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

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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
Whole-body reaching in 0g

- 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

![Graph showing arm angular velocity over duration for close and far targets in MicroG and NormoG conditions.]
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

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


Neuroscience 327 (2016) 125–135
Whole-body reaching underwater

n=7 (same subjects as in Exp 1)
Whole-body reaching underwater

n=7 (same subjects as in Exp 1)

- 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

Overview

Exp. 1

Exp. 2

Exp. 3

Discussion

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Whole-body reaching under water

Postural component

![Graph showing trunk angle comparison between land and water conditions for close and far targets.](image-url)
Arm reaching with gravity-like torque in 0g

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

L. Bringoux, J. Blouin, T. Coyle, H. Ruget, and L. Mouchino
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

![Graph showing mean angular error vs. target orientation (degrees) for different gravity conditions: 1g, 0g, and 0gE.](image-url)
Arm reaching with gravity-like torque in 0g

![Graph showing mean relative time-to-peak velocity (rTPV) with target orientation (deg) and gravity conditions (1g, 0g, 0gE).]
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.
Thank you!

Thomas Macaluso
EXTRA SLIDES
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.
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