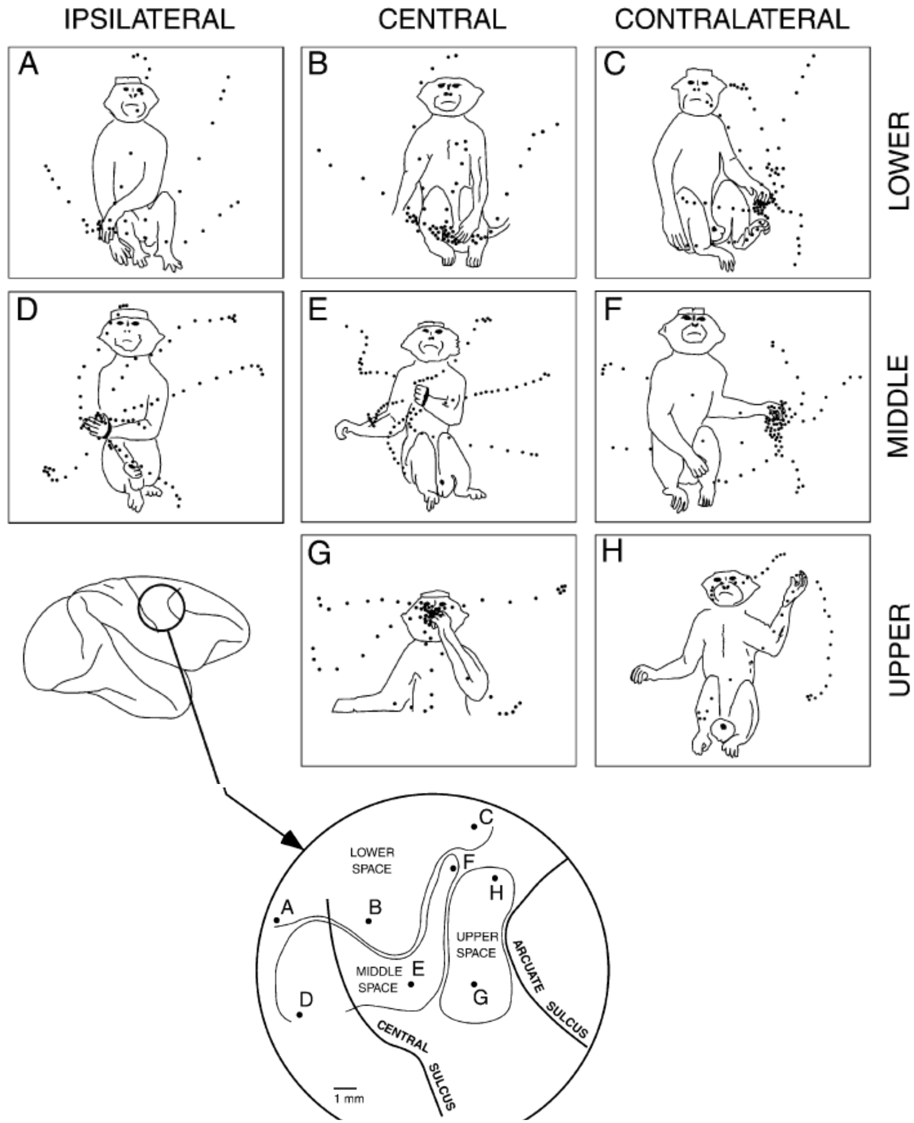


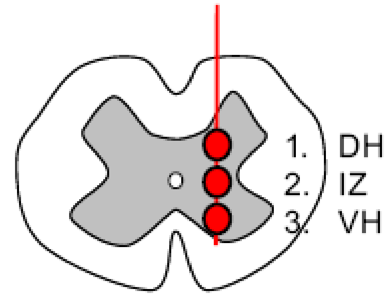
Figure 5. Eight Example Postures Illustrating the Topographic Map Found in Precentral Cortex of Monkey 1

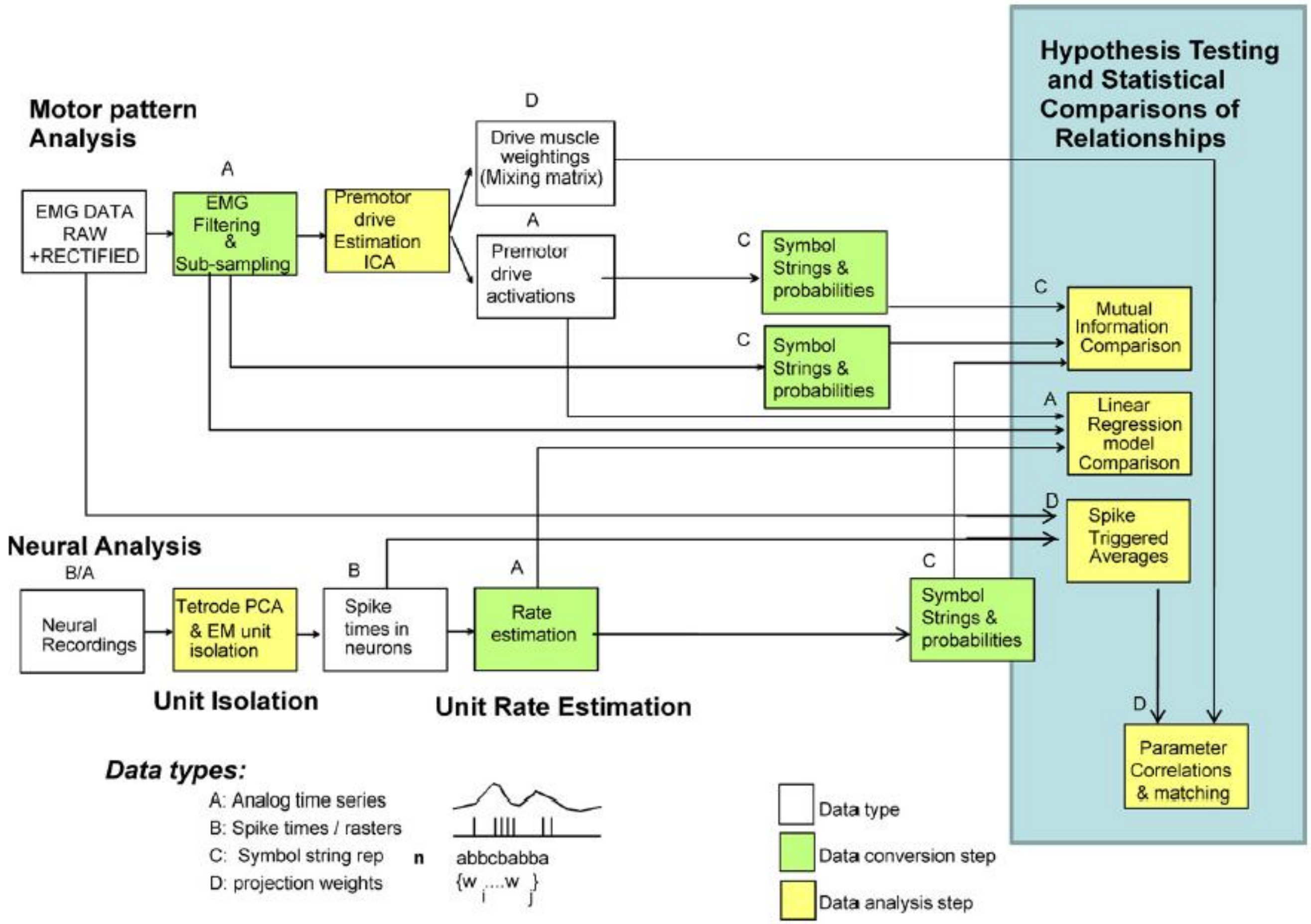
A similar map (not shown) was obtained in monkey 2. The circle on the brain shows the area that could be reached with the electrode. The magnified view at the bottom shows the locations of the stimulation sites. The area to the left of the lip of the central sulcus represents the anterior bank of the sulcus. Stimulation on the right side of the brain caused movements mainly of the left side of the body. Postures of the right arm shown in these traced video frames are incidental and not dependant on the stimulation. For the evoked movements shown in (A) and (G), stimulation was at 50 μA. In (B)–(F) and (H), stimulation was at 100 μA. For all sites, stimulation trains were presented for 500 ms at 200 Hz.

