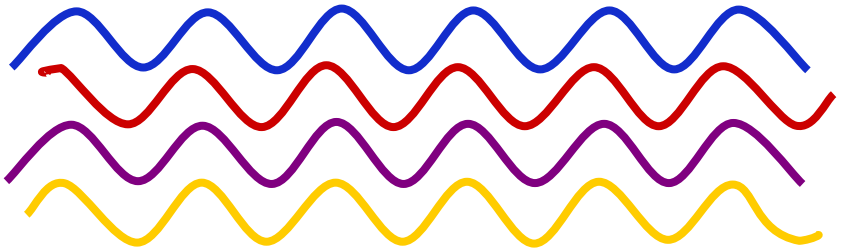
Then 3, 4, 5 etc… toward reaching an ensemble coordination

Illustration of spontaneous order in ensemble coordination



Start

Incoherent behaviors of components



Final

Order : collective pattern

Origines : Couplages

Interactions

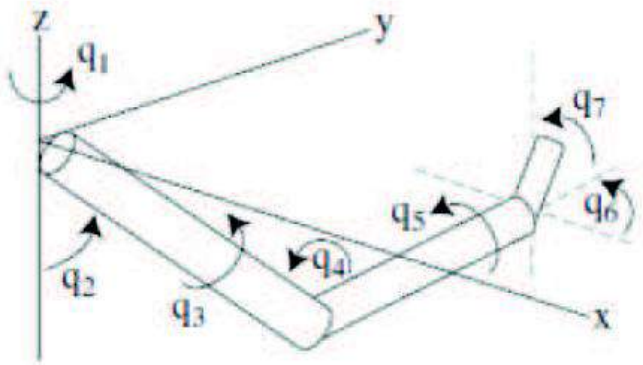


Figure 2 : 7-Degrees of freedom, 3-link chain in 3D space

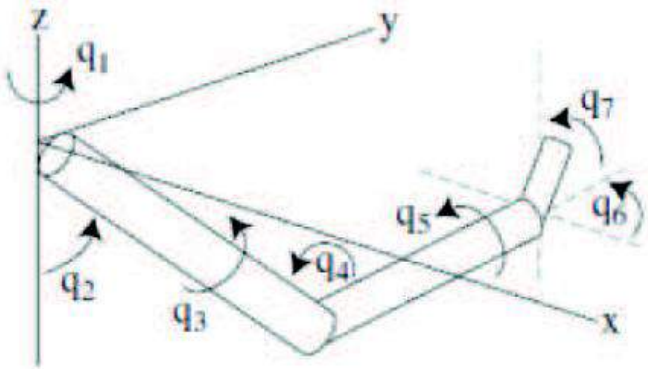


Figure 2 : 7-Degrees of freedom, 3-link chain in 3D space

Dans/ entre les bras :

- Couplages mécaniques : Couples d'interactions, anatomie.

- Couplages neurophysiologiques :

  - Muscles pluri- articulaires.
  - Connections Neuronales (moelle épinière et cerveau) échangeant des informations.
  - Couplages Inter- hémisphériques.

- Relation corps en mouvement- l'environnement :
  - Objets/ surface/ Obstacles/ partenaires : Ex Vision de la distance entre mains, entre articulations, entre articulations et un référentiel externe.

