Initial state estimates of gravity-related force field shape motor planning of goal-directed movements

Lionel Bringoux

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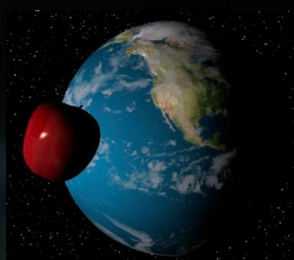
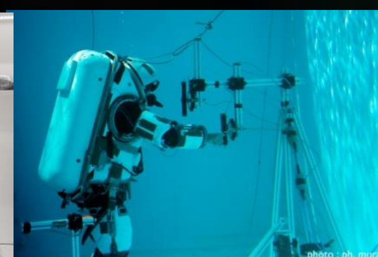




Institut des Sciences du Mouvement (ISM E.J. Marey)

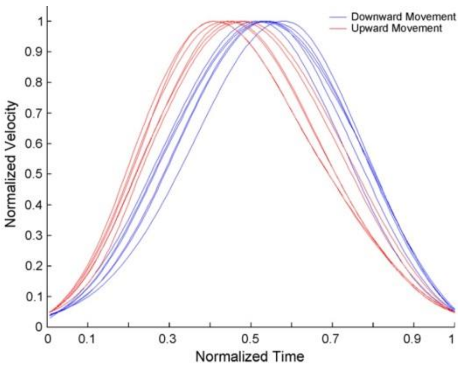
Aix-Marseille Université / CNRS

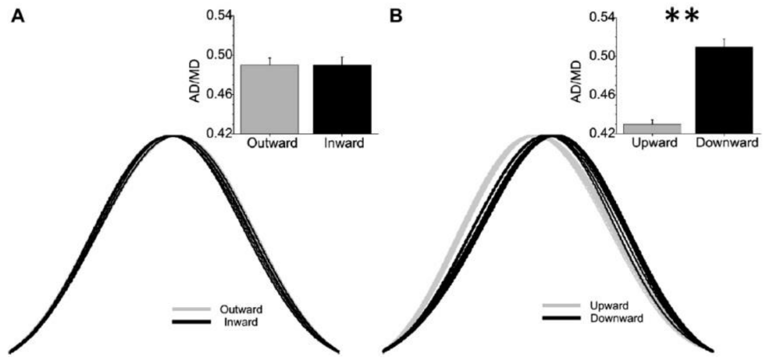
Symposium B-7 : Rôle des informations vestibulaires et gravito-inertielles dans la planification du mouvement

Gravity and motor behavior on Earth

Direction-dependent kinematic asymmetries in arm movements

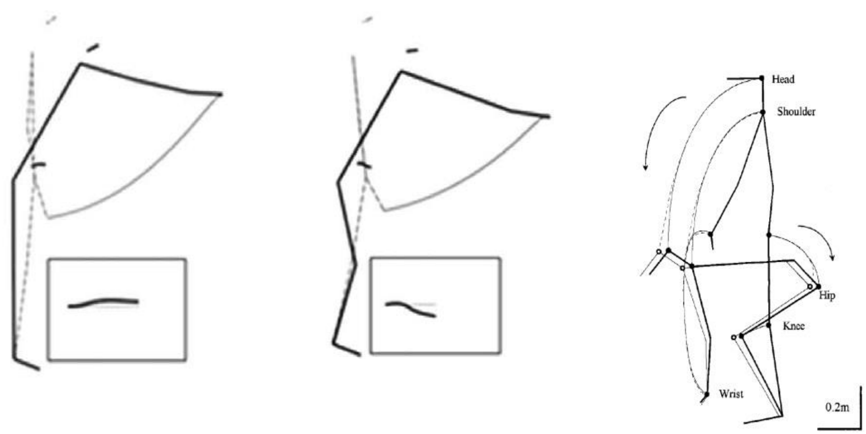
Papaxanthis et al., 1998; 2003; Gentili et al., 2007; Le Seac'h & McIntyre, 2007; Sciutti et al., 2012; Gaveau et al., 2014





Control of Center of Mass (CoM) projection

Babinski, 1899; Massion et al., 1992; 2004; Vernazza et al., 1996



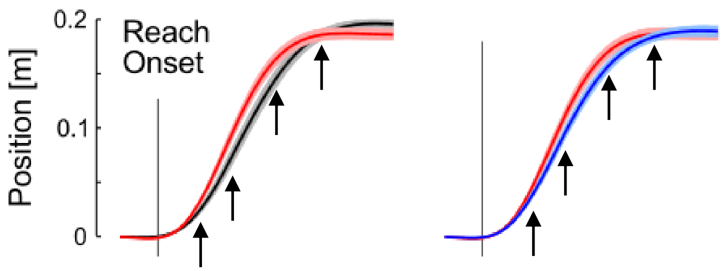
Temporal structure of focal component

An ubiquitous force playing an important role in motor control

Postural strategy

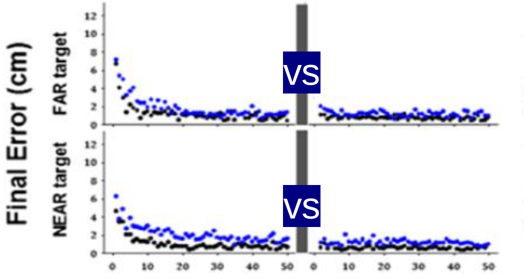
Pending questions…

- Online motor adjustments relative to the gravity-related force field or prior account in motor planning?



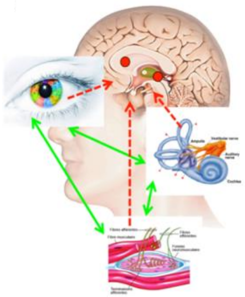
- Earliest changes or late corrections?
- Prior info / Force field exposure?
- Prior estimates / Internal models?

- Progressive adaptation to a novel gravity-related force field?



- Experience needed?
- Slow/fast adaptive effects vs Calibration?

- Sensory inputs ?



- Sensing gravity?
- Vestibular vs somatosensory -driven?