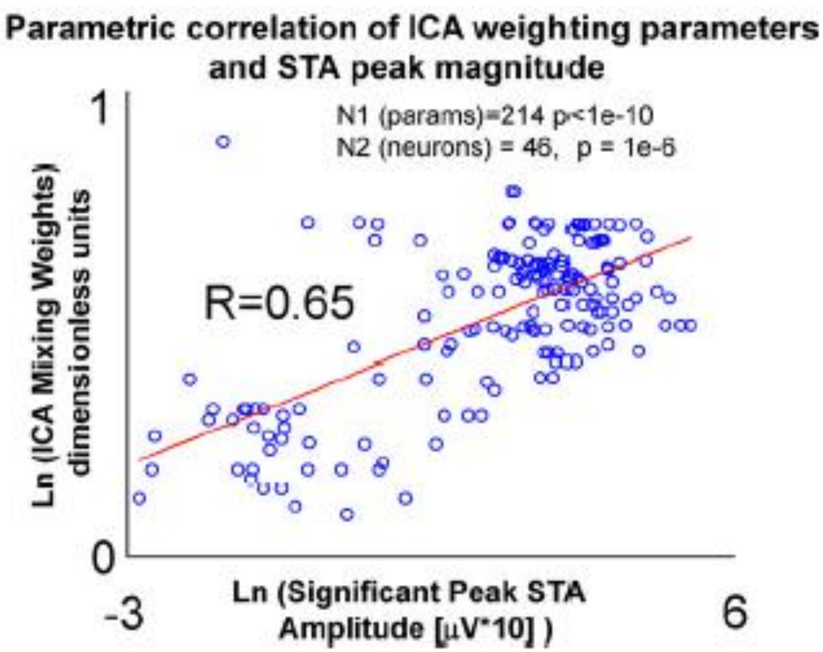
A Neural Basis for Motor Primitives in the Spinal Cord

Corey B. Hart and Simon F. Giszter

• The Journal of Neuroscience, January 27, 2010 • 30(4):1322–1336





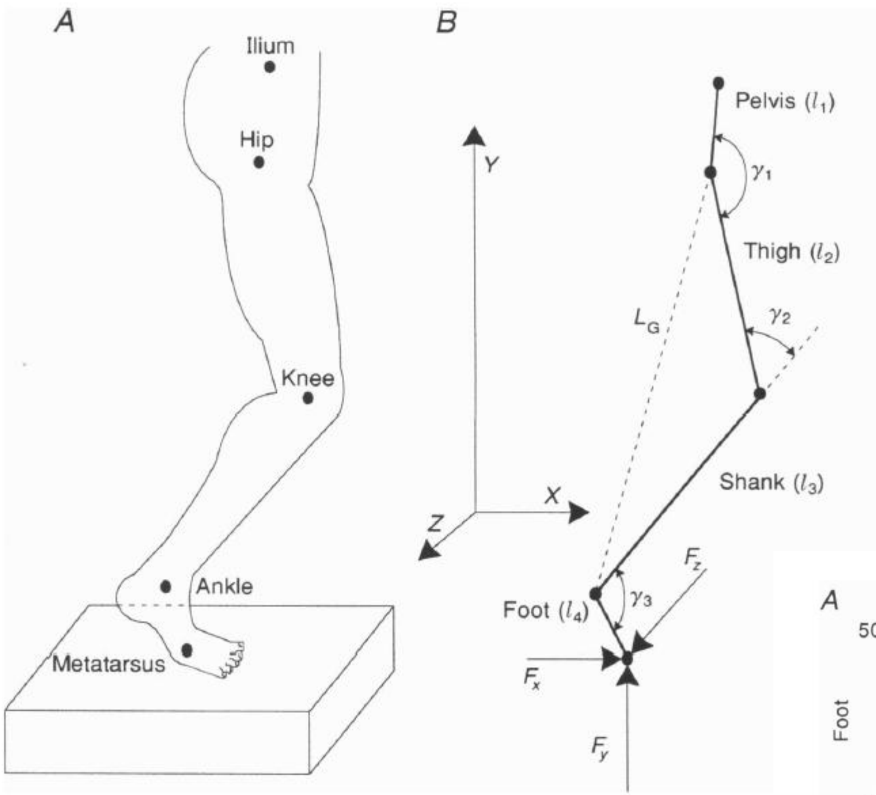


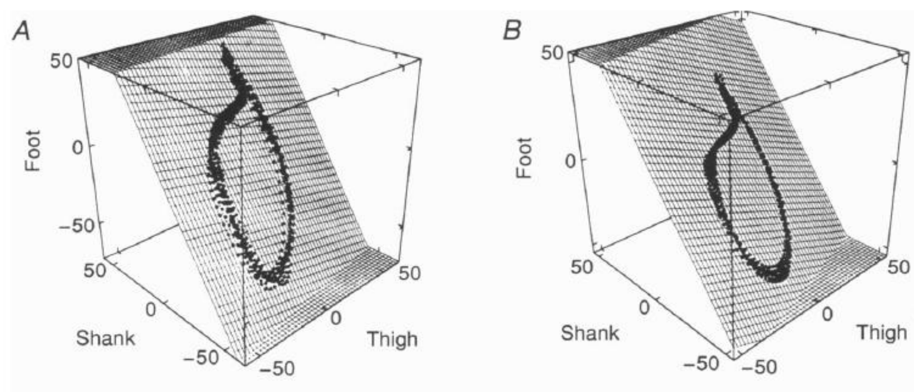
contrast, proprioceptive-related neurons and ventral horn neurons divided evenly. For 46 of the intermediate zone interneurons, we found significant postspike facilitation effects on muscle responses using spike-triggered averages representing short-latency postspike facilitations to multiple motor pools. Furthermore, these postspike facilitations matched significantly in both their patterns and strengths with the weighting parameters of individual primitives extracted statistically, although both were initially obtained without reference to one another. Our data show that sets of dedicated interneurons may organize individual spinal primitives. These may be a key to understanding motor development, motor learning, recovery after CNS injury, and evolution of motor behaviors.

