Is underwater environment a good way to simulate microgravity? Some cues from arm reaching and postural control

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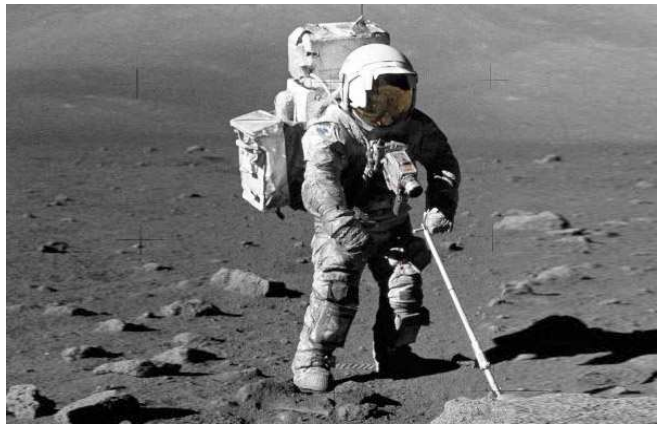
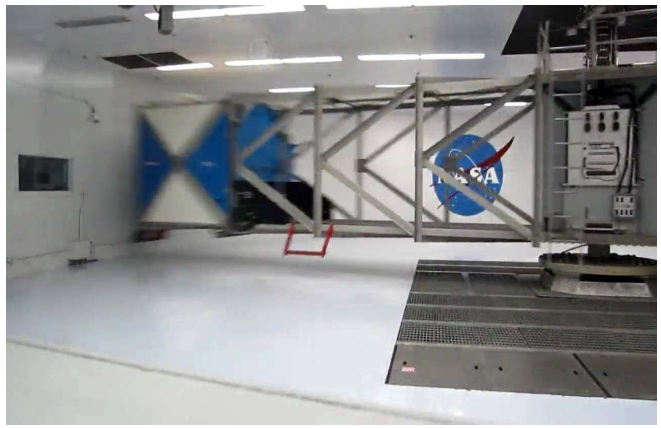
PMC X – July 24th 2015

Space exploration: exposure to unusual environments

Space missions and extra-vehicular activities (EVA)



Intensive training



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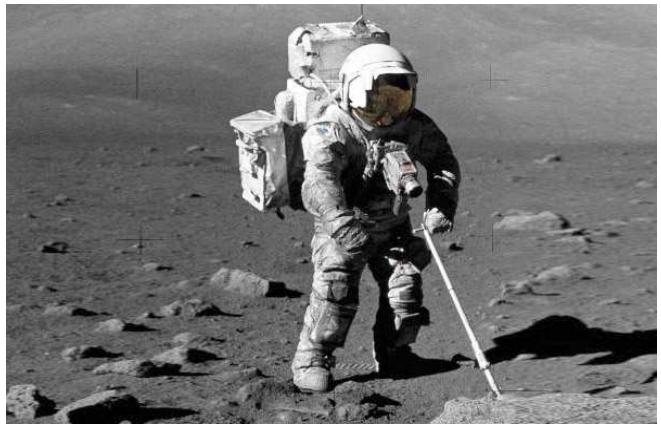

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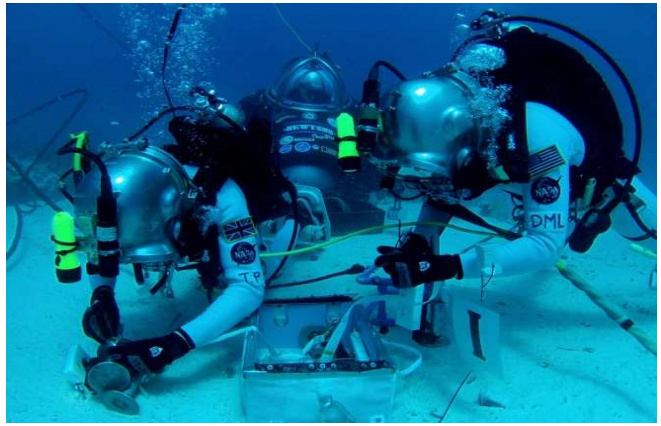
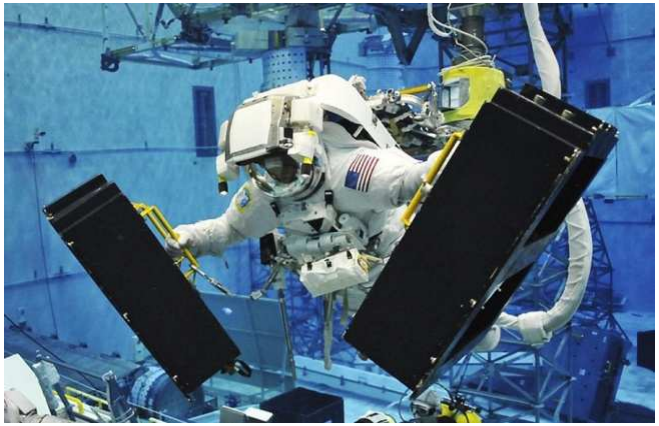
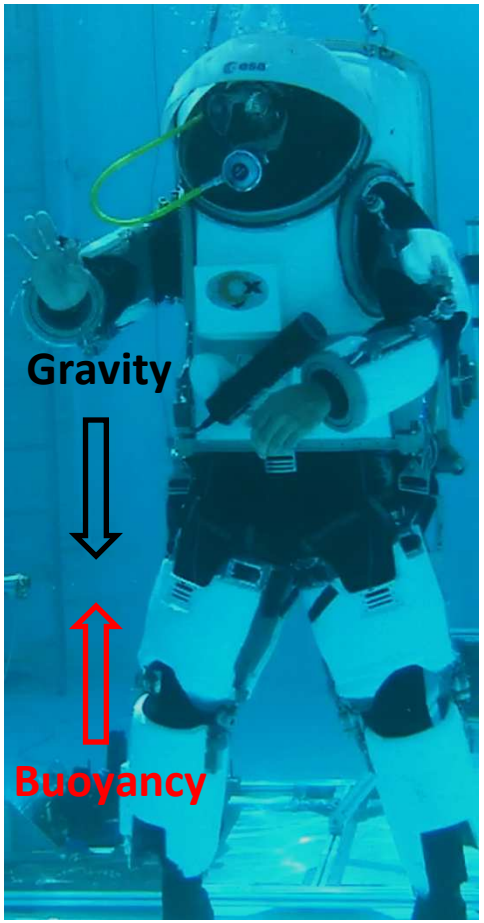