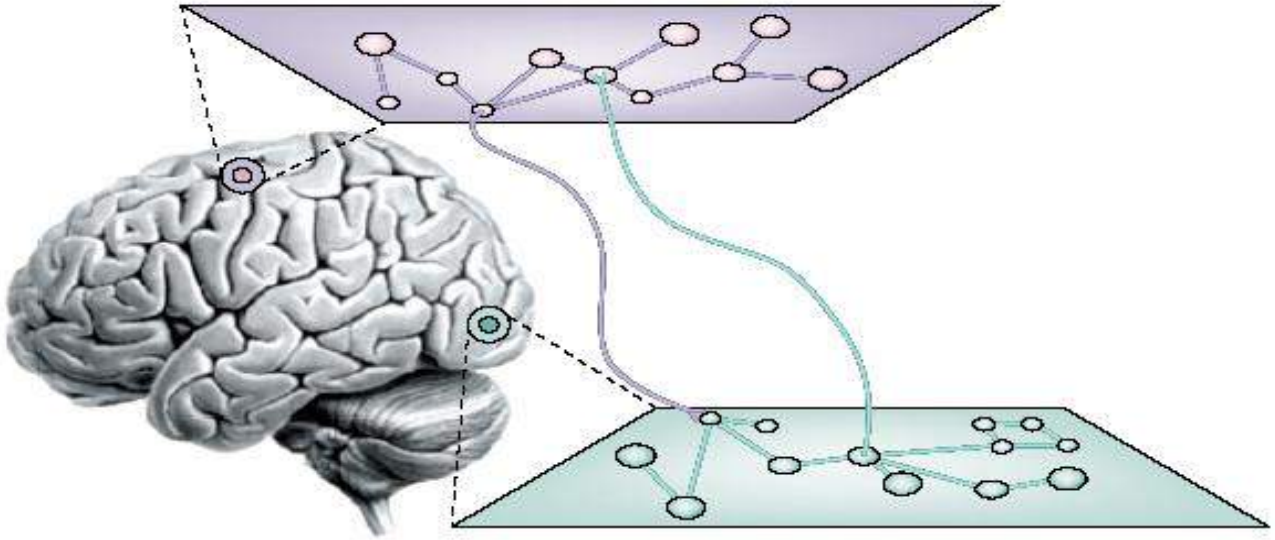
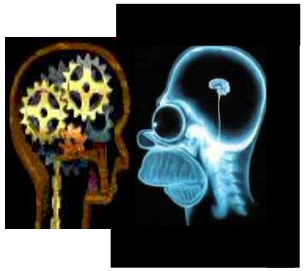
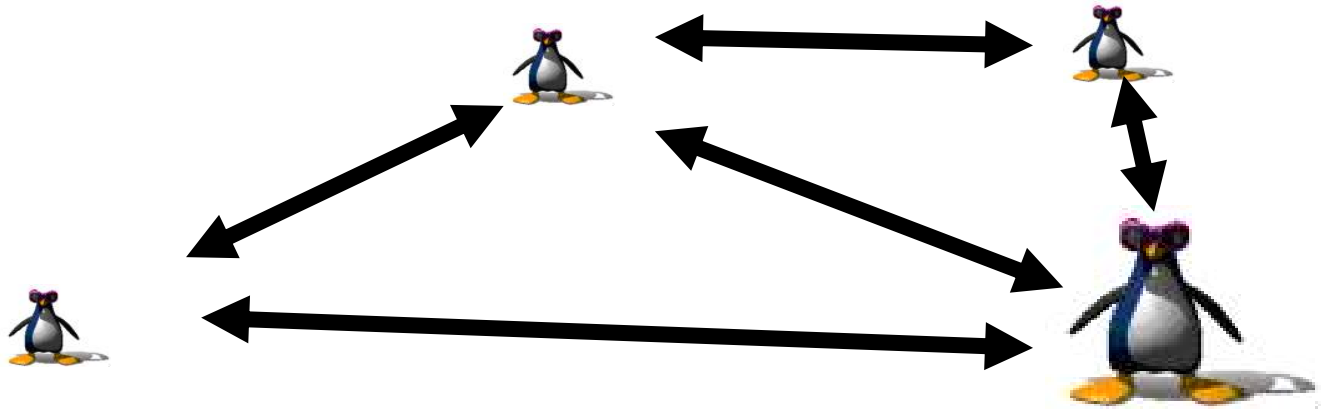


Figure 1 | **Schematic representation of transient distributed neural assemblies with dynamic long-range interactions.**