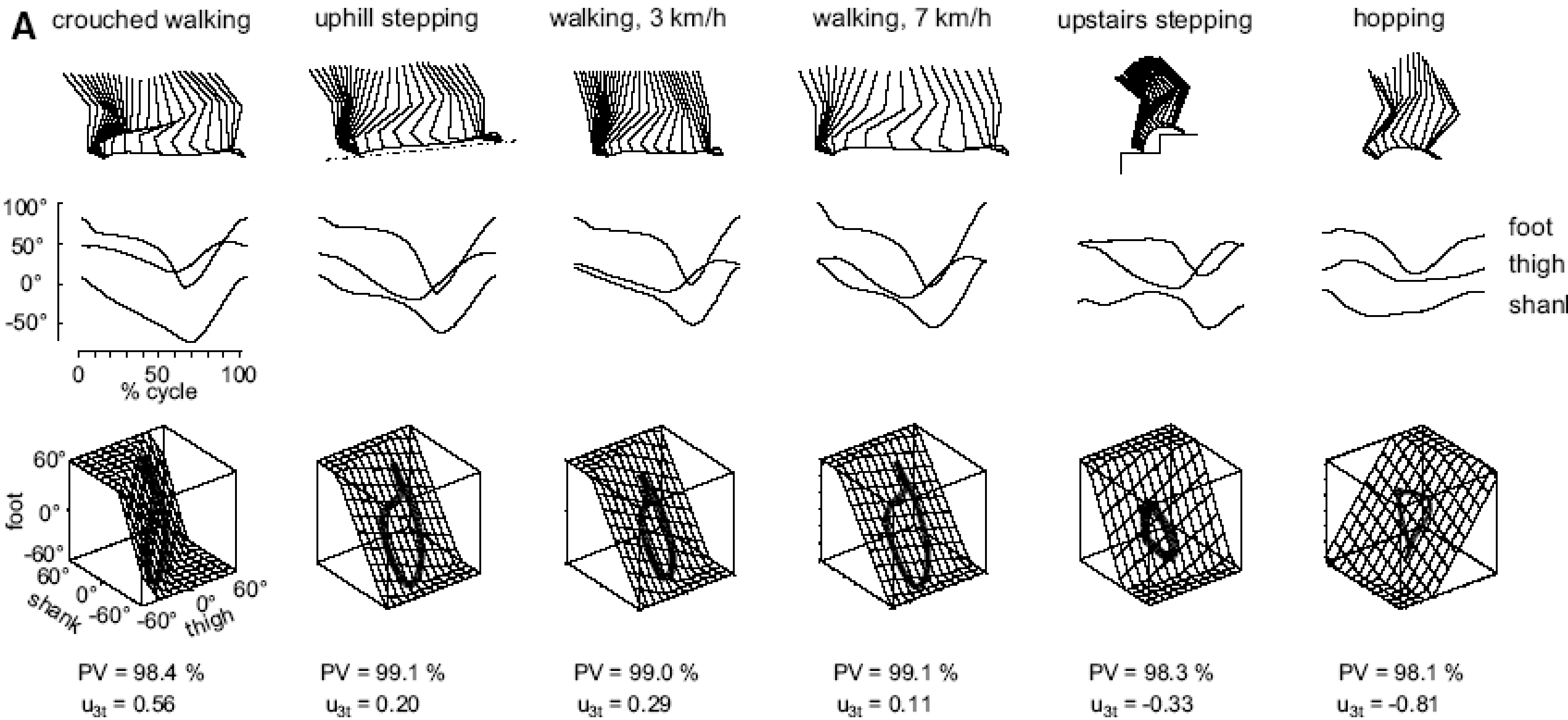
On the Origin of Planar Covariation of Elevation Angles During Human Locomotion

J Neurophysiol 99: 1890–1898, 2008.

Y. P. IVANENKO, A. D'AVELLA, R. E. POPPELE, AND F. LACQUANITI







A
crouched walking
uphill stepping
walking, 3 km/h
walking, 7 km/h
upstairs stepping
hopping
100°
50°
0°
-50°
0
50
100
% cycle
foot
thigh
shank
60°
foot
0°
-60°
60°
0°
shank
-60°
-60°
0°
thigh
60°
PV = 98.4 %
u_{3t} = 0.56
PV = 99.1 %
u_{3t} = 0.20
PV = 99.0 %
u_{3t} = 0.29
PV = 99.1 %
u_{3t} = 0.11
PV = 98.3 %
u_{3t} = -0.33
PV = 98.1 %
u_{3t} = -0.81

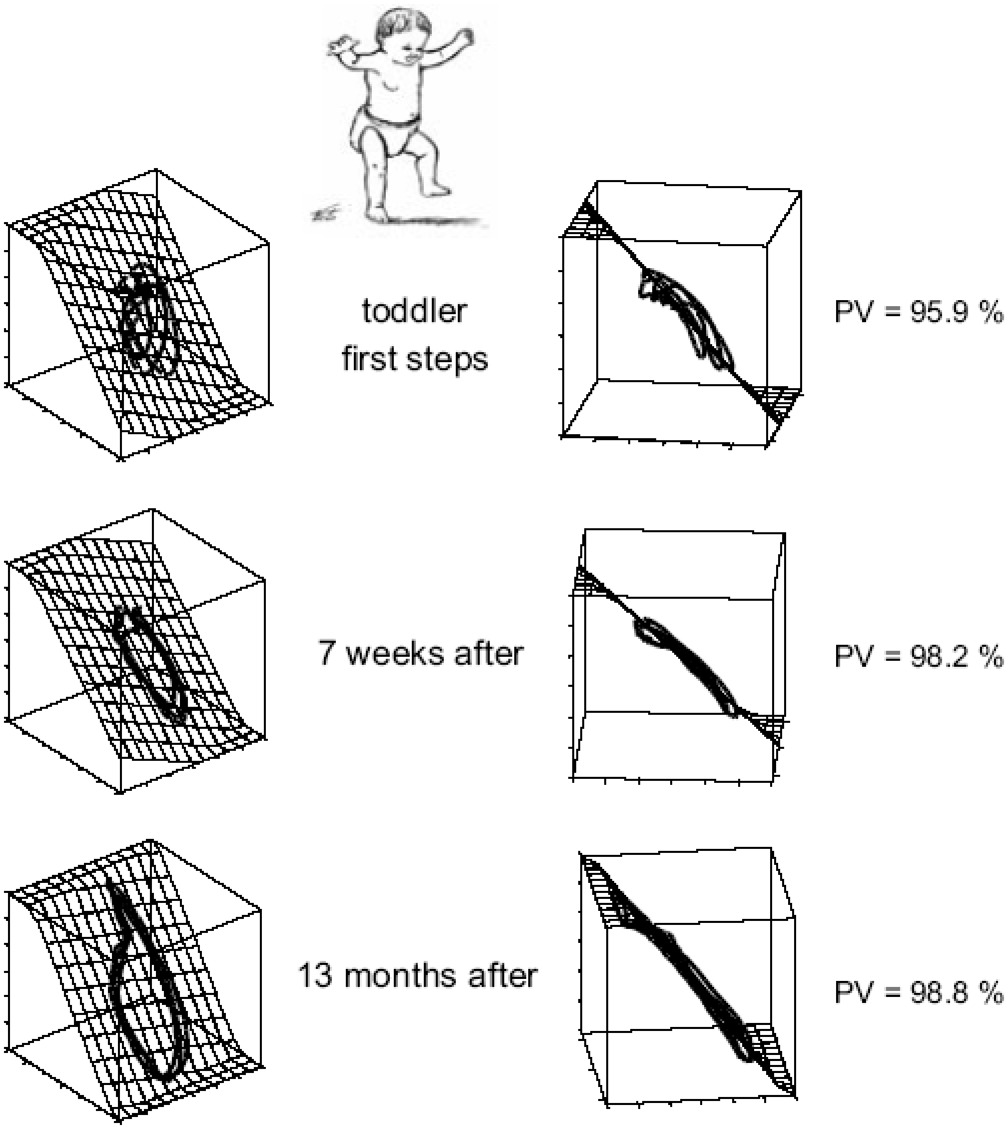
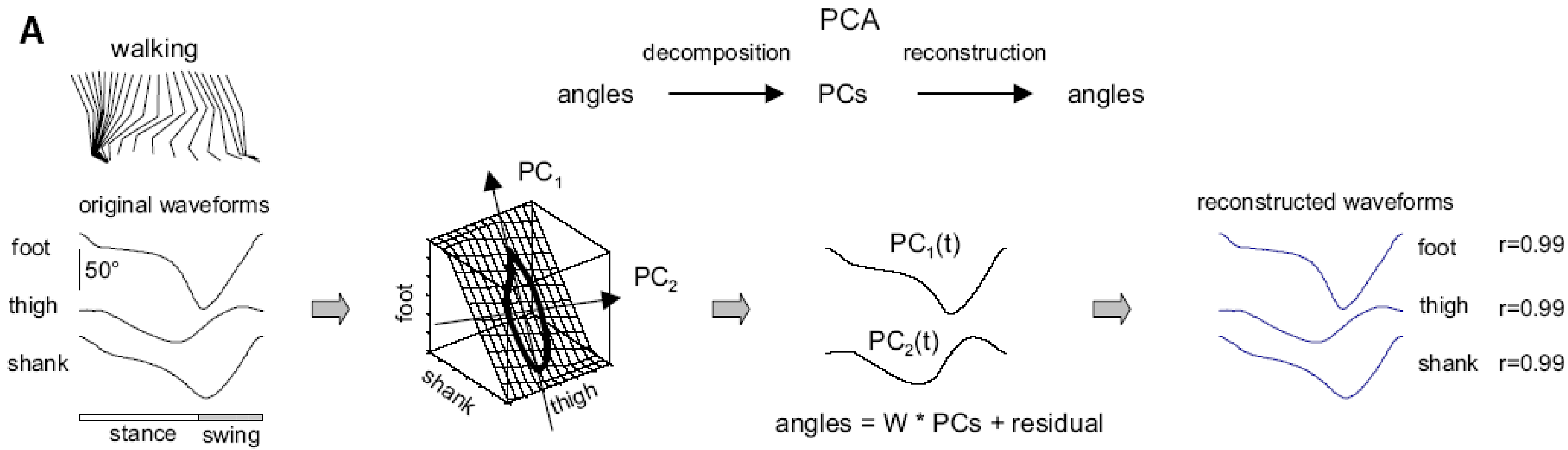