Underwater training with space suits

Submersible wet suit « **Gandolfi** » (COMEX)



Specifications

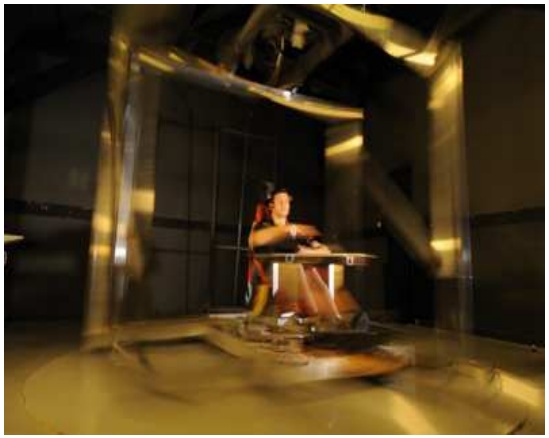
Control of **neutral buoyancy** on each body segment

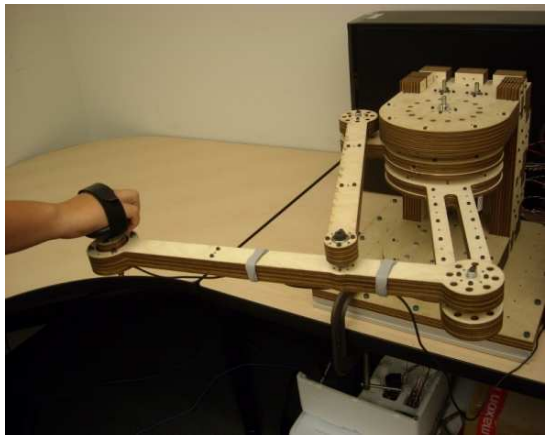
Homogeneous pressure with **few contact forces** on the body surface

Joint stiffness similar to astronauts' pressurized suit

The impact of underwater exposure on motor behavior remains unknown

Motor control studies in novel environments





Some impacts on arm movements

Inaccuracy
(Carriot et al., 2004; Lackner & Dizio, 1994; Shadmehr & Mussa-Ivaldi, 1994)

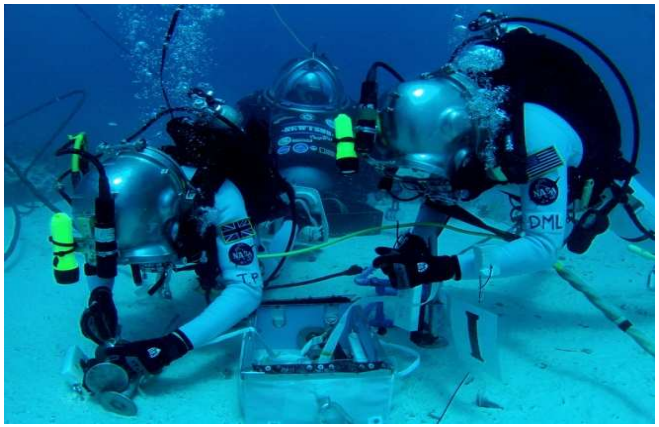
Modified trajectories
(Lackner & Dizio, 1994; Scheidt et al., 2005; Sainburg et al., 1999; Shadmehr & Mussa-Ivaldi, 1994)

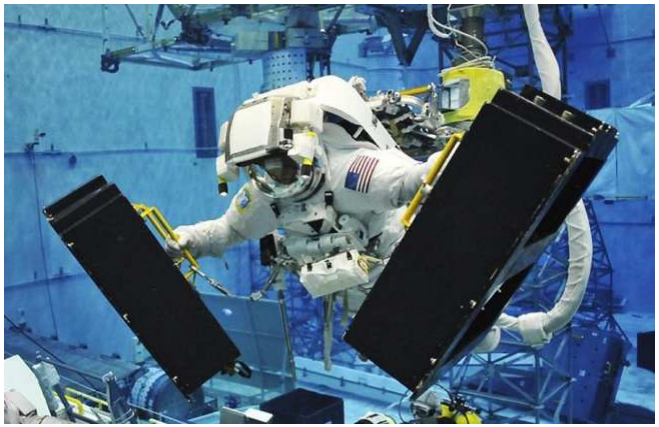
Slower speed
(Gaveau et al., 2011)

Main goals

1. Determine the influence of underwater exposure on motor behavior (whole body reaching movements)

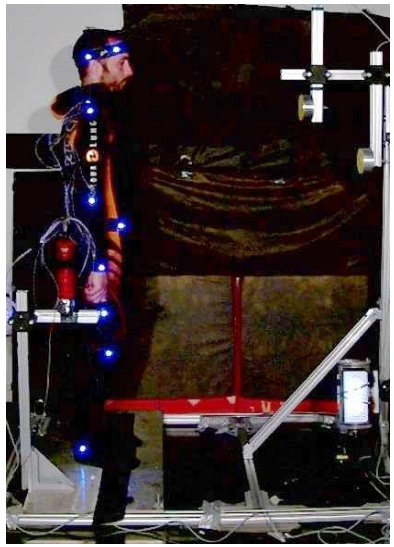
2. Question whether underwater environment is a good way to simulate weightlessness

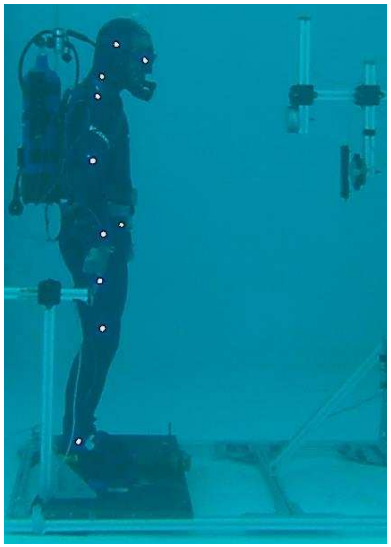


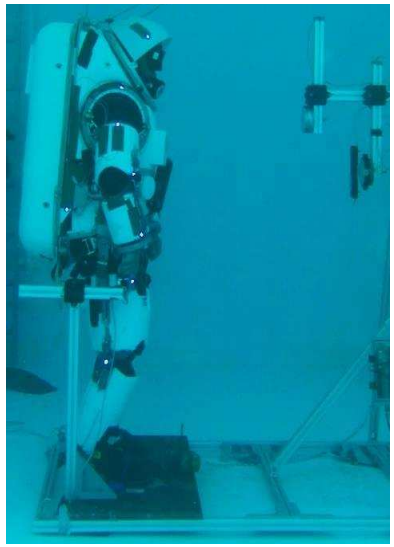


Procedure and experimental setup

3 environments
repeated measures
n=8







« Ground »