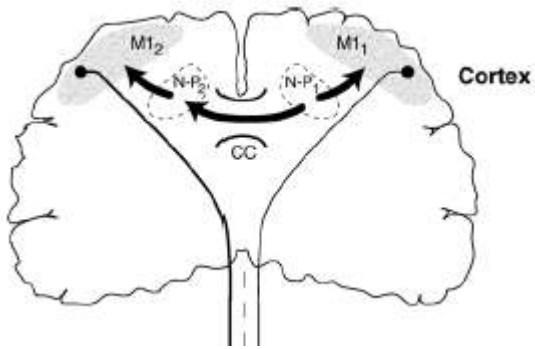
Communication entre zones distantes par synchronisation des activités

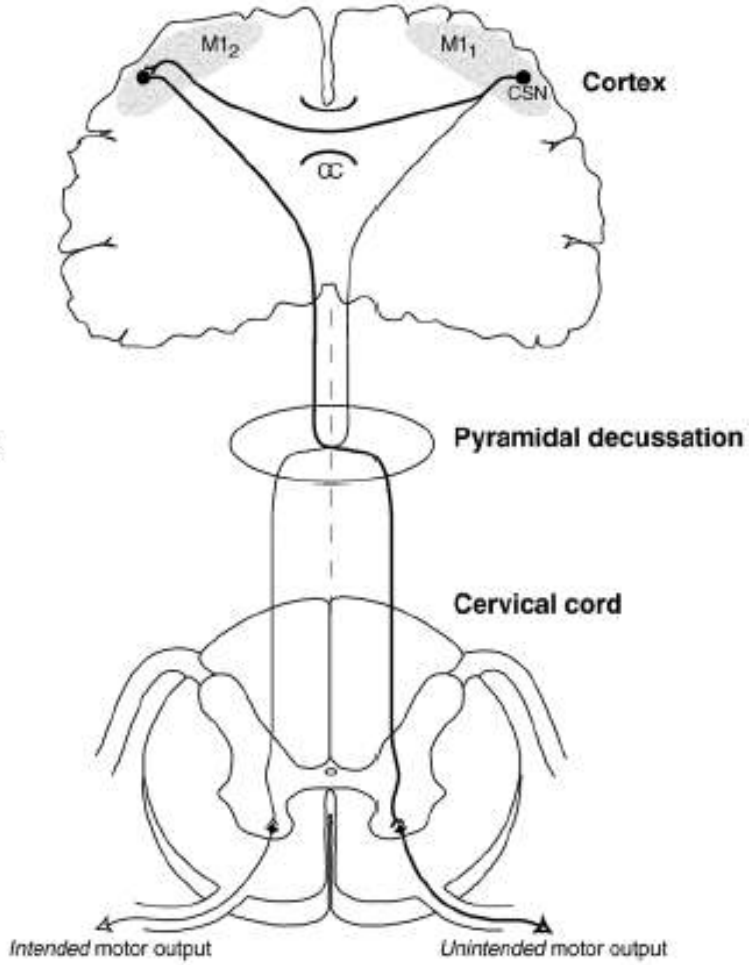