FIG. 4. Emergence of planar covariation of elevation angles. Covariation of thigh, shank, and foot elevation angles during 3 successive gait cycles performed by the same toddler at the onset of independent walking (*top*), 7 wk after (*middle*), and 13 mo after (*bottom*). The data are represented with respect to the best-fitting plane (grids) in 2 different perspectives (*left* and *right*). Note higher inter-step variability and smaller percent of total variation (PV) explained by the 1st and 2nd principal components (PCs) at the onset of independent walking.

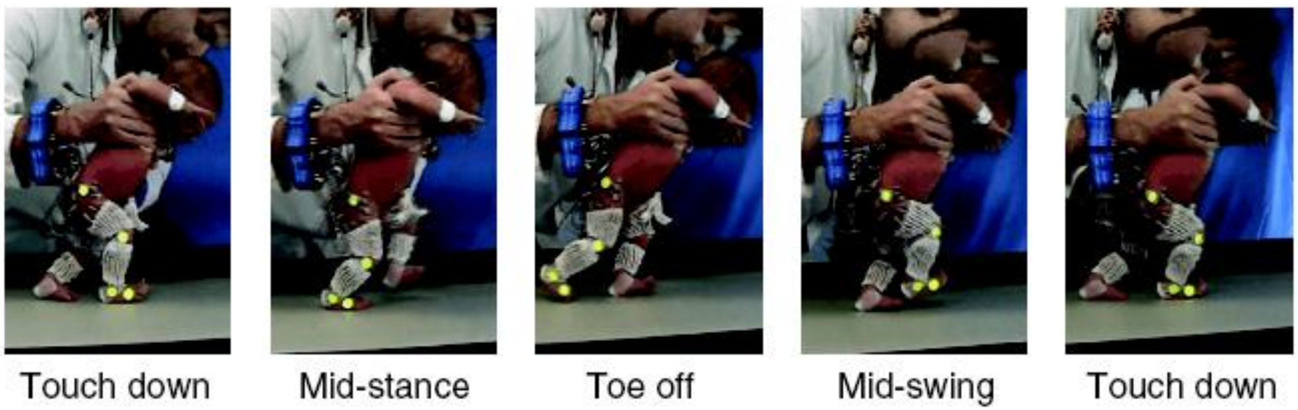

A
walking
PCA
decomposition
reconstruction
angles
PCs
angles
original waveforms
foot
50°
thigh
shank
stance
swing
PC1
PC2
foot
shank
thigh
PC1(t)
PC2(t)
angles = W * PCs + residual
reconstructed waveforms
foot r=0.99
thigh r=0.99
shank r=0.99

Locomotor Primitives in Newborn Babies and Their Development

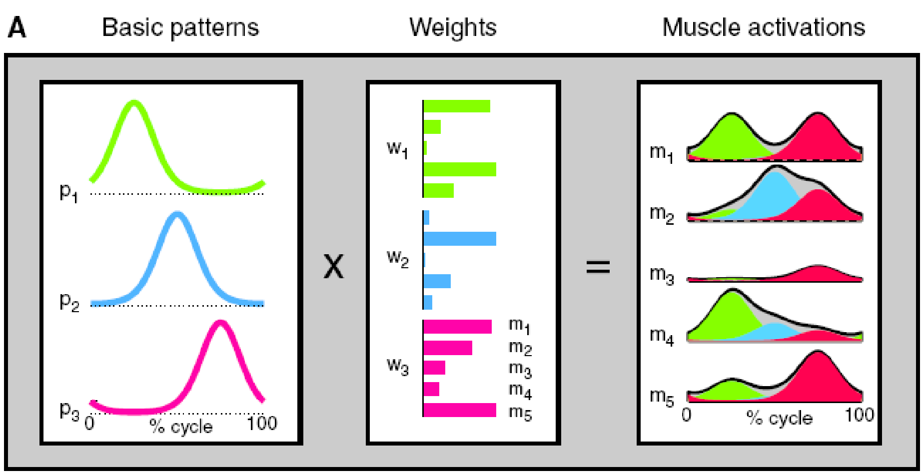
Nadia Dominici,[1,2] Yuri P. Ivanenko,[1] Germana Cappellini,[1] Andrea d'Avella,[1] Vito Mondì,[3] Marika Cicchese,[3] Adele Fabiano,[3] Tiziana Silei,[3] Ambrogio Di Paolo,[3] Carlo Giannini,[4] Richard E. Poppele,[5] Francesco Lacquaniti[1,2,6]*