Whole-body reaching in 0g

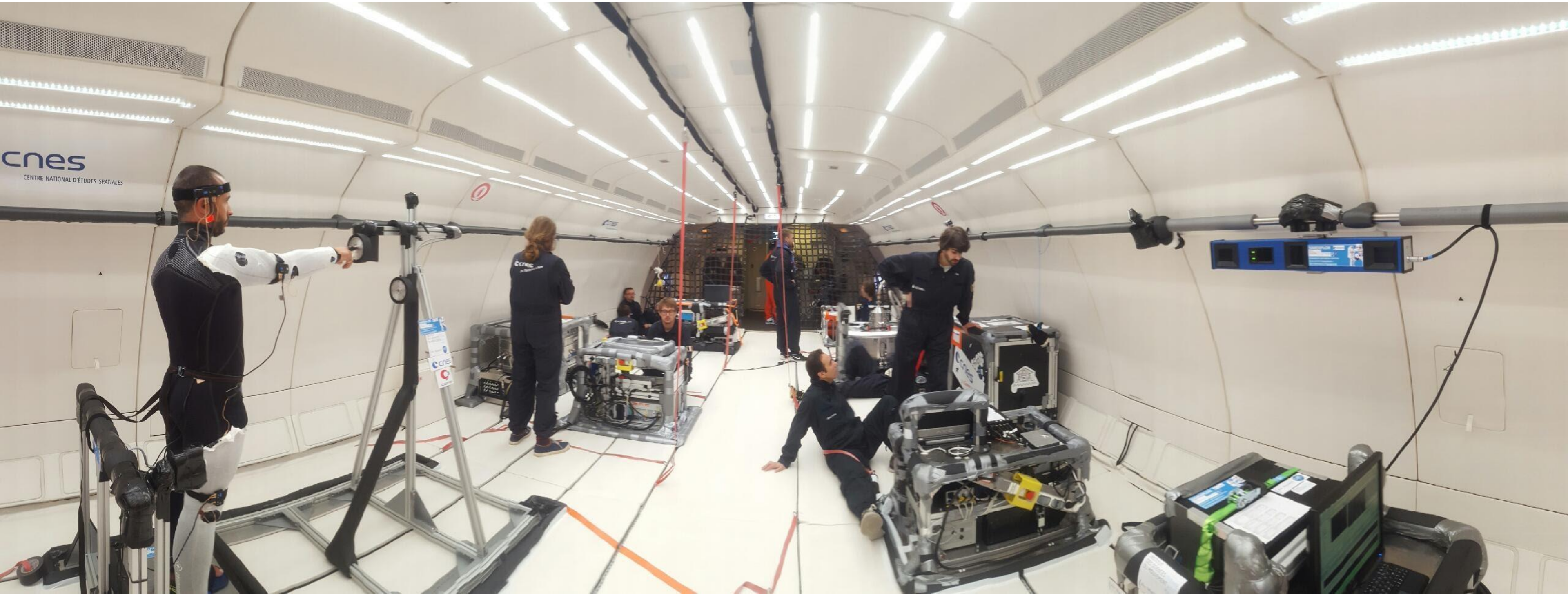
frontiers in Physiology

ORIGINAL RESEARCH
published: 20 October 2017
doi: 10.3389/fphys.2017.00821

Check for updates

Sensorimotor Reorganizations of Arm Kinematics and Postural Strategy for Functional Whole-Body Reaching Movements in Microgravity

Thomas Macaluso[1], Christophe Bourdin[1], Frank Buloup[1], Marie-Laure Mille[1,2,3], Patrick Sainton[1], Fabrice R. Sarlegna[1], Jean-Louis Vercher[1] and Lionel Bringoux[1]*

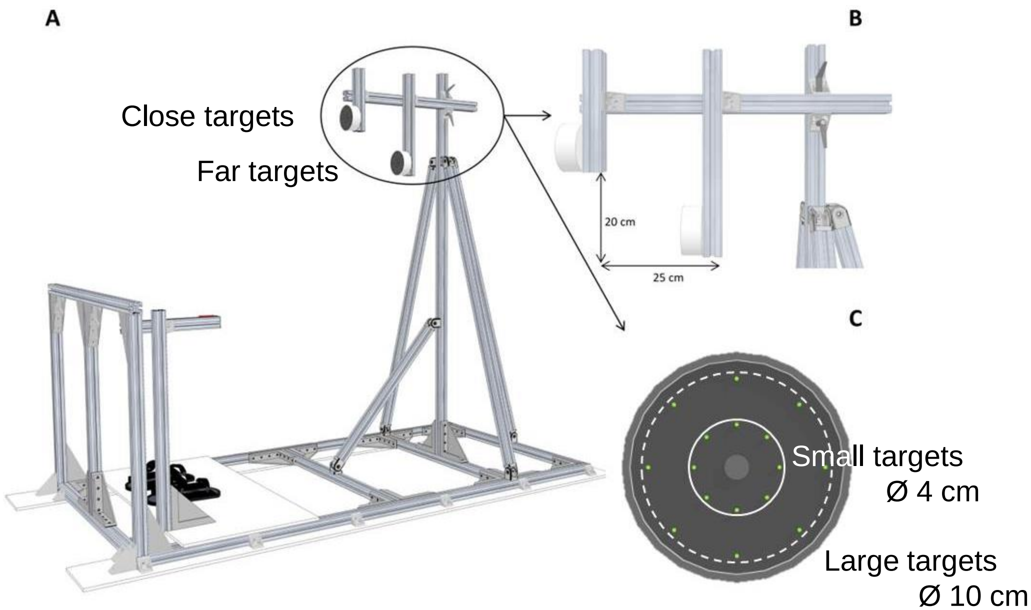


Whole-body reaching in 0g


NormoG


MicroG

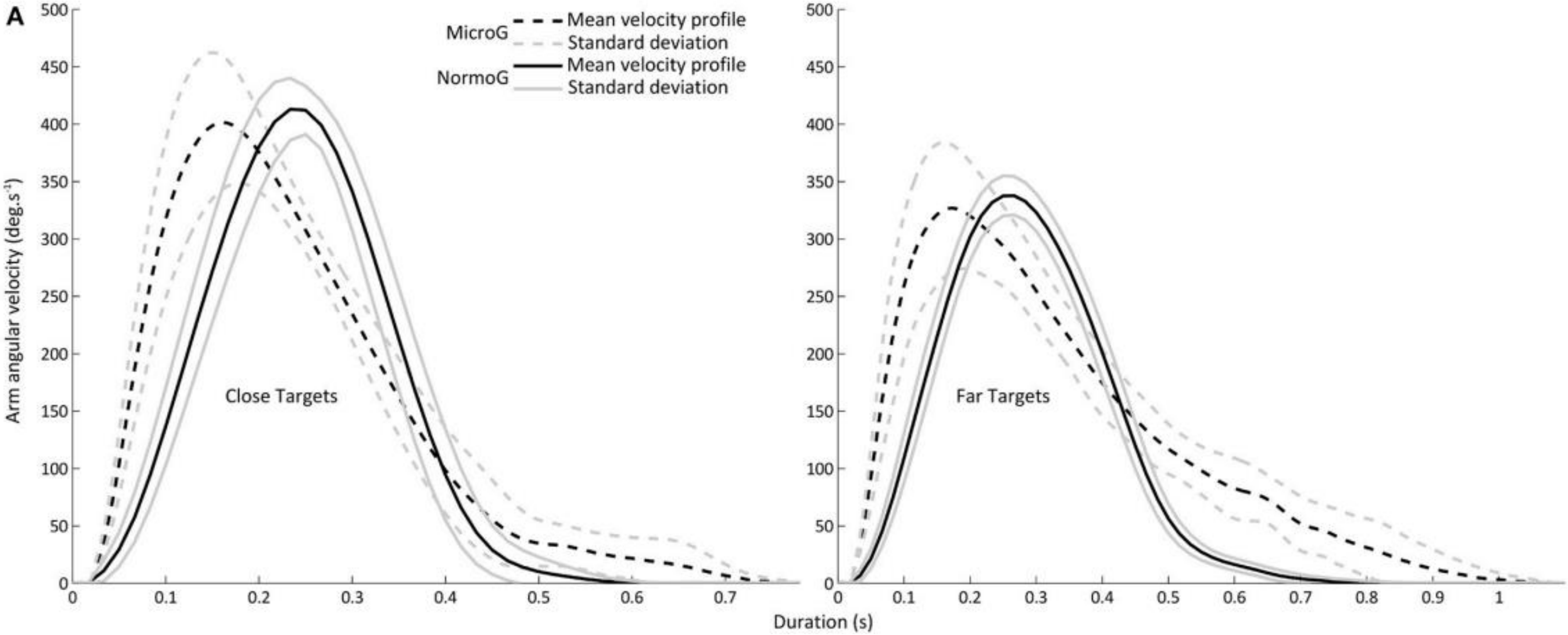
n=7



- Movement duration (655 ms) and reaction time (326 ms) unaffected by the Environment
- Success rate unaffected by the Environment (>95%)
- Final deviation to target center: Higher in MicroG only for large targets (1.3 vs 0.7 cm; p<,01)
- No learning effect during sessions (40 trials)