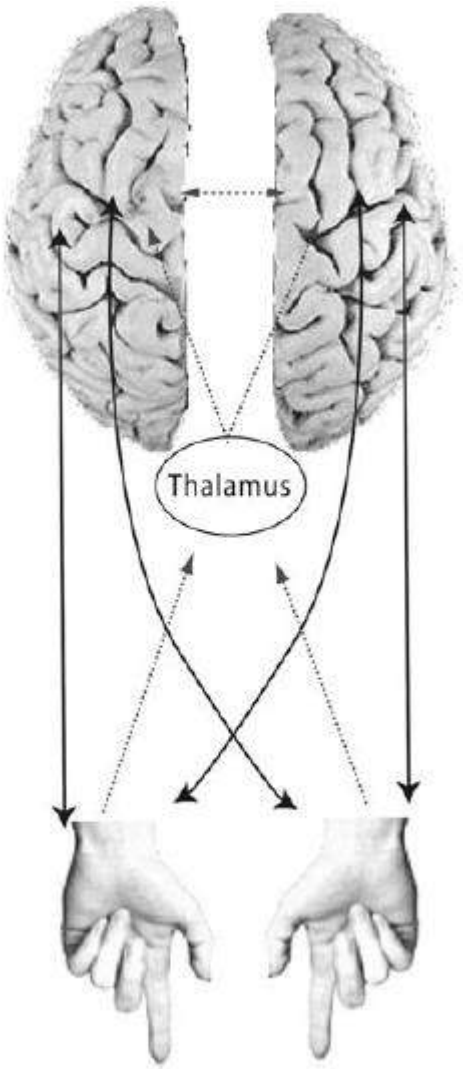


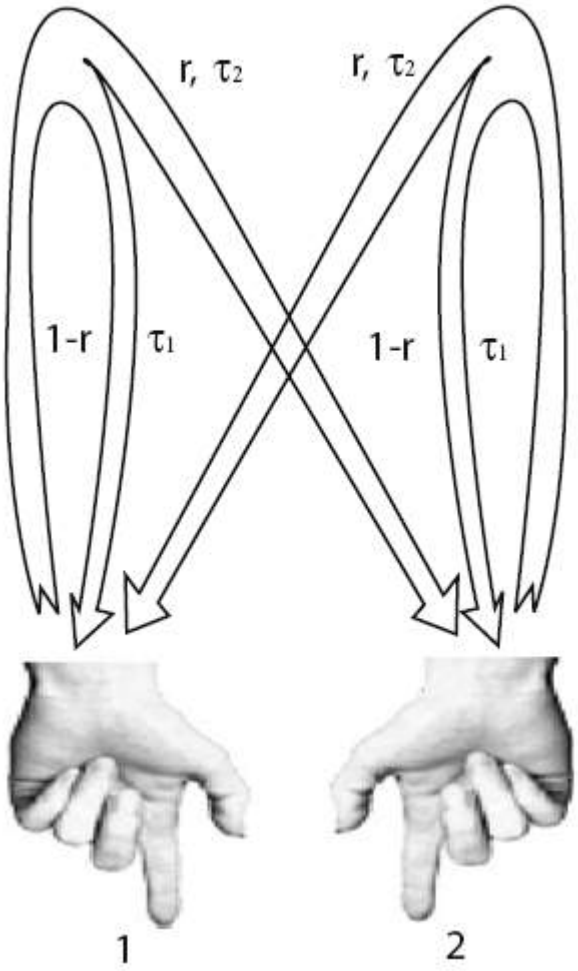
Couplages ?

- Neurophysiologie (connectivité)