SCIENCE VOL 334 18 NOVEMBER 2011

B



A



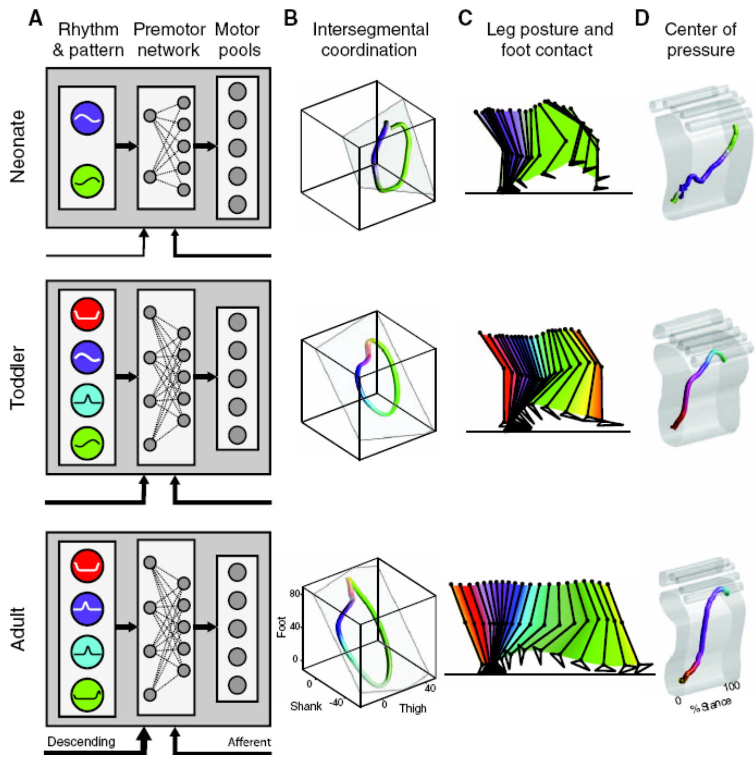
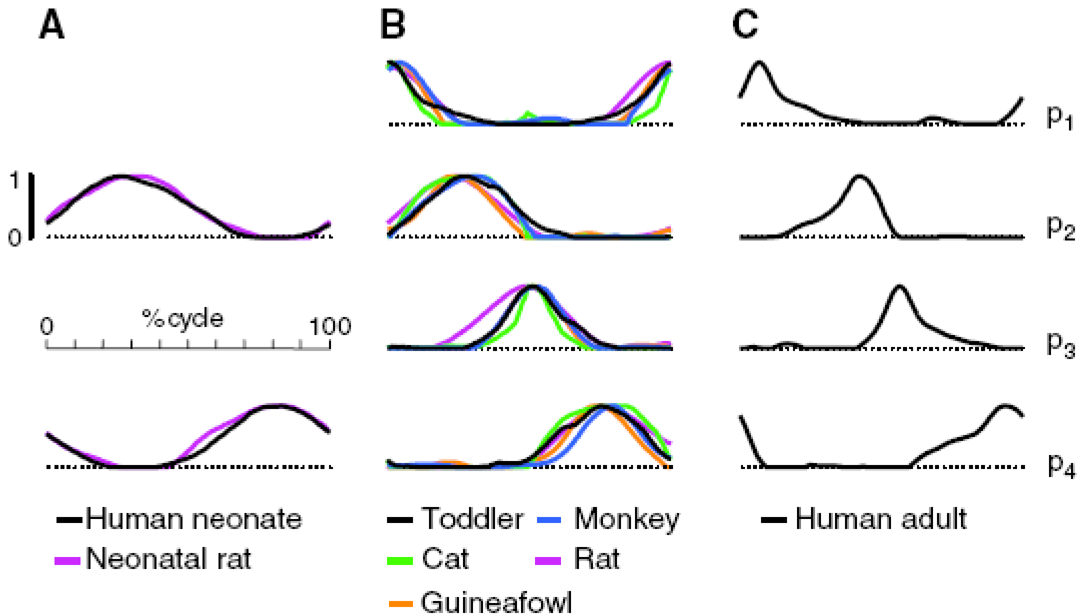


Fig. 3. Relationship between neural control modules and key biomechanical features of locomotion. (**A**) Motor rhythms and patterns generated by CPGs under descending and sensory influence (conceptual scheme). Activation patterns are distributed to different motoneuronal pools via a premotor network, dynamically reconfigurable through flexible weights. Intersegmental coordination (**B**), stick diagrams (**C**), and shifts of the center of pressure (**D**) are color-matched to the corresponding activation patterns. In toddlers, the first pattern (red) is timed at foot strike, the second (violet) at weight acceptance, the third (cyan) at forward propulsion, the fourth (green) at lift-off. In newborns, there are only two patterns, corresponding to the second and fourth of toddlers. Planar covariation of thigh elevation angle versus shank and foot angles identifies counterclockwise loops, with foot strike and lift-off at the top and bottom (B).

Fig. 4. Comparison of activation patterns for locomotion in humans and other vertebrates. (**A**) Average patterns of human newborns are superimposed on those of neonatal rats; (**B**) patterns of human toddlers are superimposed on those of adult rats, cats, monkeys, and guineafowls; and (**C**) patterns of human adults stand alone.



Functionally Specific Articulatory Cooperation Following Jaw Perturbations During Speech: Evidence for Coordinative Structures

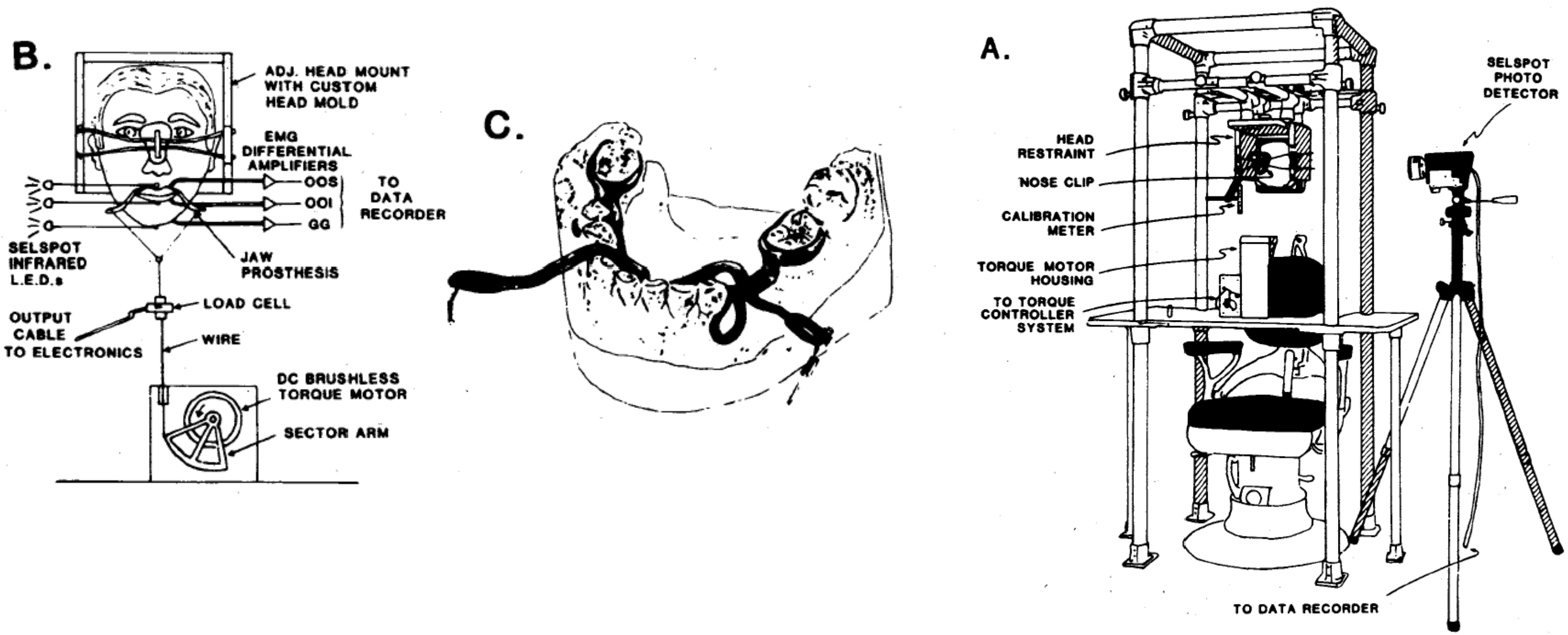
J. A. Scott Kelso

Betty Tuller

E. Vatikiotis-Bateson

Carol A. Fowler

Journal of Experimental Psychology: Human Perception and Performance
1984, Vol. 10, No. 6, 812–832