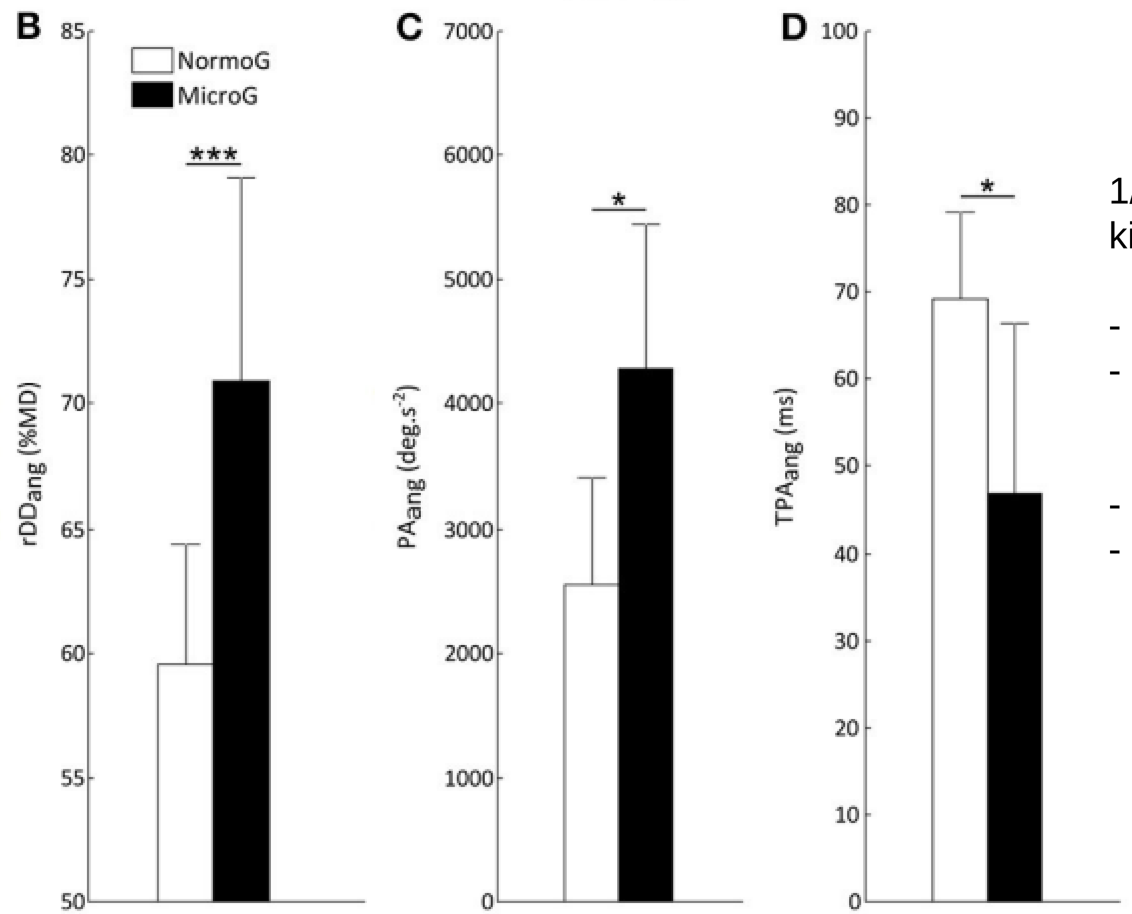
Whole-body reaching in 0g

- Focal component



Whole-body reaching in 0g

- Focal component



1/ Immediate reorganization of focal kinematics for arm angular elevation:

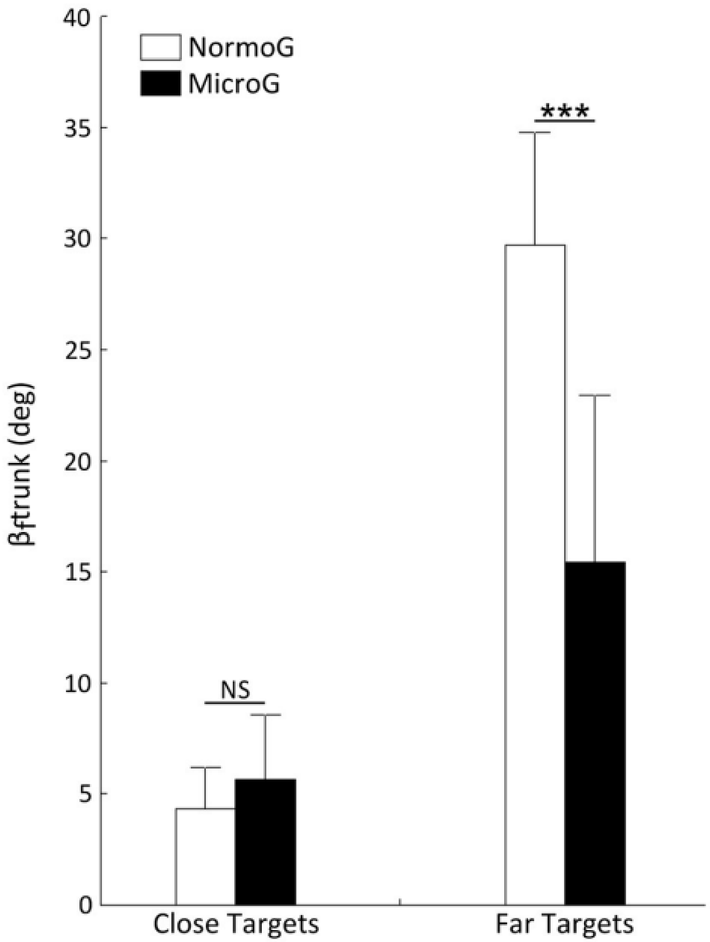
- ↘ time-to-peak acceleration
- ↗ Peak Acceleration