« Aqua »

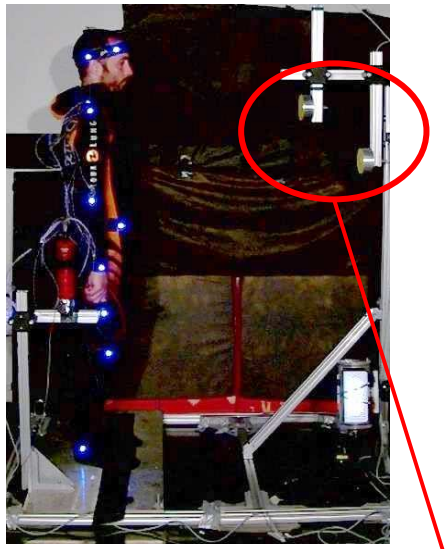
« AquaS »

Constraints

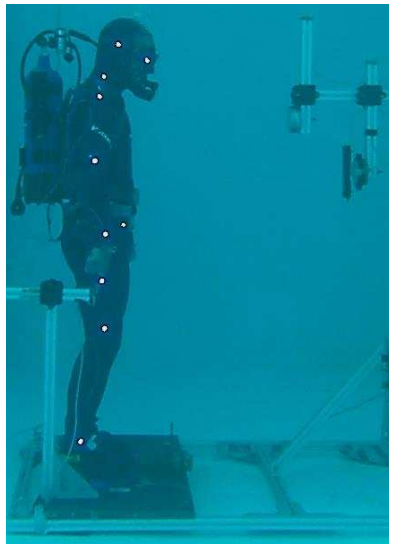
« Ground »	« Aqua »	« AquaS »
Gravity	Gravity **Buoyancy** Viscosity	Gravity **Controlled segmental buoyancy** Viscosity Stiffness

Procedure and experimental setup

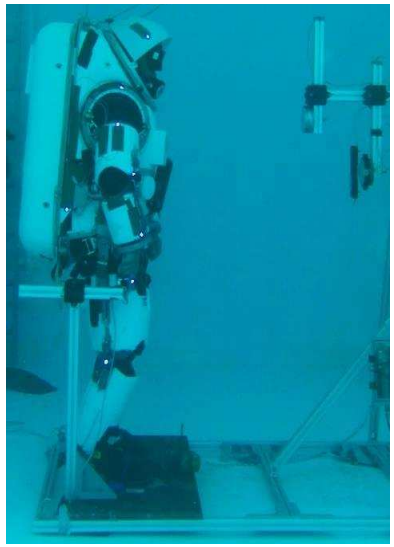
3 conditions
repeated
measures
n=8



« Ground »

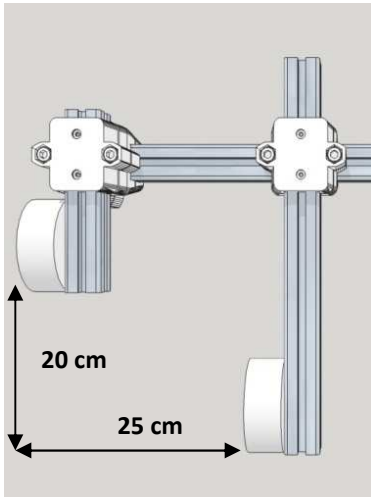


« Aqua »



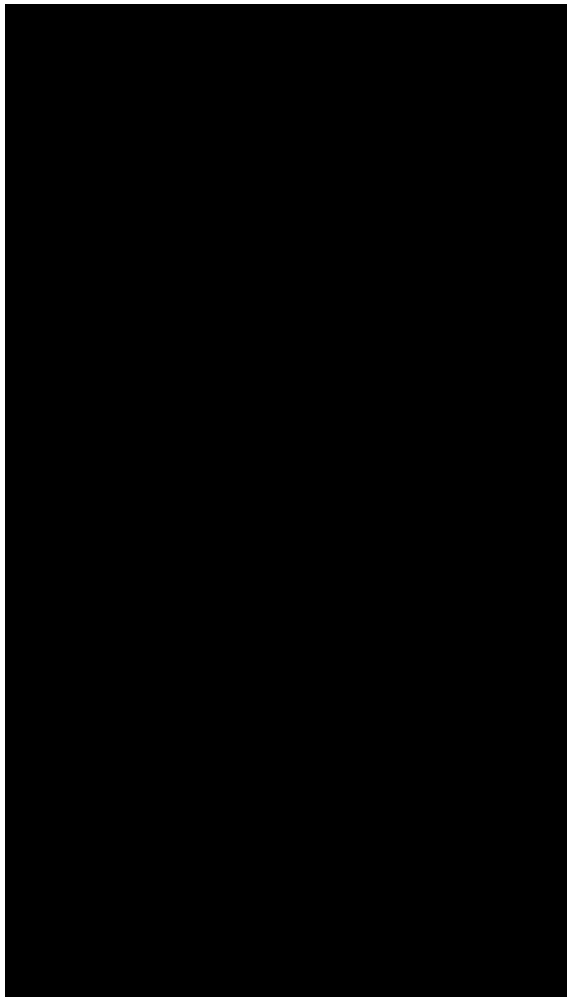
« AquaS »

2 target
positions:
-Close
-Far



Focal and Postural component

Focus on two variables:



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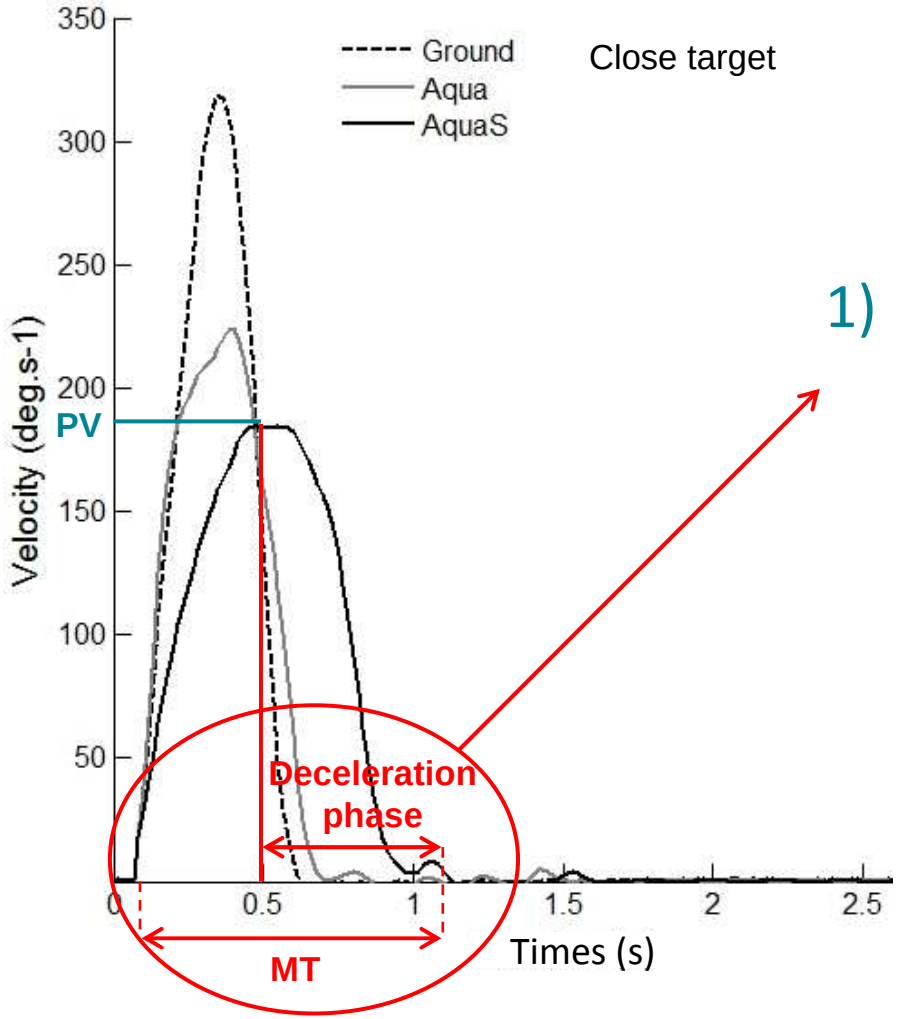
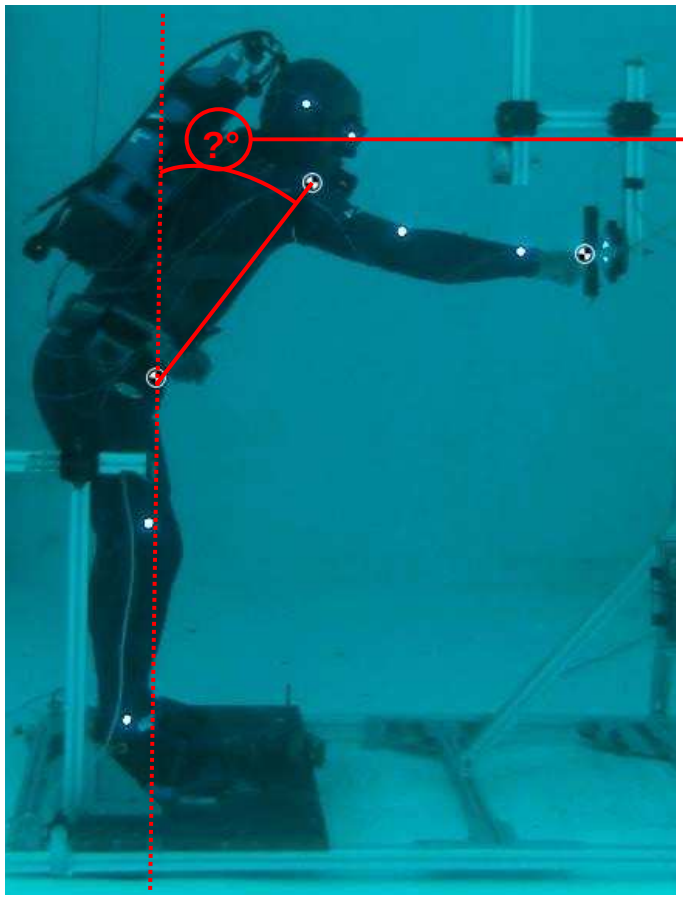


1) Relative deceleration phase (%MT)

⇒ Temporal organisation of focal movement

Focal and Postural component

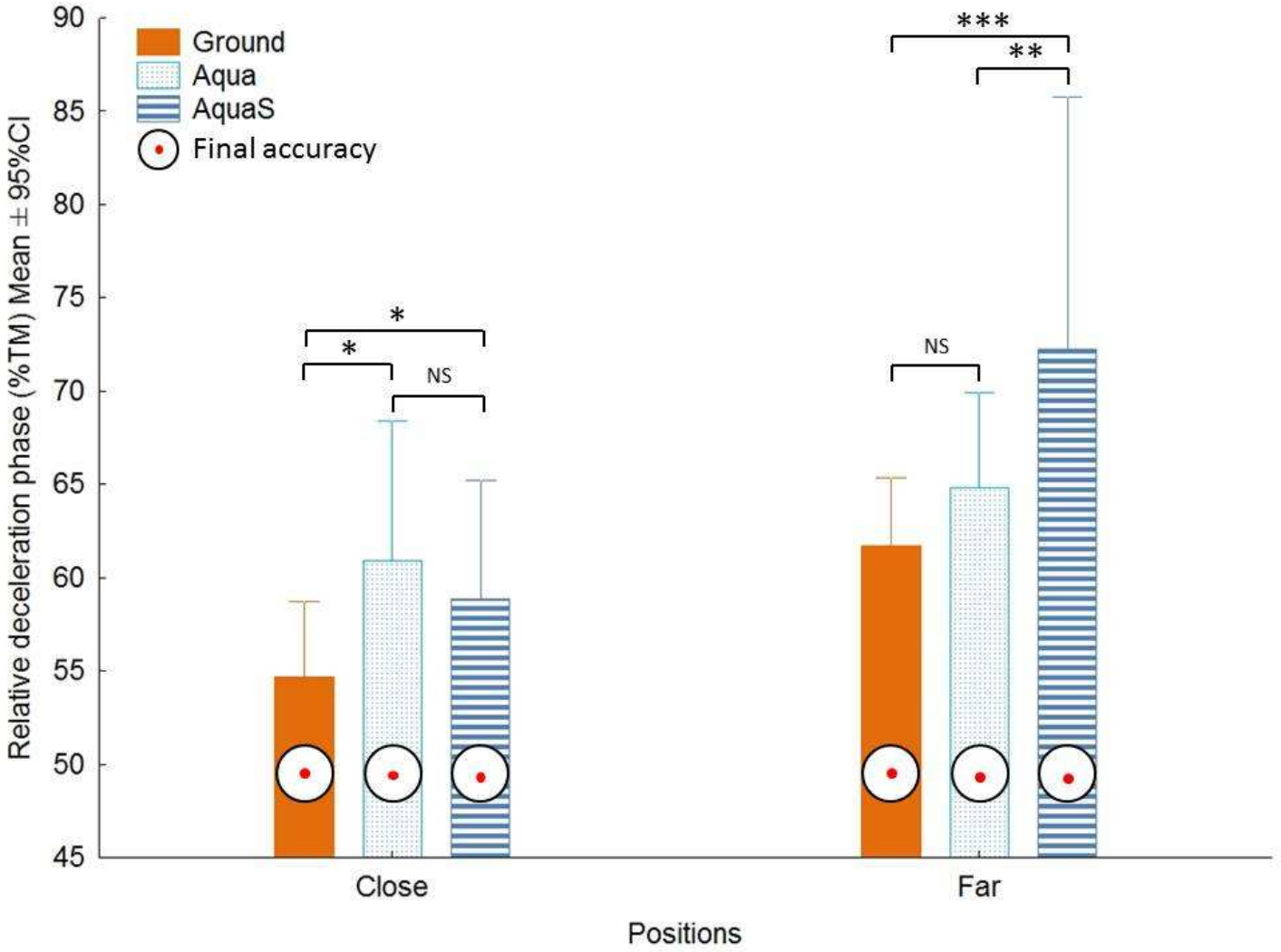
Focus on two variables:

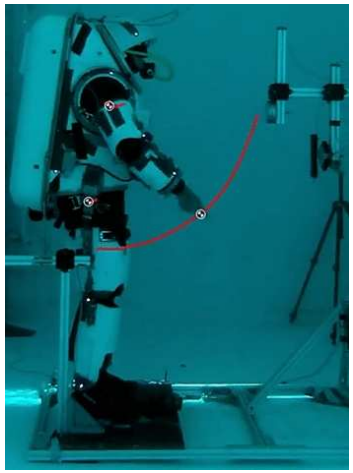


2) Trunk flexion at movement end relative to vertical (deg)

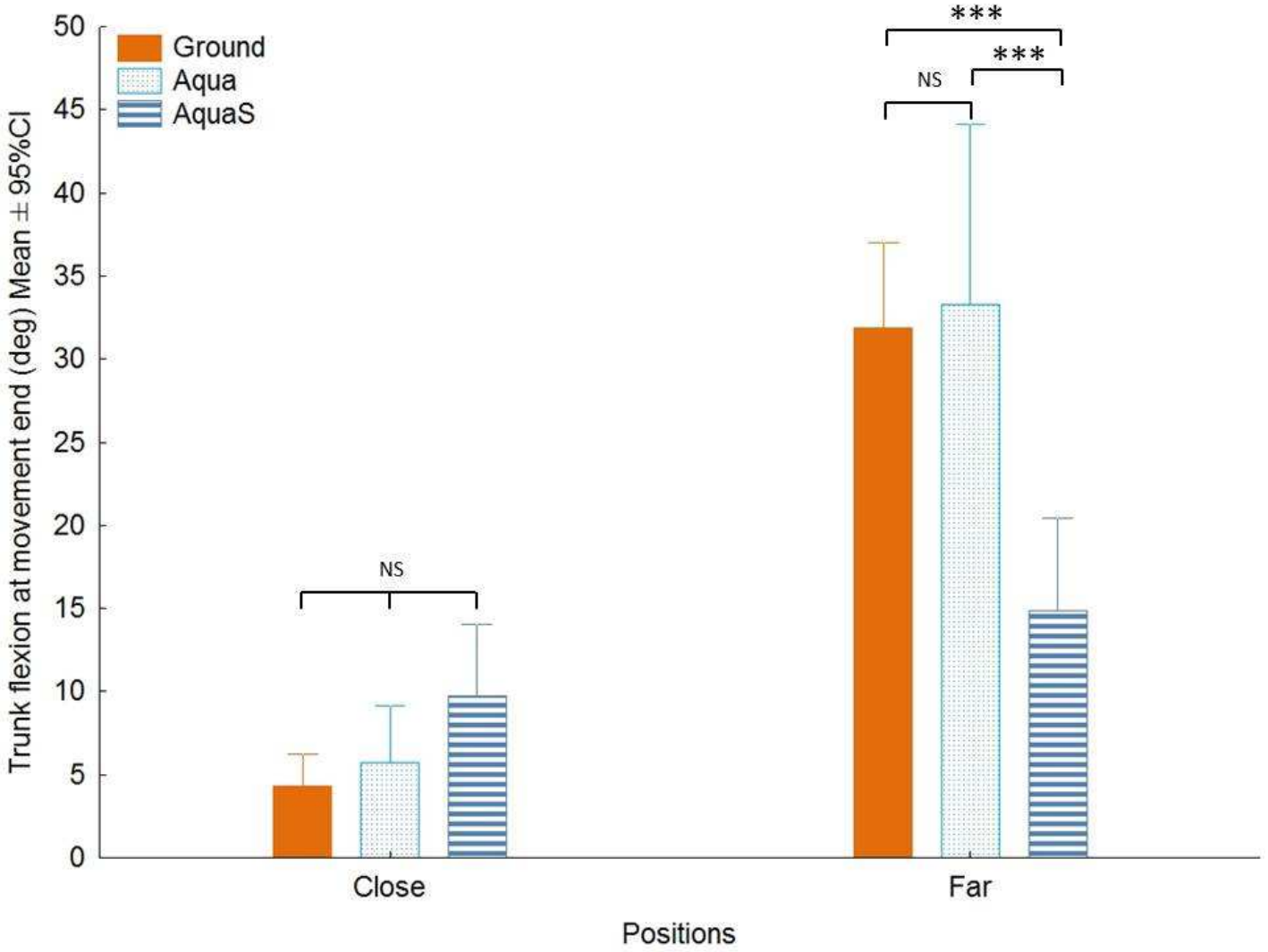
⇨ Postural strategy

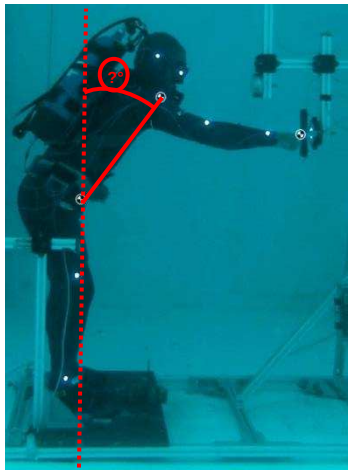
Temporal organization of focal movement



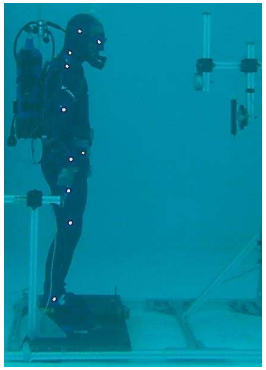
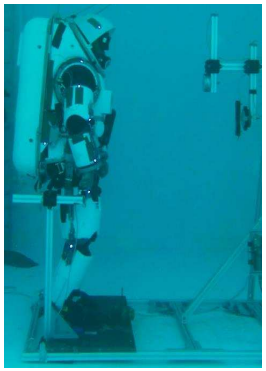