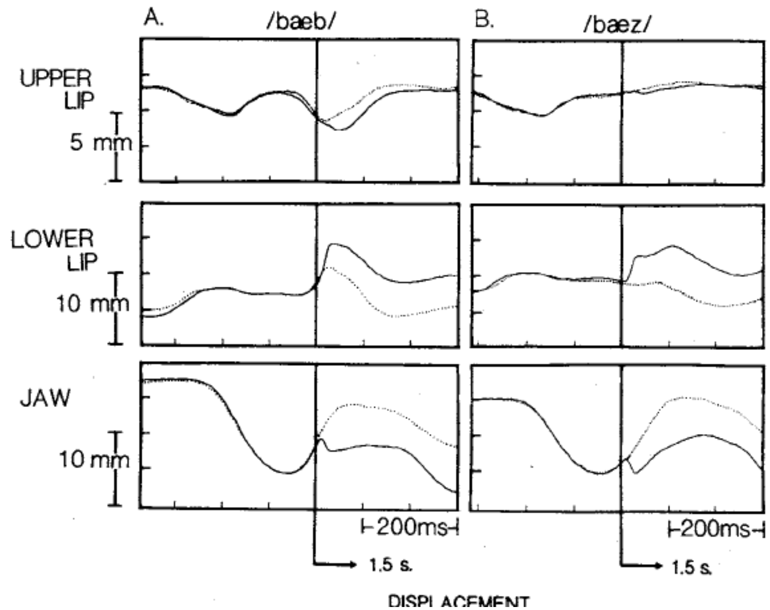


Figure 3. Upper lip, lower lip (with jaw movement contribution subtracted), and jaw displacement for the utterances /bæb/ and /bæz/. (Each trace represents the average of 10 tokens for perturbed [solid line] and control [dotted line] conditions. The vertical line in each window marks the onset of torque to the jaw. For illustration purposes, the two conditions have been overlaid by temporally sliding the control condition, which does not have a torque line-up point, relative to the perturbed condition, which does, taking the jaw as a reference point.)

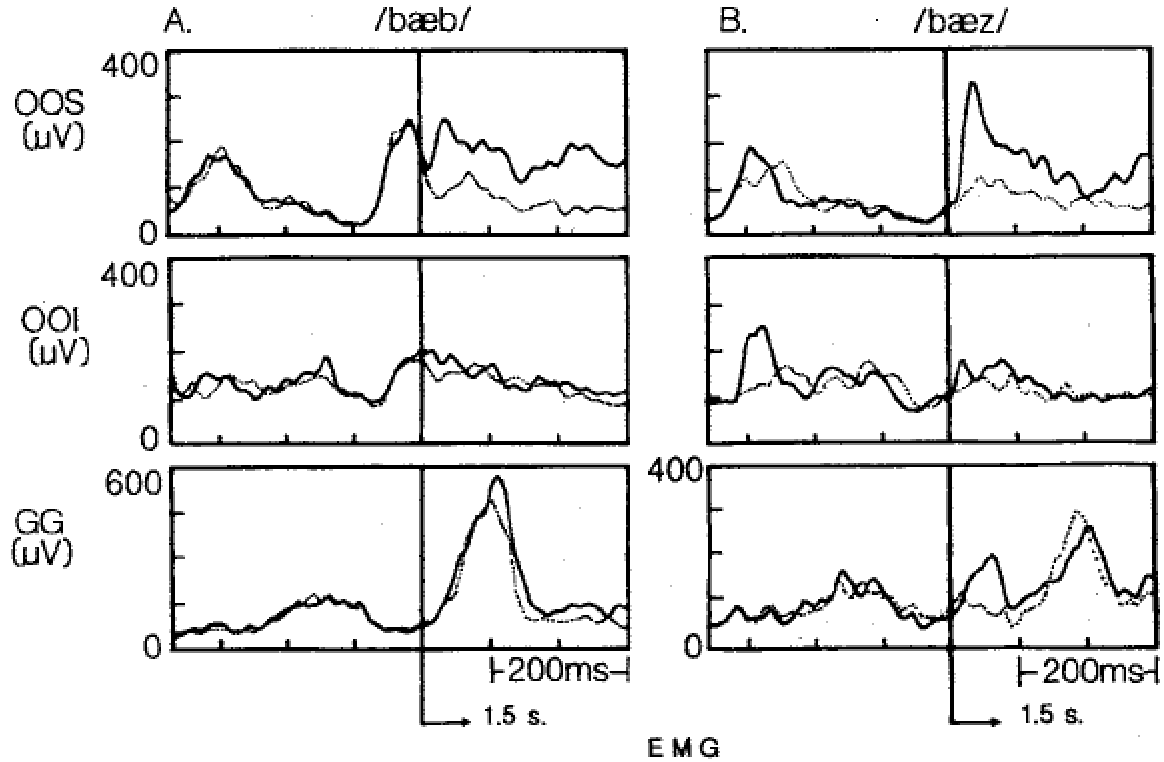


Figure 5. Average rectified electromyographic (EMG) activity of upper lip (OOS), lower lip (OOI), and tongue (GG) muscles for perturbed (solid trace) and control (dotted line) conditions.