⇓

- ↗ relative deceleration duration
- Peak and mean Velocity unaffected

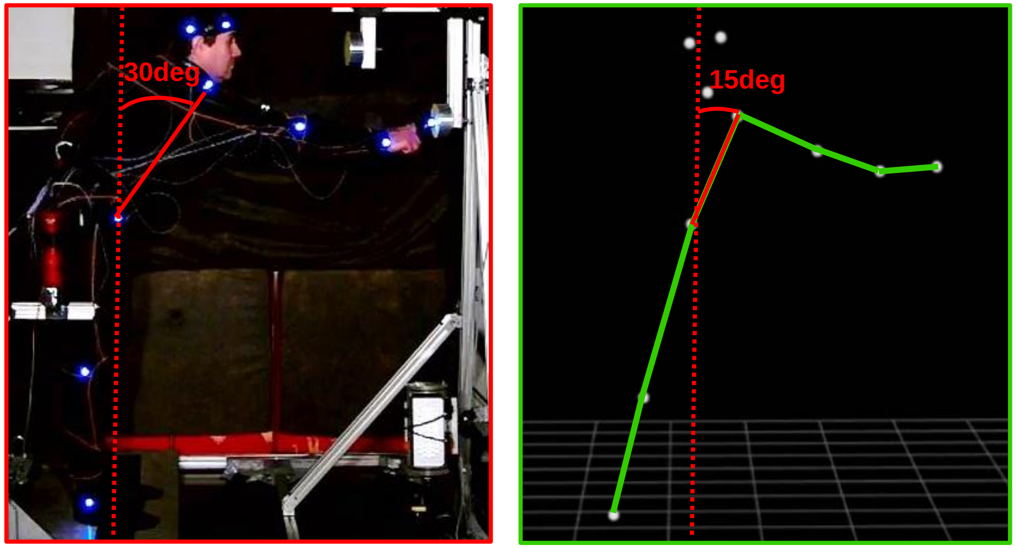
Whole-body reaching in 0g

- Postural component



2/ Immediate reorganization of postural strategy serving whole-body reaching:

- From "hip" to "ankle" strategy

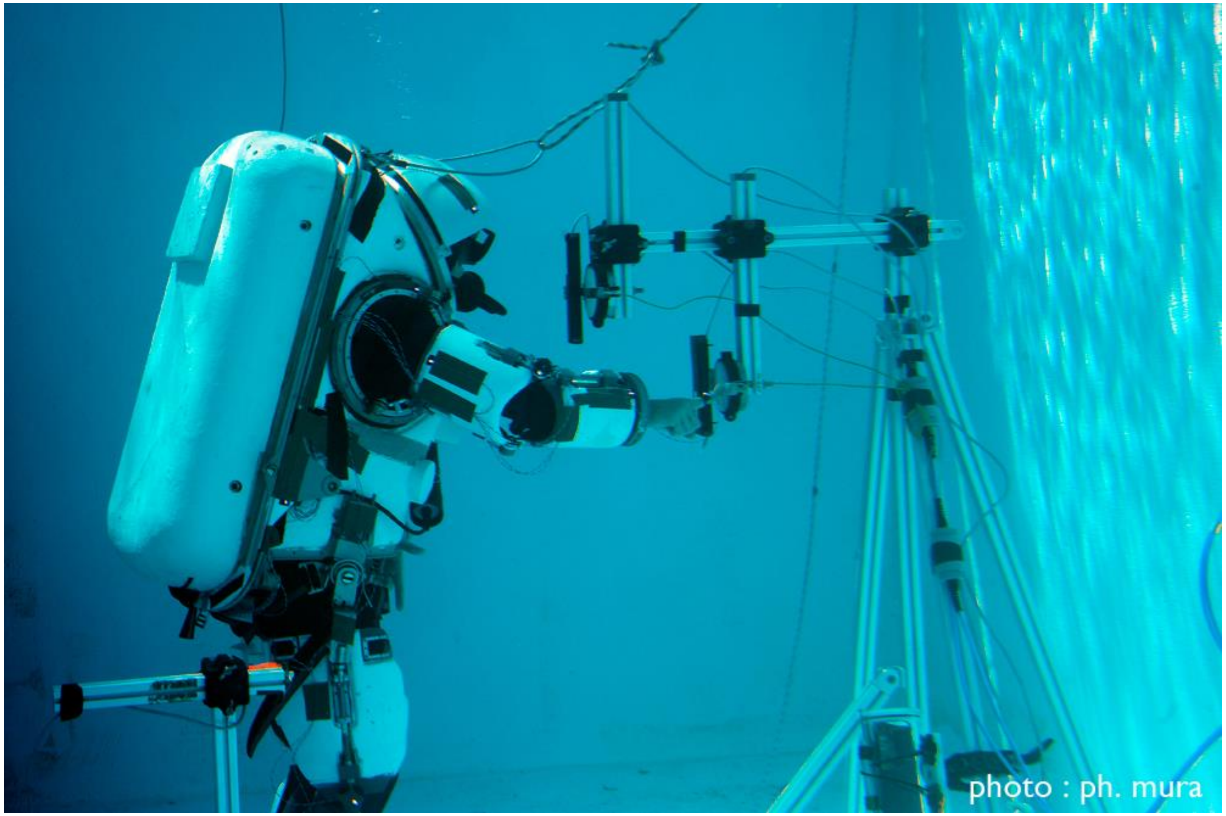


Whole-body reaching underwater

Neuroscience 327 (2016) 125–135

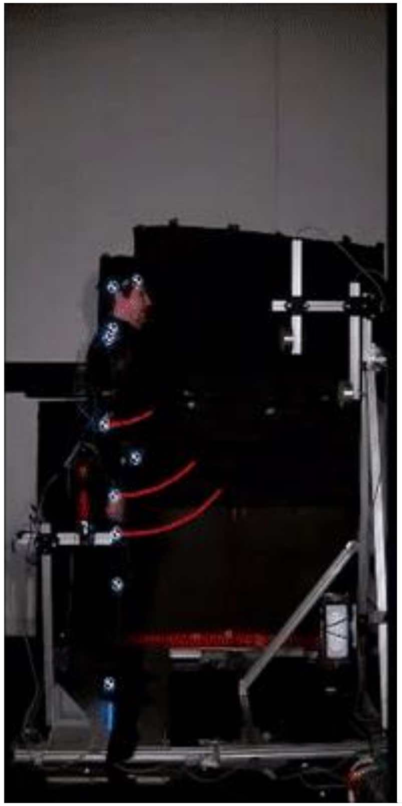
KINEMATIC FEATURES OF WHOLE-BODY REACHING MOVEMENTS UNDERWATER: NEUTRAL BUOYANCY EFFECTS

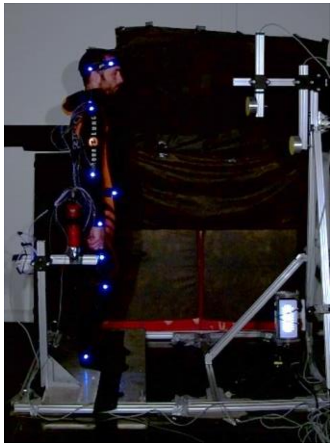
T. MACALUSO,[a] C. BOURDIN,[a] F. BULOUP,[a] M.-L. MILLE,[a,b,c] P. SAINTON,[a] F. R. SARLEGNA,[a] V. TAILLEBOT,[d] J.-L. VERCHER,[a] P. WEISS[d] AND L. BRINGOUX[a]*



Whole-body reaching underwater

n=7 (same subjects as in Exp 1)