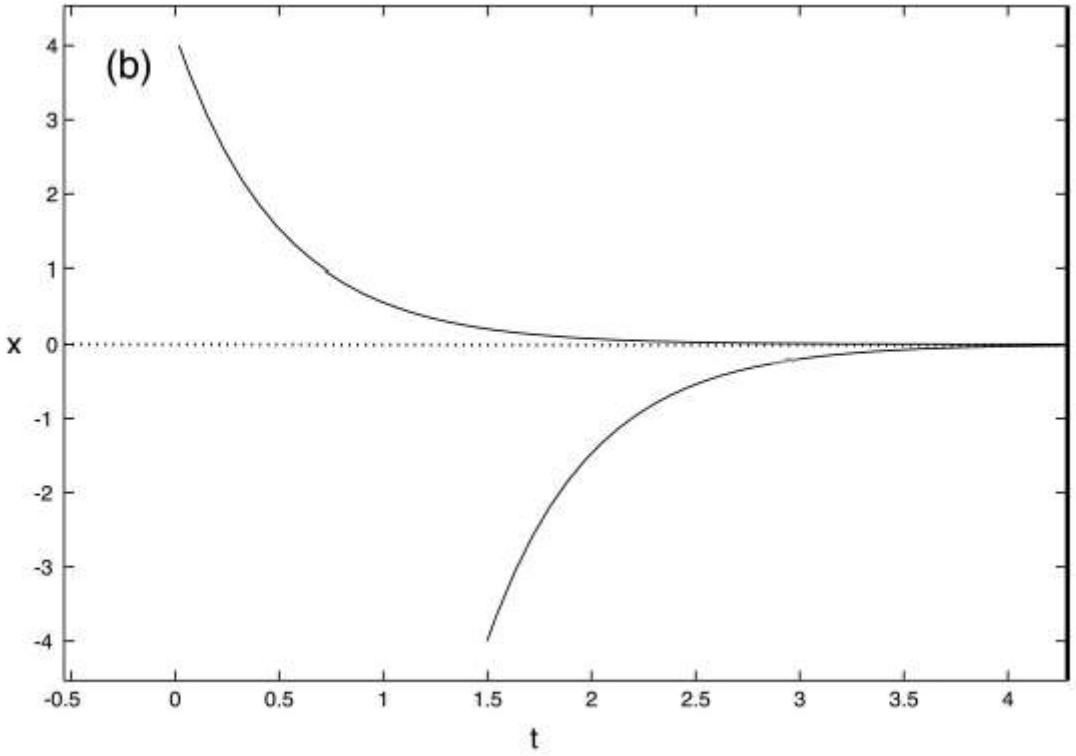



Thalamus

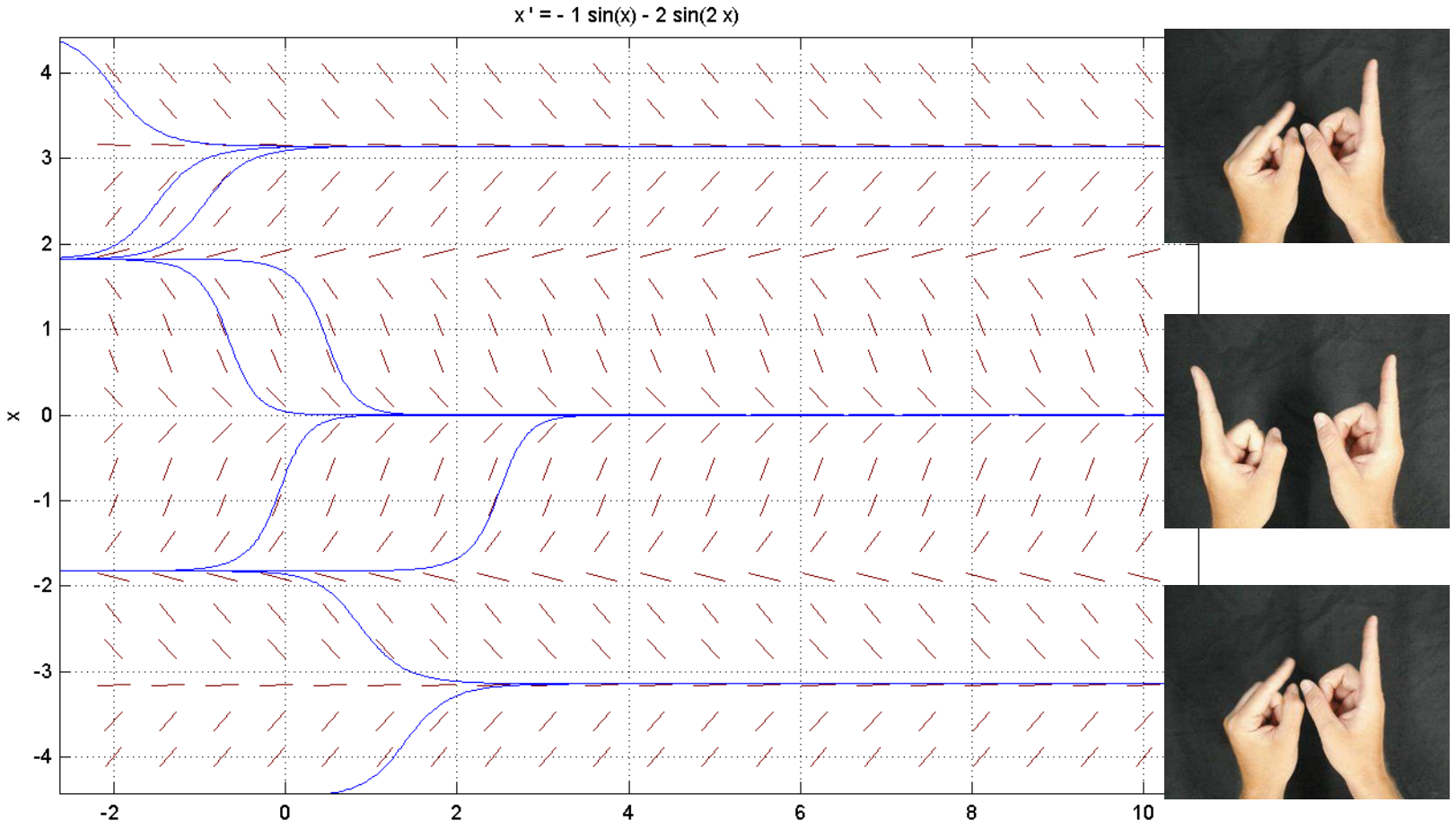

r, τ2
r, τ2
1-r
τ1
1-r
τ1
1
2

Stabilité?