Trunk flexion at movement end relative to vertical





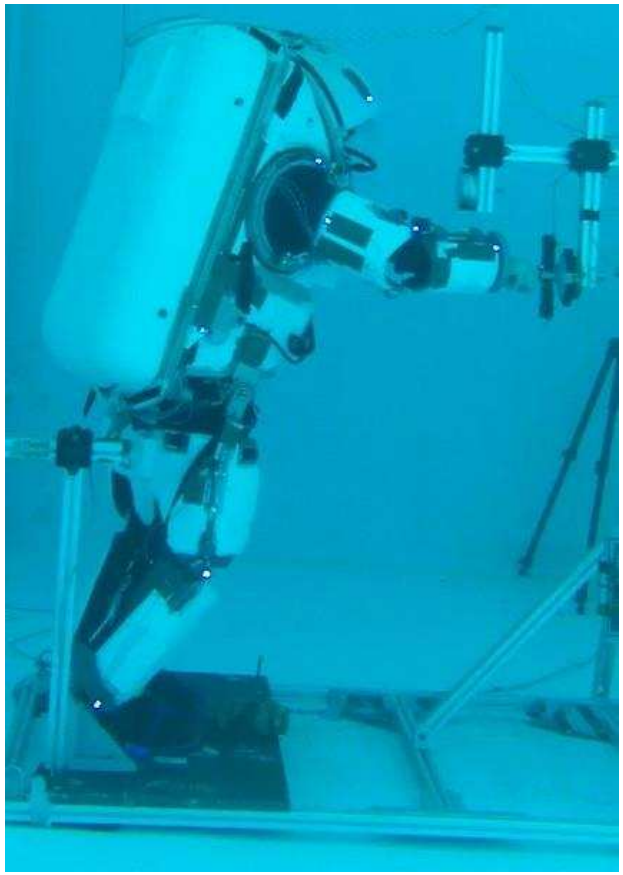
Main findings

Underwater exposure	Focal component	Postural component
Aqua 	Close to Ground	Close to Ground
AquaS 	Increase of the movement deceleration phase	New postural strategy: CoM projection beyond the base of support

Substantial motor reorganization in AquaS

⟹ Control of neutral buoyancy exerted on each body segment

Behavioral similarities between AquaS and microgravity



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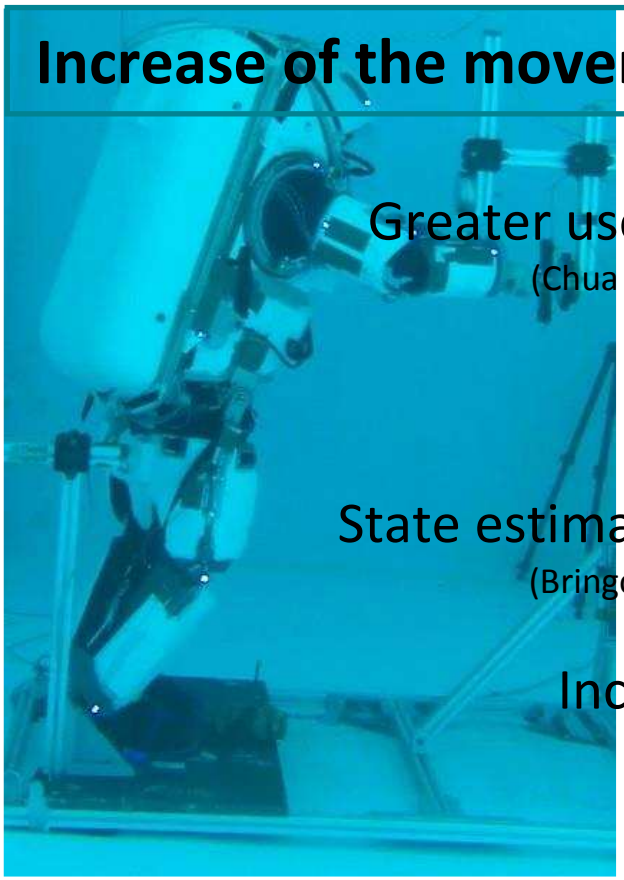
Behavioral similarities between AquaS and microgravity



Increase of the movement deceleration phase (Bringoux et al., 2012)

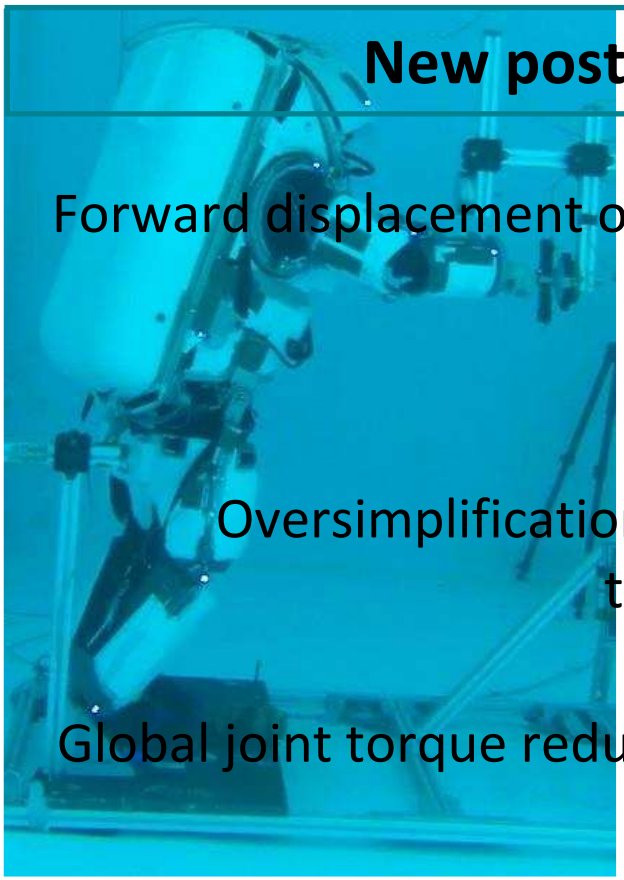
Greater use of online correction process
(Chua & Elliott, 1993 ; Terrier et al., 2011)

⇔

State estimate prior and during movement
(Bringoux et al., 2012; Carriot et al., 2004)

Increased feedback gain
(Franklin et al., 2012)

Behavioral similarities between AquaS and microgravity



New postural strategy (Casellato et al., 2012)

Forward displacement of all body segments reducing joint motions
(Casellato et al., 2012)

⇔

Oversimplification of postural component to support the focal movement
(Casellato et al., 2012)

Global joint torque reduction: Optimal control of motor command
(Berret et al., 2011)

Is underwater environment a good way to simulate microgravity?