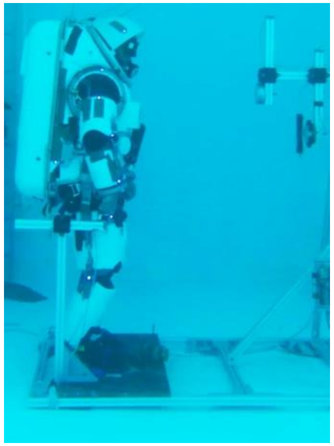


Land

Gravity

Aqua

Gravity
Buoyancy
Viscosity

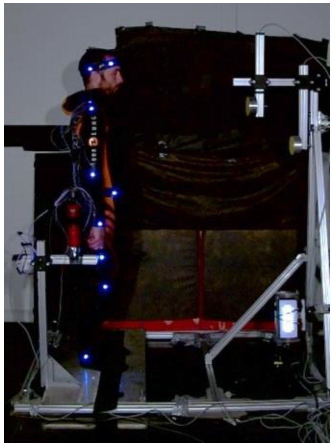


AquaS

Gravity
Neutral Boyancy
(Limb & Body)
Viscosity

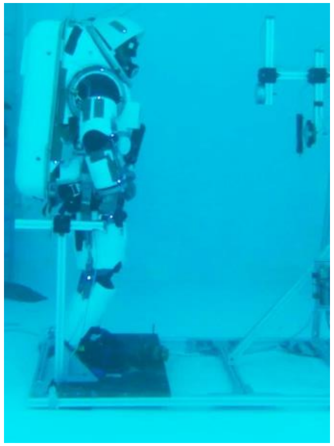
Whole-body reaching underwater

n=7 (same subjects as in Exp 1)



Land

Aqua

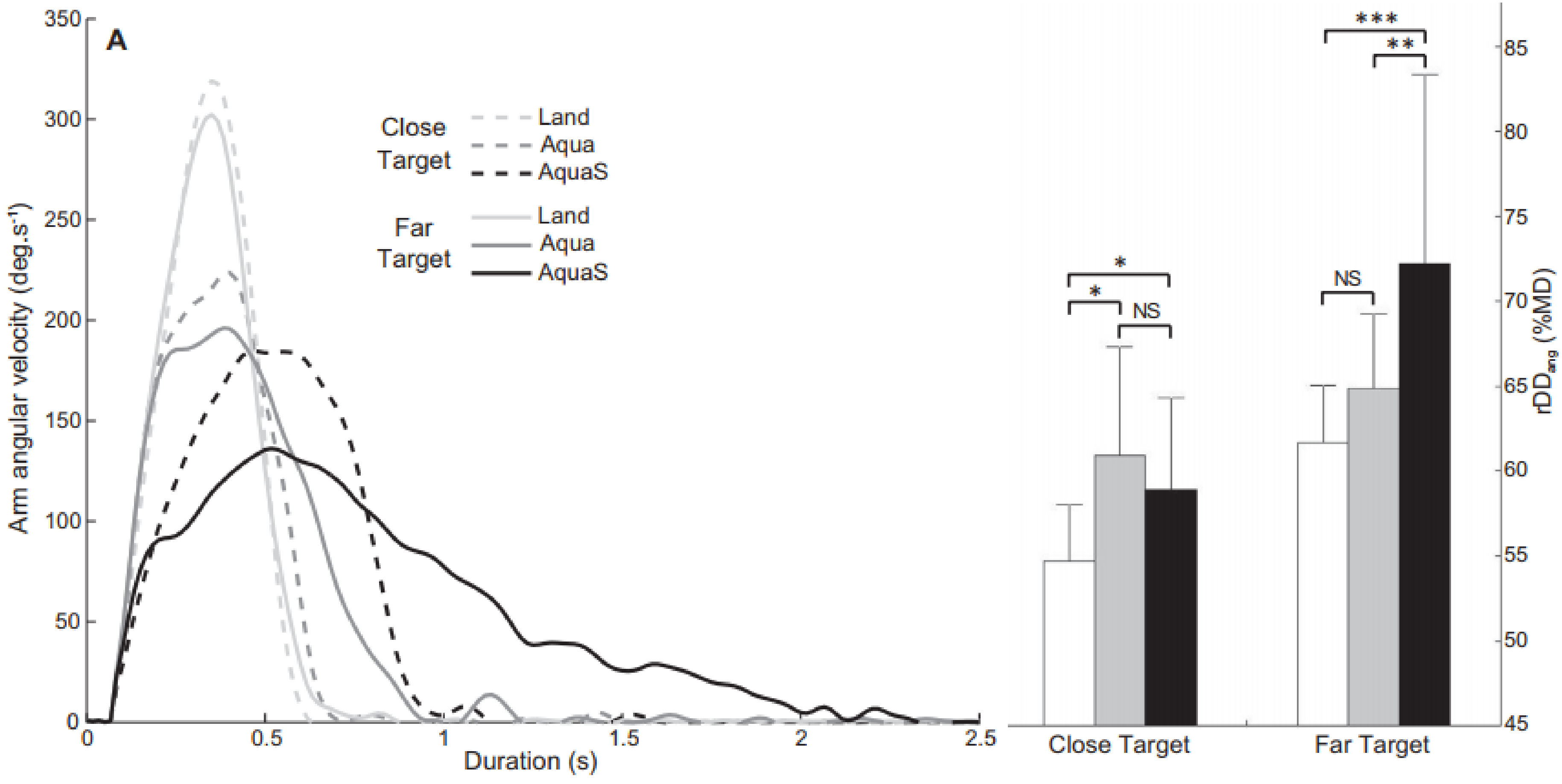


AquaS

- Success rate unaffected by the Environment (>98%)
- Movement duration longer in Aqua (1240 ms) and AquaS (1930 ms) than in Land (655 ms)
- No learning effect during sessions (40 trials)