Comportement « stationnaire »



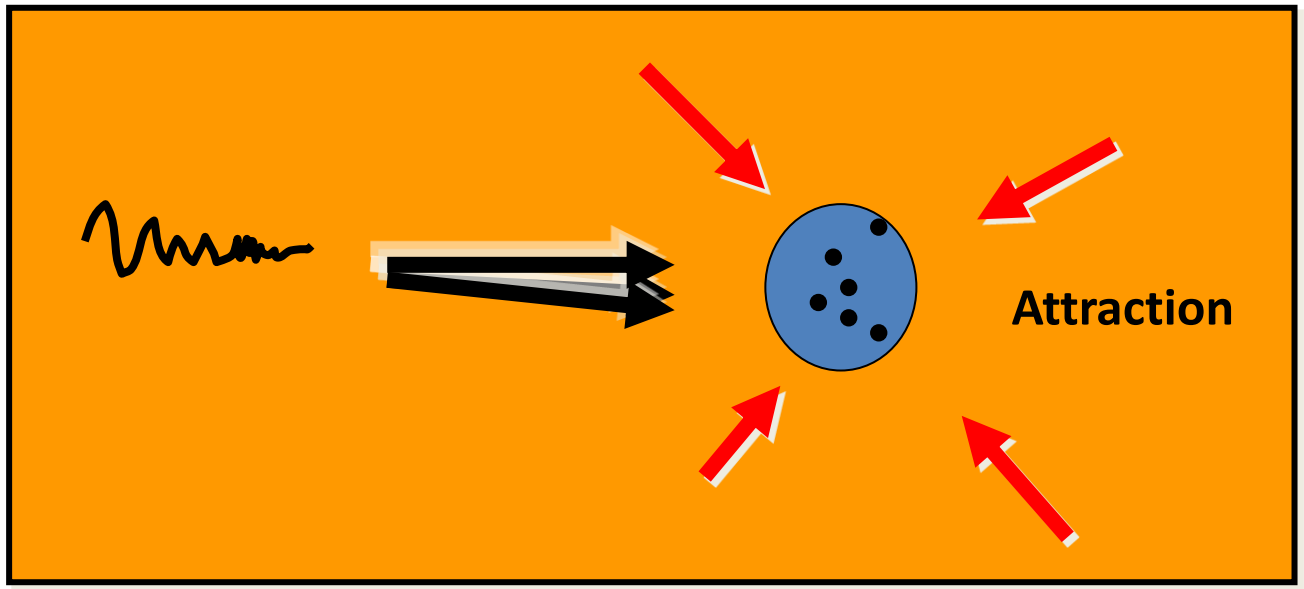
Résistance aux perturbations *(internes & externes)*