YES ! BUT …

…with a control of **neutral buoyancy on each body segment,** enabling a better simulation of space conditions

Gandolfi *in the bay of Marseilles (2012) reproducing Apollo XI activities*

N.Armstrong on lunar surface (1969) during the space mission Apollo XI

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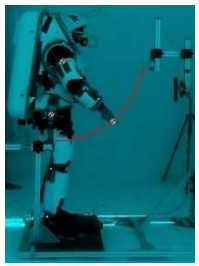
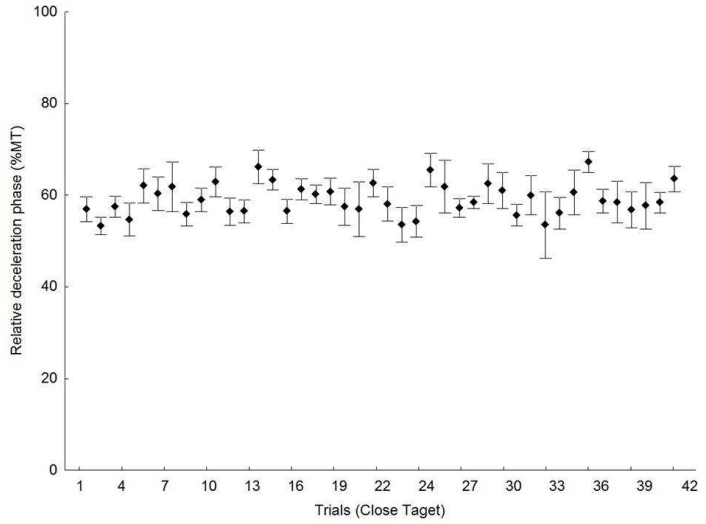
Thank you for your attention