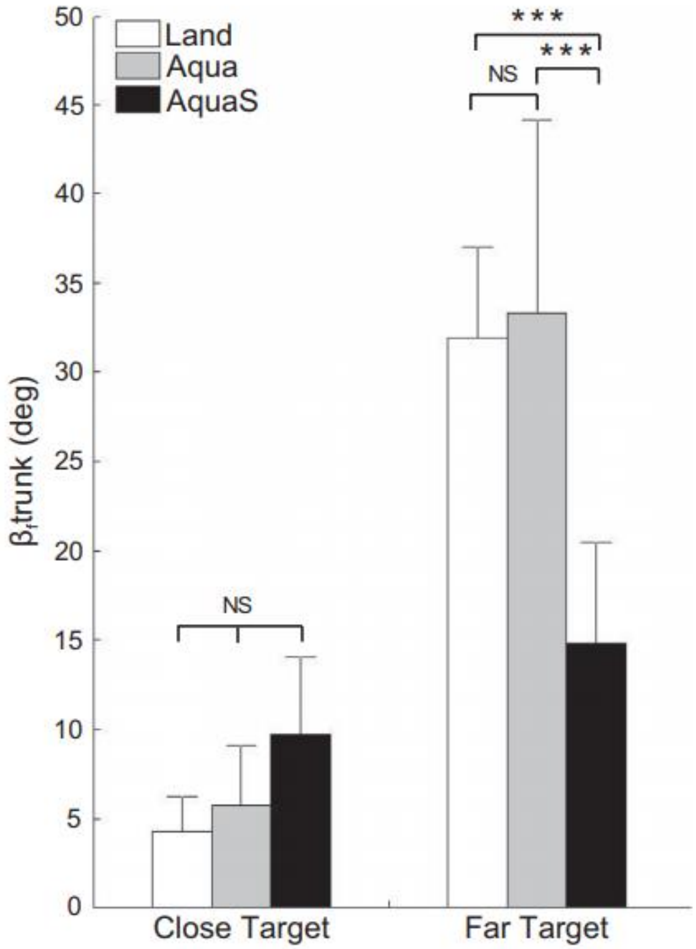
Whole-body reaching underwater

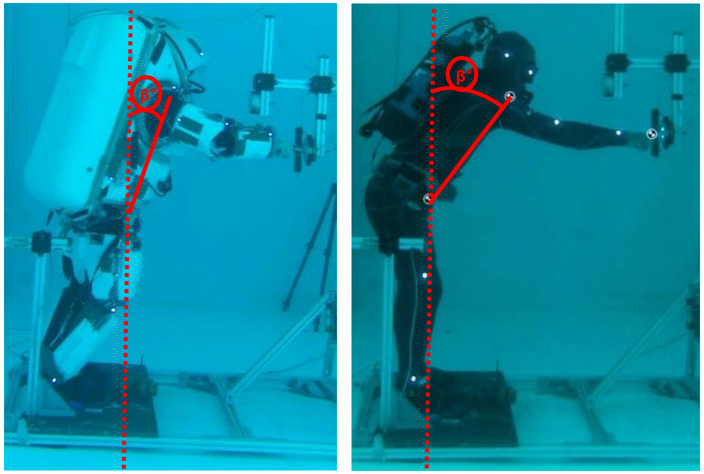
- Focal component



Whole-body reaching underwater

- Postural component





Arm reaching with gravity-like torque in 0g

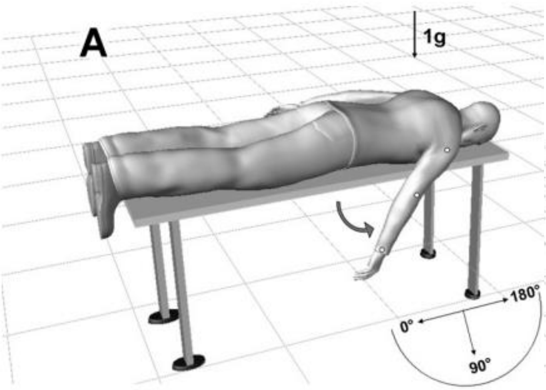
J Neurophysiol 107: 2541–2548, 2012.
First published February 1, 2012; doi:10.1152/jn.00364.2011.

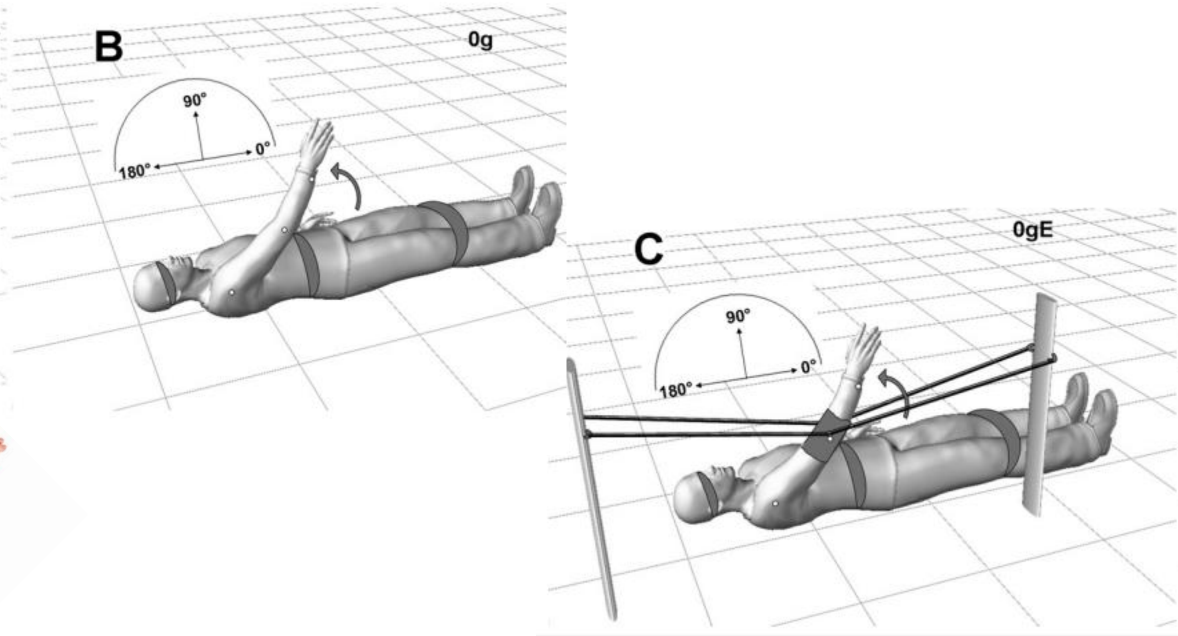
Effect of gravity-like torque on goal-directed arm movements in microgravity

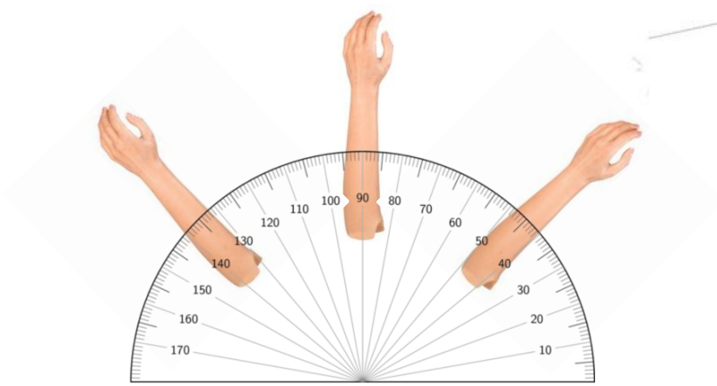
L. Bringoux,[1] J. Blouin,[2] T. Coyle,[1] H. Ruget,[2,3] and L. Mouchnino[2]