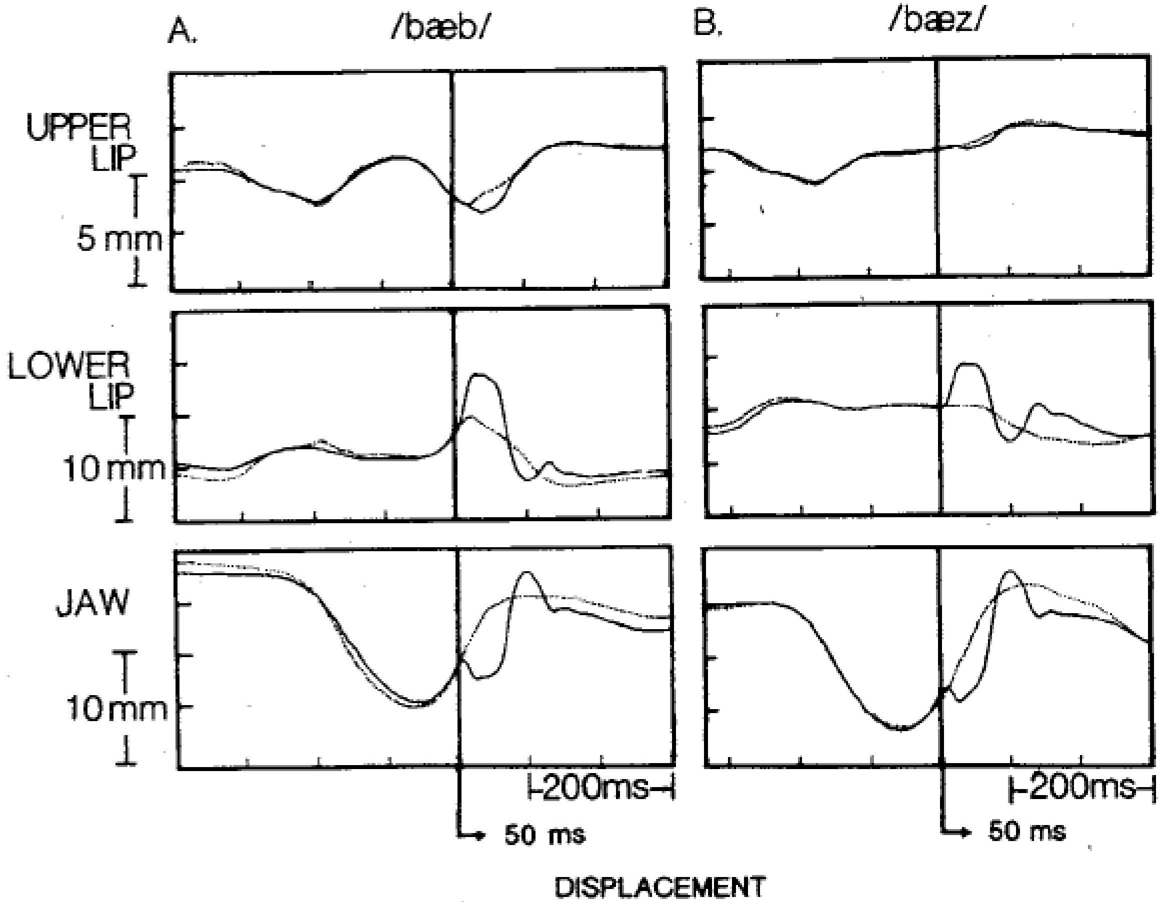


Figure 7. Upper lip, lower lip (with jaw movement contribution subtracted), and jaw displacement for the utterances /bæb/ and /bæz/. (Each trace represents the average of 10 tokens for perturbed [solid line] and control [dotted line] conditions. The vertical line in each window marks the onset of torque to the jaw. In this case a torque of 5.88 N is applied for only 50 ms.)

INVARIANT CHARACTERISTICS OF A POINTING MOVEMENT IN MAN[1]

J. F. SOECHTING[2] AND F. LACQUANITI

The Journal of Neuroscience
Vol. 1, No. 7, pp. 710–720
July 1981

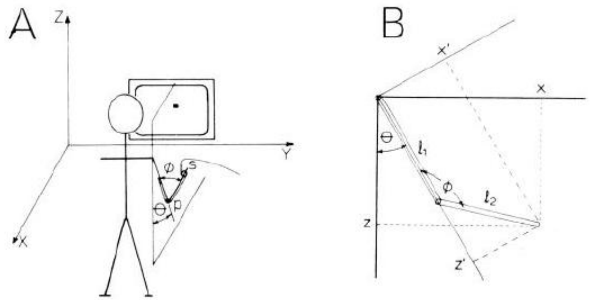


Figure 1. Schematic of experimental setup. Arm movements were executed in the sagittal plane to a target displayed on a television screen. Wrist position in three-dimensional coordinates (X, Y, Z) was measured by ultrasound; the source (s) is located at the wrist. Elbow angle (ϕ) was measured by means of a potentiometer (p). Shoulder angle (θ) was calculated indirectly, using the geometrical relationships between x, z and x', z' depicted in B. The length of the upper arm is l_1 and that of the forearm is l_2.

participate in the organization of the movement. The first such invariance to be identified was that the trajectory in space is independent of movement speed. Secondly, the movement can be viewed as consisting of two phases, an acceleratory phase and a deceleratory one, with the movement during the acceleratory phase being so organized as to maintain the ratio of elbow angular velocity to shoulder angular velocity invariant with respect to target location in the deceleratory phase. It is

design, rather simple. Subjects were asked to point toward a target with a movement which, in a first approximation, involves only two degrees of freedom (elbow extension and shoulder flexion), is unidirectional, and is performed in the vertical plane. A large degree of accuracy was not required and the subjects would on occasion miss the target by as much as 0.5 cm. Presumably then, terminal corrective actions were not a prominent feature

The first of these invariances is that the trajectory in space described by the movement differs little from trial to trial and is independent of the speed of the movement. This agrees with the conclusion that the trajectory described by handwriting is independent of the speed or the size of the writing (Viviani and Terzuolo, 1981). For handwriting, this result perhaps is not unexpected since the trajectory also defines the script. In our experiments, there was no such external constraint because only the initial and final positions were determined.

The fact that the trajectory of the movement does not depend on its speed implies that movement duration, and thus absolute time, is a free variable (Viviani and Terzuolo, 1981). This conclusion agrees with the finding that the pattern which characterizes the way a word is typed by professional typists is independent of the speed with which it is typed or the forces required to produce the movement (Terzuolo and Viviani, 1980). Our finding also implies that it is the trajectory and not the forces required to produce it which is invariant and which thus, by implication, is planned and controlled. In fact (Figs.

and elbow. The net torque acting at each joint is a combination of gravitational torques (related to angular displacement and independent of speed), Coriolis forces (proportional to the square of angular velocity), and inertial torques (proportional to angular acceleration).

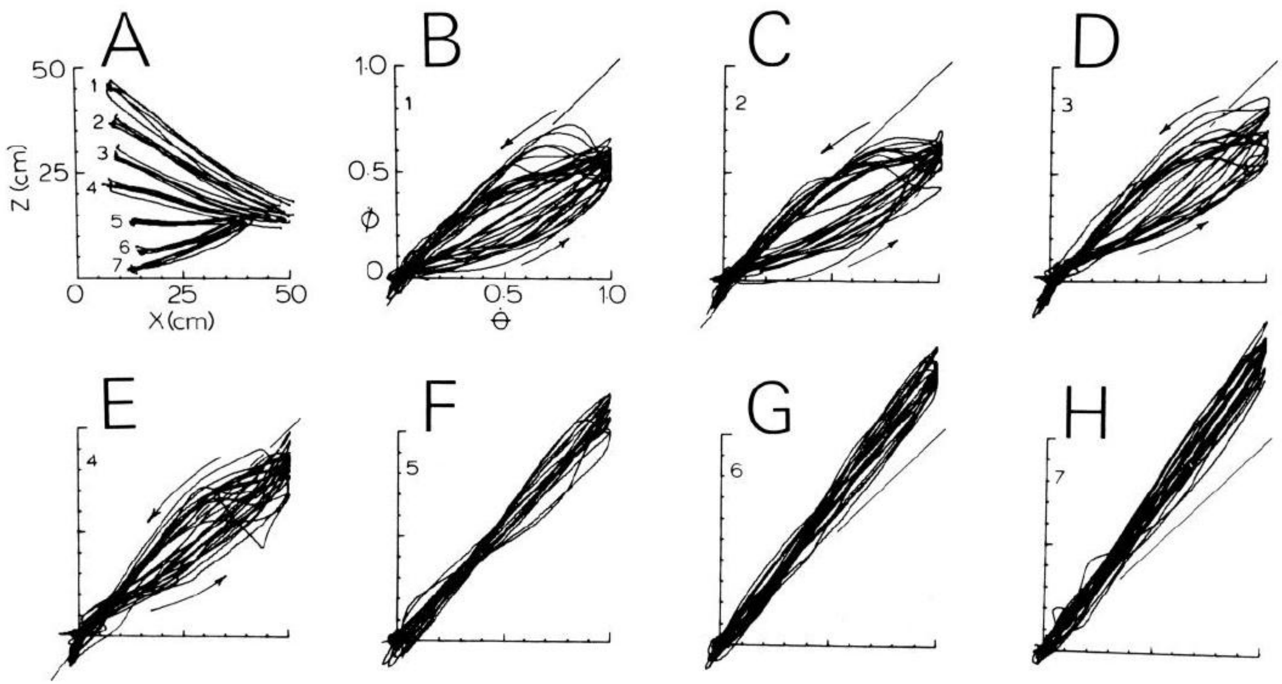
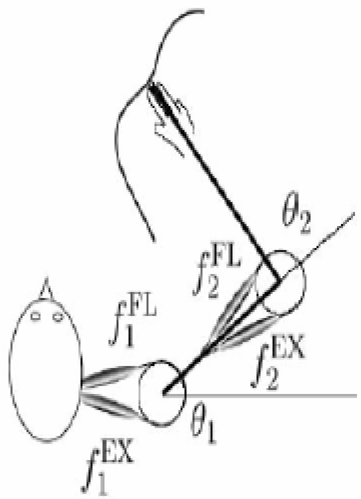
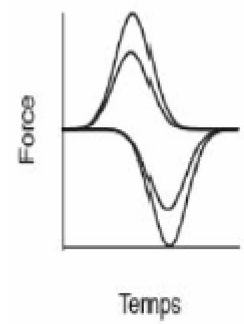