$$\dot{\phi} = -a\sin\phi - 2b\sin 2\phi$$

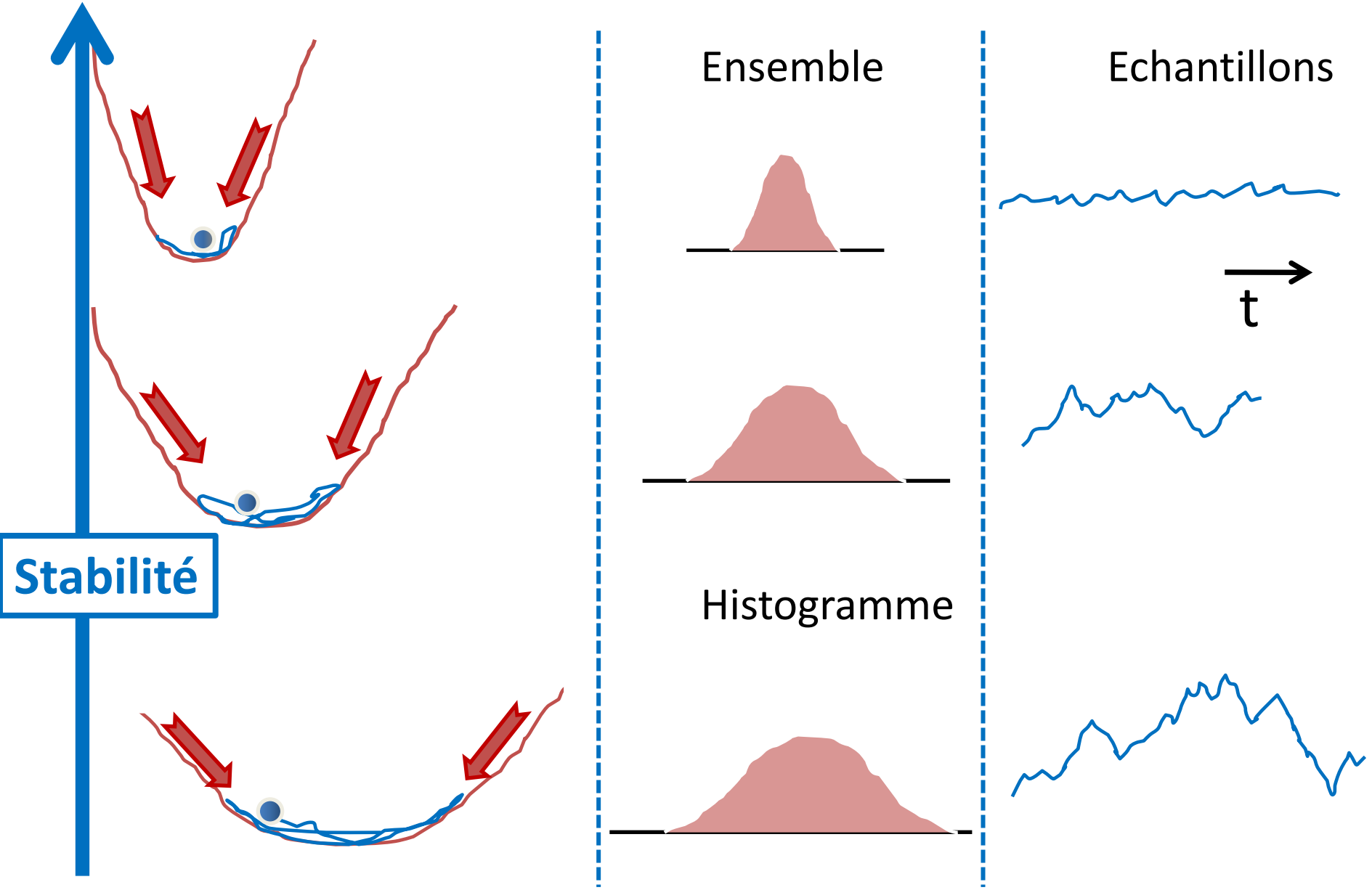
temps

Equilibre



Ex.:

- Pointage sur une cible (relation spatiale)
- Maintenir une relation temporelle invariante entre les mains


Stabilité
Ensemble
Echantillons
t
Histogramme