Arm reaching with gravity-like torque in 0g

n=8

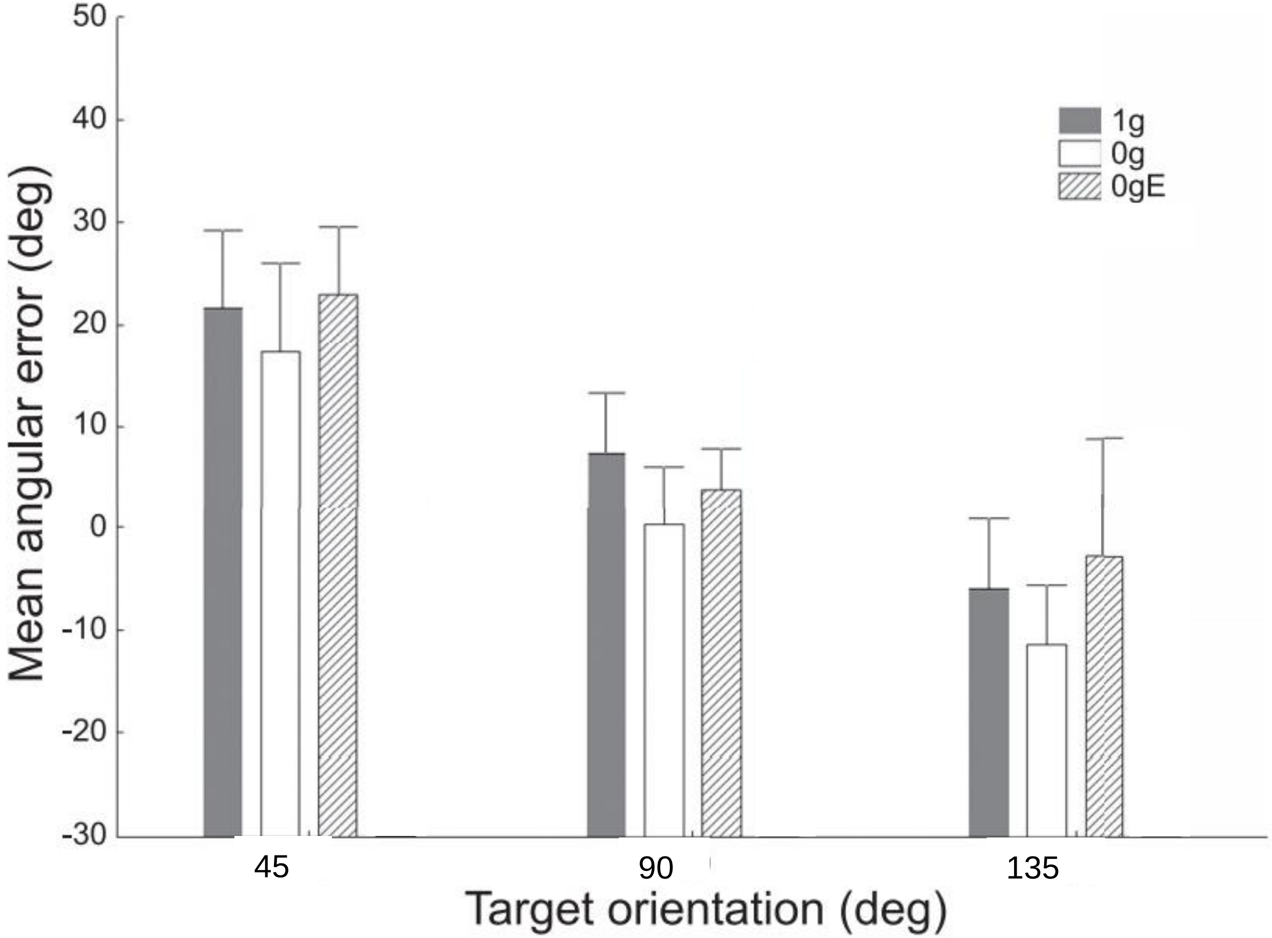




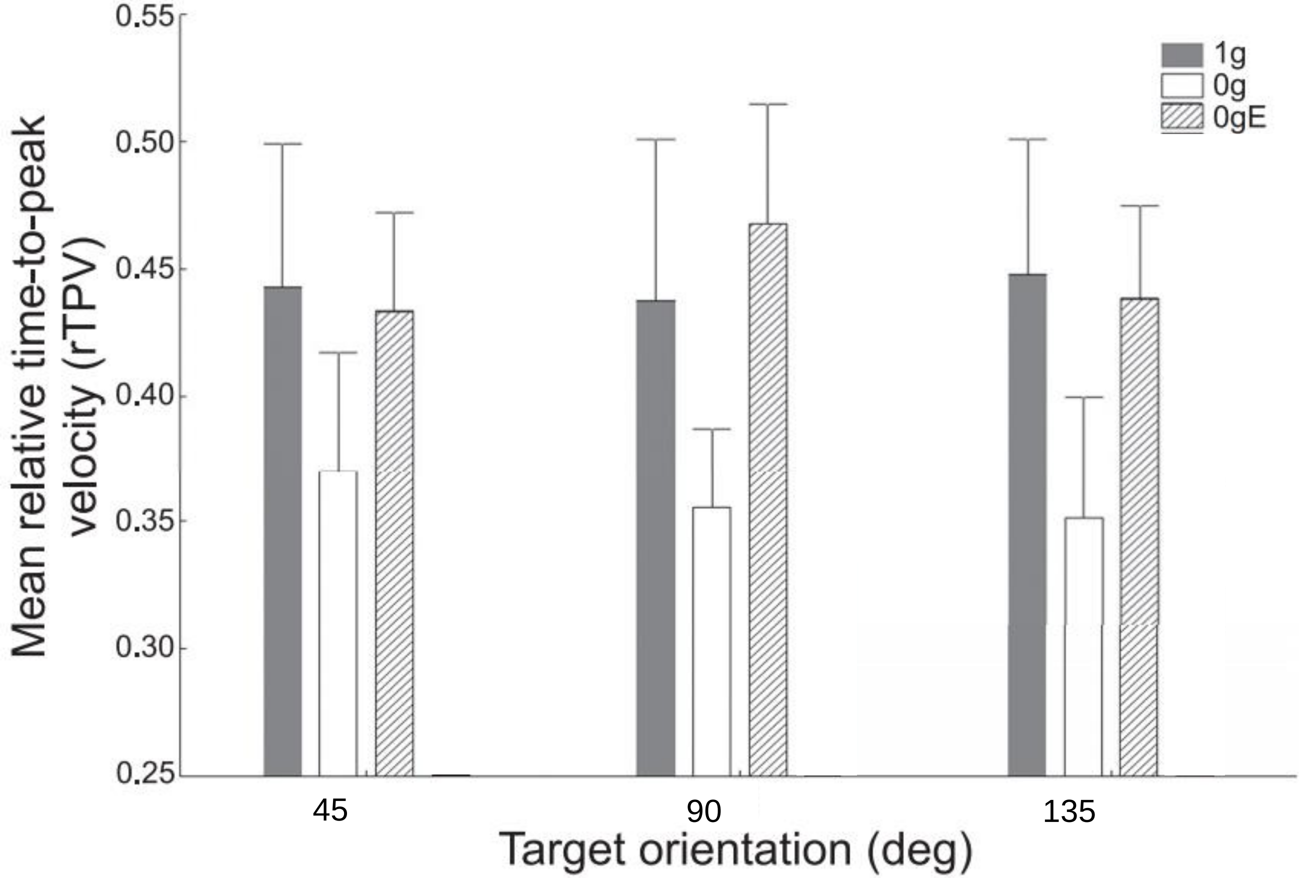


Arm reaching with gravity-like torque in 0g

Arm reaching with gravity-like torque in 0g



Arm reaching with gravity-like torque in 0g



Back to pending questions…

Online motor adjustments relative to the gravity-related force field or prior account in motor planning?

- The kinematic changes following arm movement onset in a novel but predictable force field are earlier than the shortest time for feedback-based corrections (Scott, 2016 for a review).
- These changes are thus likely based on feedforward control mechanisms, directly expressed in the motor intention (Gaveau and Papaxanthis, 2011).

Progressive adaptation to a novel gravity-related force field?

- The immediate and sustained motor reorganization we observed did not support the presence of sensorimotor adaptation (Crevecoeur, et al., 2014).
- Initial state estimates before reaching are thus likely used to account for the new dynamic properties of the environment in the motor commands (Rousseau et al., 2017).

Sensory inputs ?