Figure 5. Dependence of movement trajectory on target locations. *A*, Five representative trials from one subject to each of seven different target locations; *B* to *H*, The phase plane representation of all of the data from that subject to each of the target locations. *Arrows* indicate the direction of movement and a *45° line* ($\dot{\phi} = \dot{\theta}$) has been drawn for reference. Data are from subject 2 in Table I.

Calcul des couples articulaires

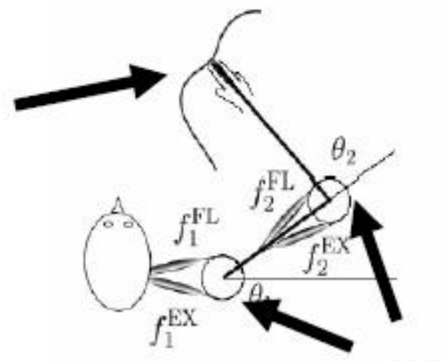
- Pour réaliser la trajectoire articulaire désirée





Mathématiquement : dynamique inverse

Espace de la tâche



Espace articulaire

Sources d'erreur

- Localisation de la cible (cible/œil, œil/tête, tête/corps)
- Localisation de la main et posture du bras (visible ou non)
- Estimation des grandeurs physiques (longueur, masse, inertie)
- Approximation des transformations
- Perturbations (e.g. la cible a bougé)
- Bruit

Solution : correction en ligne

- Utilisation de la vision et de la proprioception
- Délais dans les retours sensoriels

Points-clé

- Débat non résolu : boucle ouverte ou boucle fermée?
- Programme moteur vs élaboration en ligne
- Réflexe vs volontaire

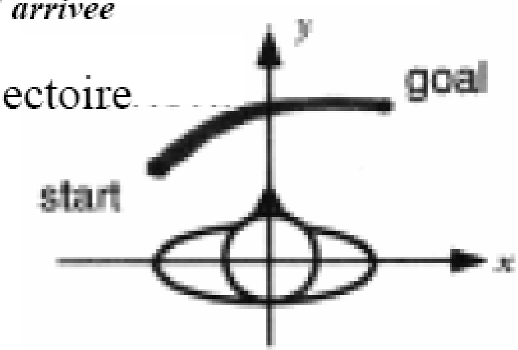
Emmanuel Guigon

Système visuel

Coordonnées cartésiennes

But:
[X, Y] départ- [X, Y] arrivée

Planification de la trajectoire

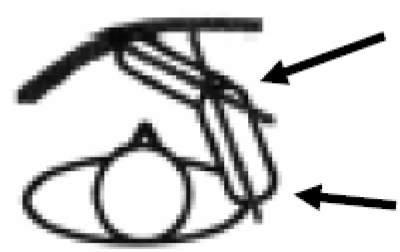


Déplacement
de la main:
X(t), Y(t)

Cinématique inverse

Coordonnées articulaires

Angles articulaires
θ(t)



Dynamique inverse

Moments ou « couples »
(forces)
Commande motrice

Contrôle du bras

2 Solutions pour résoudre les transformations

- Feedback perceptifs

-Feedforward

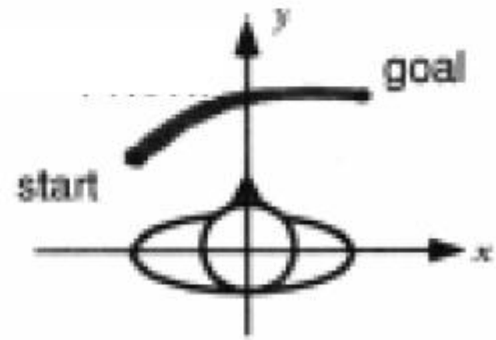
→Modèles internes pour être plus rapide que les boucles de feedback
(100ms proprioceptif, 200ms pour feedback visuel; Keele, 1981)

→Modèles appris et affinés, pour effectuer les transformation cinématiques et / ou dynamiques

Le contenu des modèles internes

- Qu'est ce qui est appris ?
- Quel est le locus fonctionnel de l'apprentissage ?
- Quel est le "contenu" de l'apprentissage ?
- A quel "niveau" se situe cet apprentissage ?
- A quelles coordonnées cet apprentissage est il spécifique ?

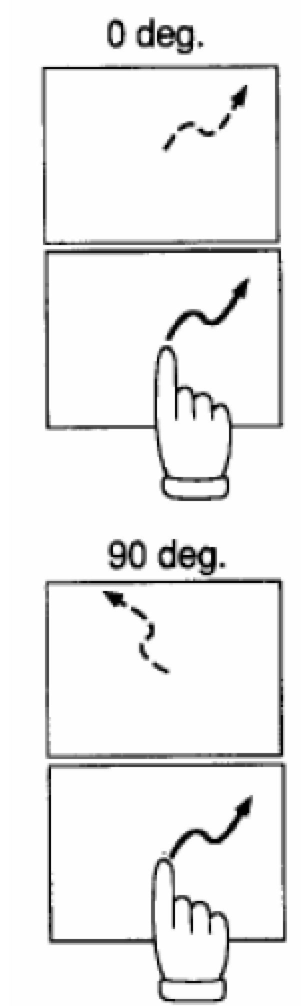
Niveau de la tâche

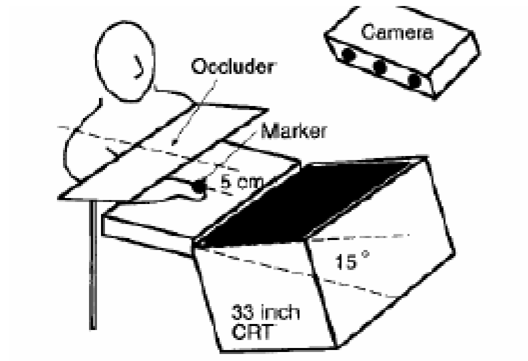


Niveau de l'effecteur

Transfert d'apprentissage intermanuel

Apprentissage visuo-moteur :
rotation du feedback visuel





Imamizu & Shimojo (1995)

2 Prédictions :

1) l’apprentissage se situe au niveau de l’espace de la tâche :
Transfert intermanuel

2) L’apprentissage se situe au niveau articulaire
Pas de transfert intermanuel

Resultats : 100% de transfert inter-manuel

Primitives, modularity, synergies, coordination structure

Abstractness
Motor equivalence
Goals activations (Graziano)
Equifinality
Abundance/ flexibility (self motion- UCM)
Noise robustness

Difference ?

Continuum/ categorial → qualitative

Singularity/ catastrophic difference

Uno-Temprado/ transfer

Postural strategies, transfer of learning
Flaugoire???

Group symmetry de Turvey et al odometry

Underlying stuff: *primitive* network ? 8 cells network Golubitsky