- Exp 2: 0g-like somatosensory cues vs 1g vestibular cues → 0g-like reaching pattern
- Exp 3: 1g-like somatosensory cues vs 0g vestibular cues → 1g-like reaching pattern
- Initial state estimates relevant for motor planning are likely based on somatosensory inputs, presumably through the presence / absence of antigravity resisting forces at the level of muscles, joints and skin, rather than on vestibular inputs.

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INSTITUT DES SCIENCES DU MOUVEMENT ETIENNE JULES MAREY

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Thank you!

Thomas Macaluso

Aix-Marseille université

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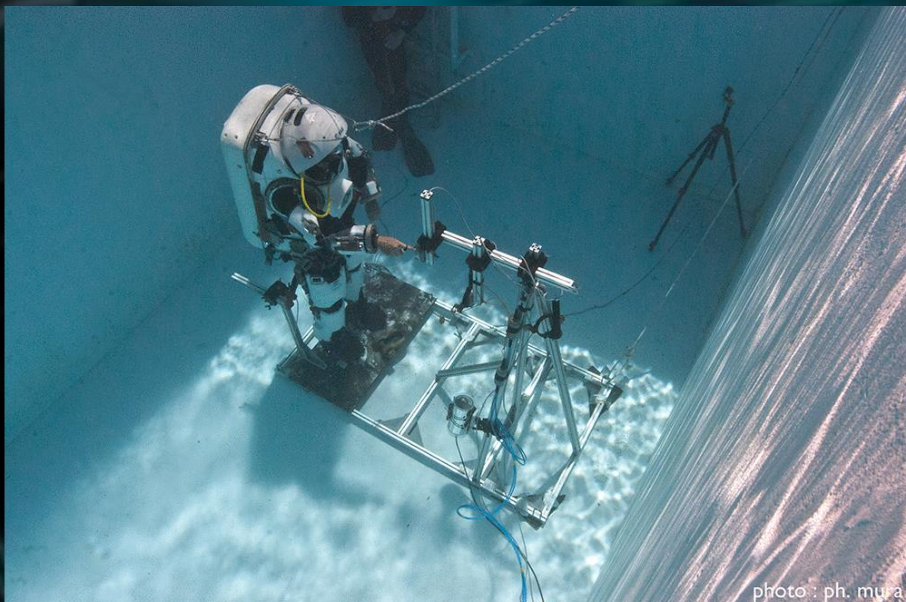


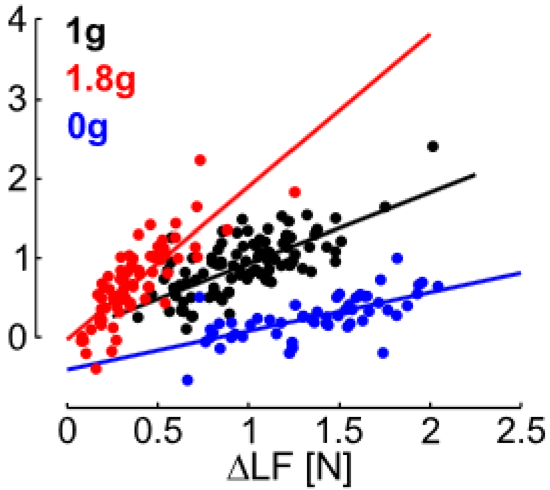
cnes

noveSpace

comex

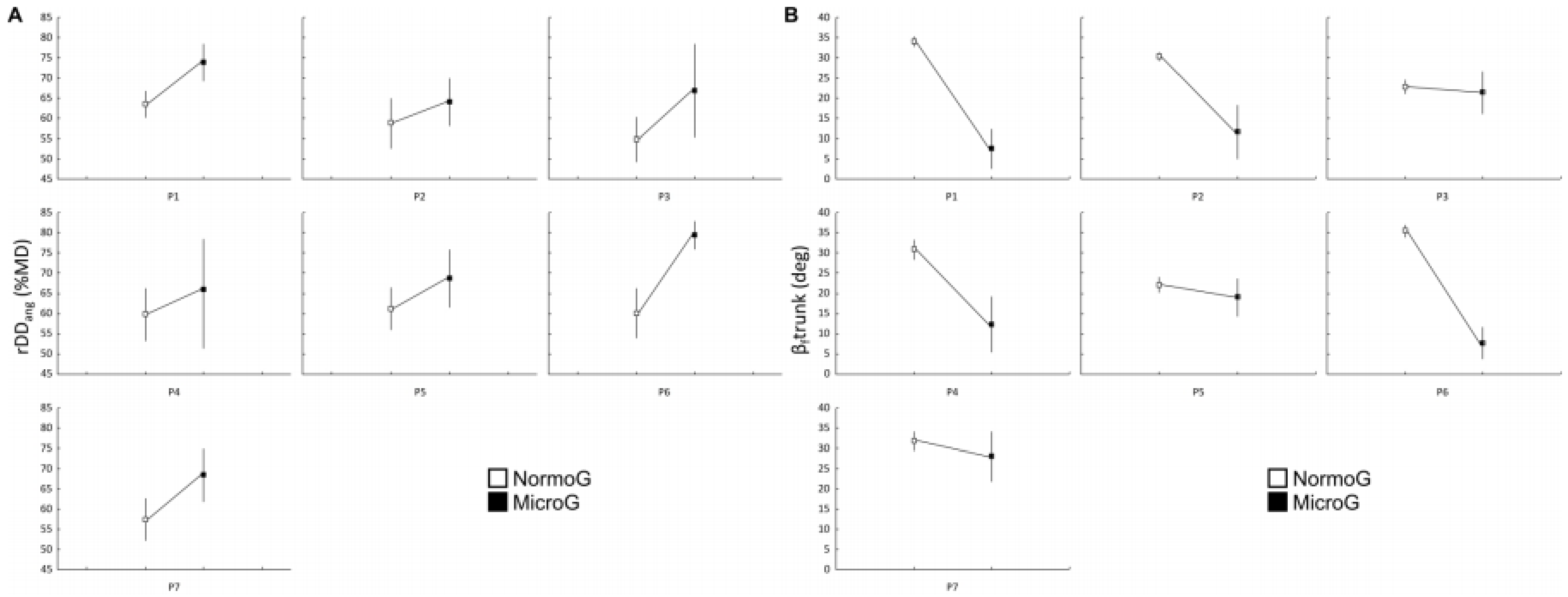
EXTRA SLIDES

Gravity and motor behavior on Earth



Crevecoeur et al. 2014
since grip force/load force coupling is often considered to reflect predictive mechanisms (Flanagan and Wing 1997; Johansson and Westling 1988; Witney et al. 1999), the gravity-dependent effects on this coupling are more readily explained by a misestimation of the inertial parameters of the limb and load during motor planning.
We did not observe any clear change in kinematic parameters occurring across parabolas
The main difference is that most learning studies use dynamic perturbations experienced during the movement (Flanagan and Wing 1997; Franklin et al. 2008; Krakauer et al. 1999; Lackner and DiZio 1994; Shadmehr and Mussa-Ivaldi 1994; Singh and Scott 2003; Smith et al. 2006), and consequently trial-by-trial changes in movement control follow from execution errors. In contrast, our data emphasize a direct effect of vertical gravity on horizontal movements and highlight the fact that initial conditions prior to the reaching movement also play a central role in the generation of the motor commands

Gravity and motor behavior on Earth



Gravity and motor behavior on Earth