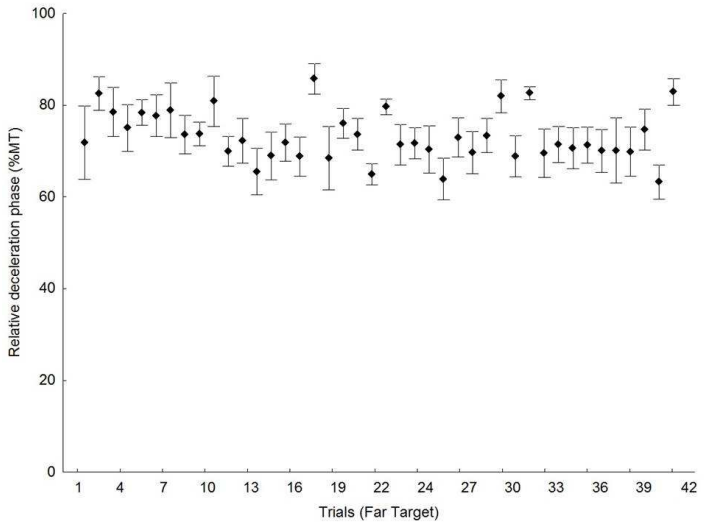
PMC X – July 24th 2015

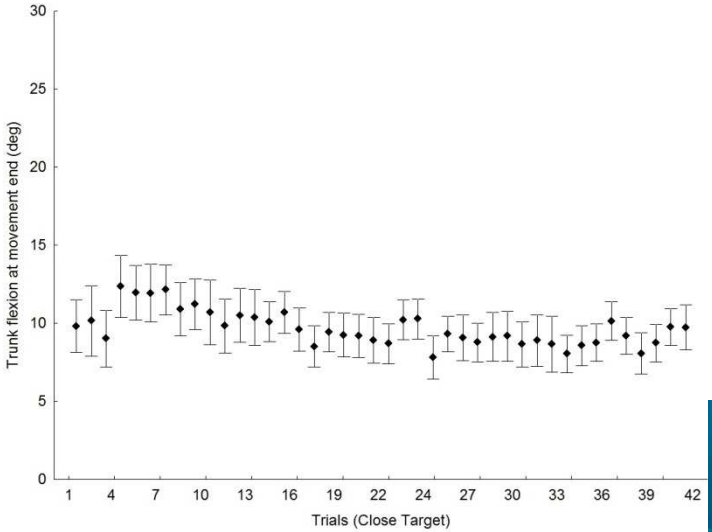
Focal component

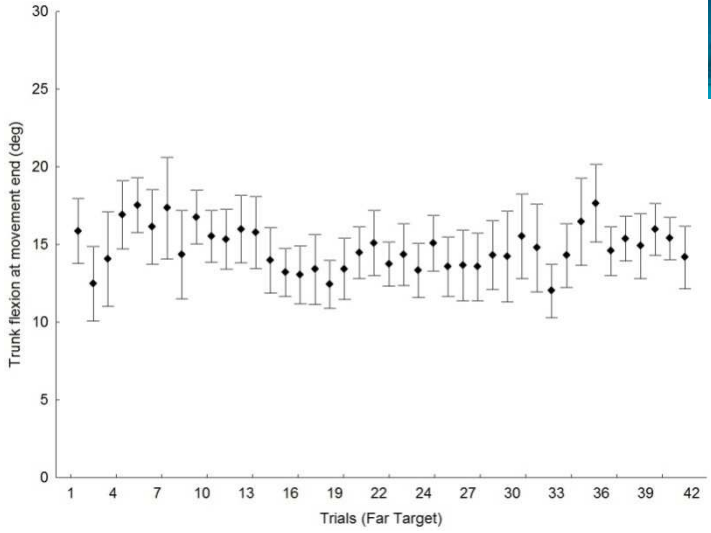
Postural component

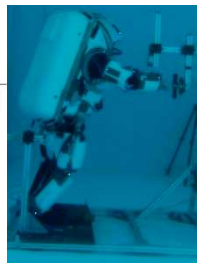






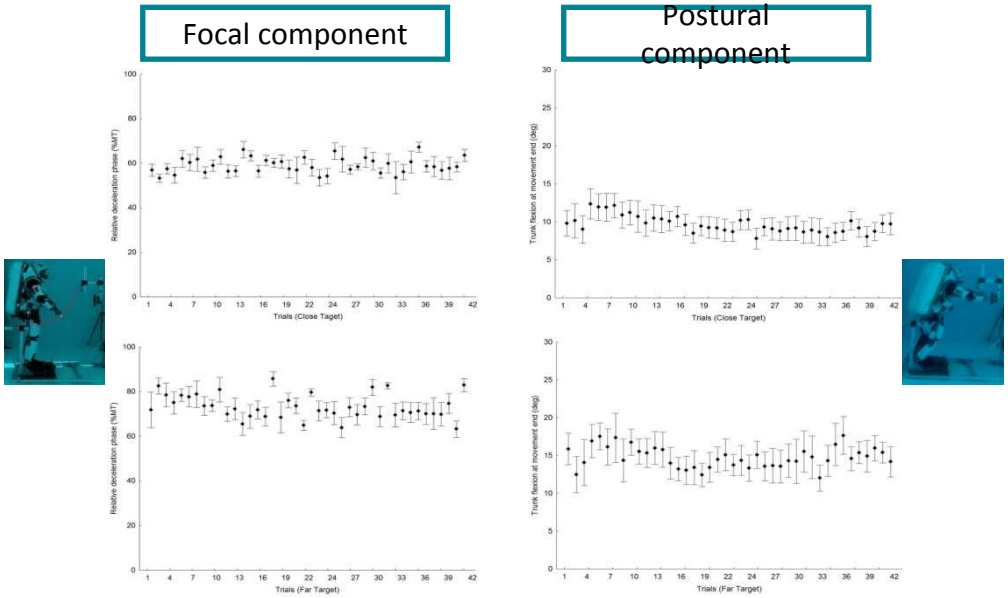




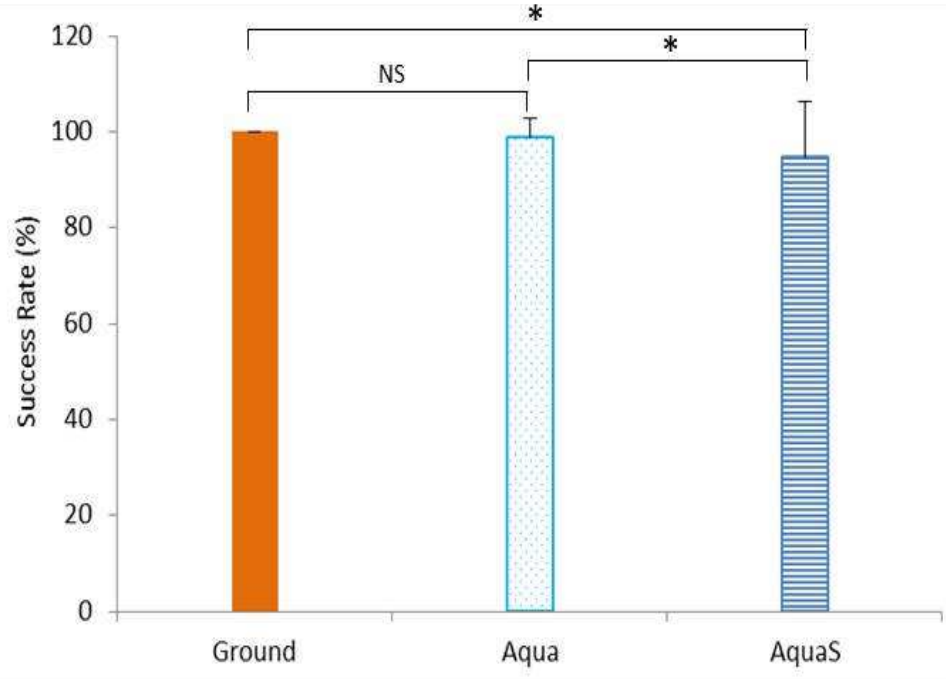


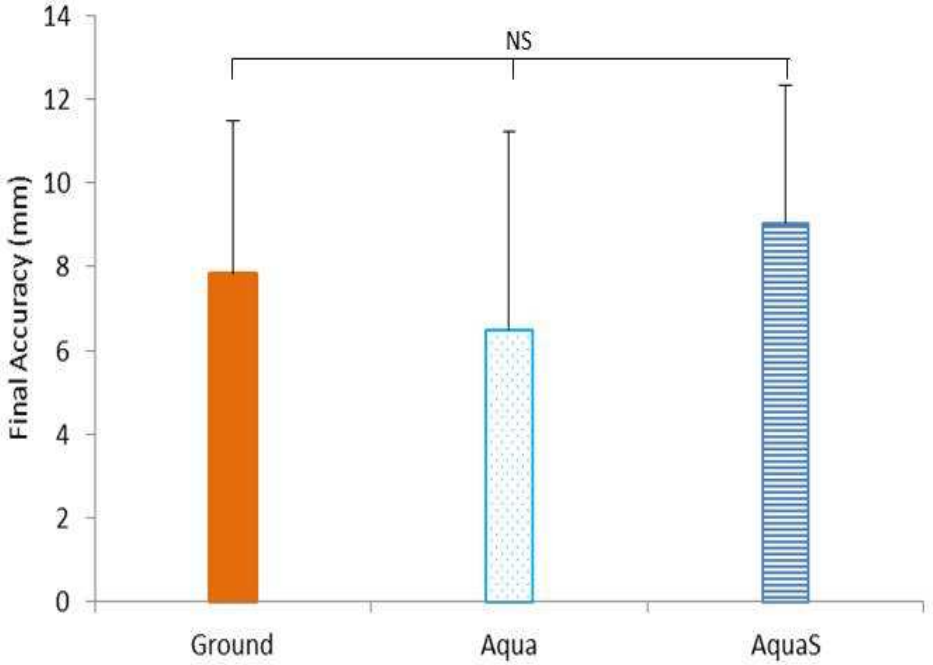
ANOVA on 3 blocks: initial / middle / final

Variables	Close Target	Far Target
Final accuracy	p = 0.52	p = 0.24
Movement Time	p = 0.12	p = 0.52
Peak Velocity	p = 0.10	p = 0.98
Deceleration phase	p = 0.19	p = 0.20
Trunk flexion	p = 0.72	p = 0.60

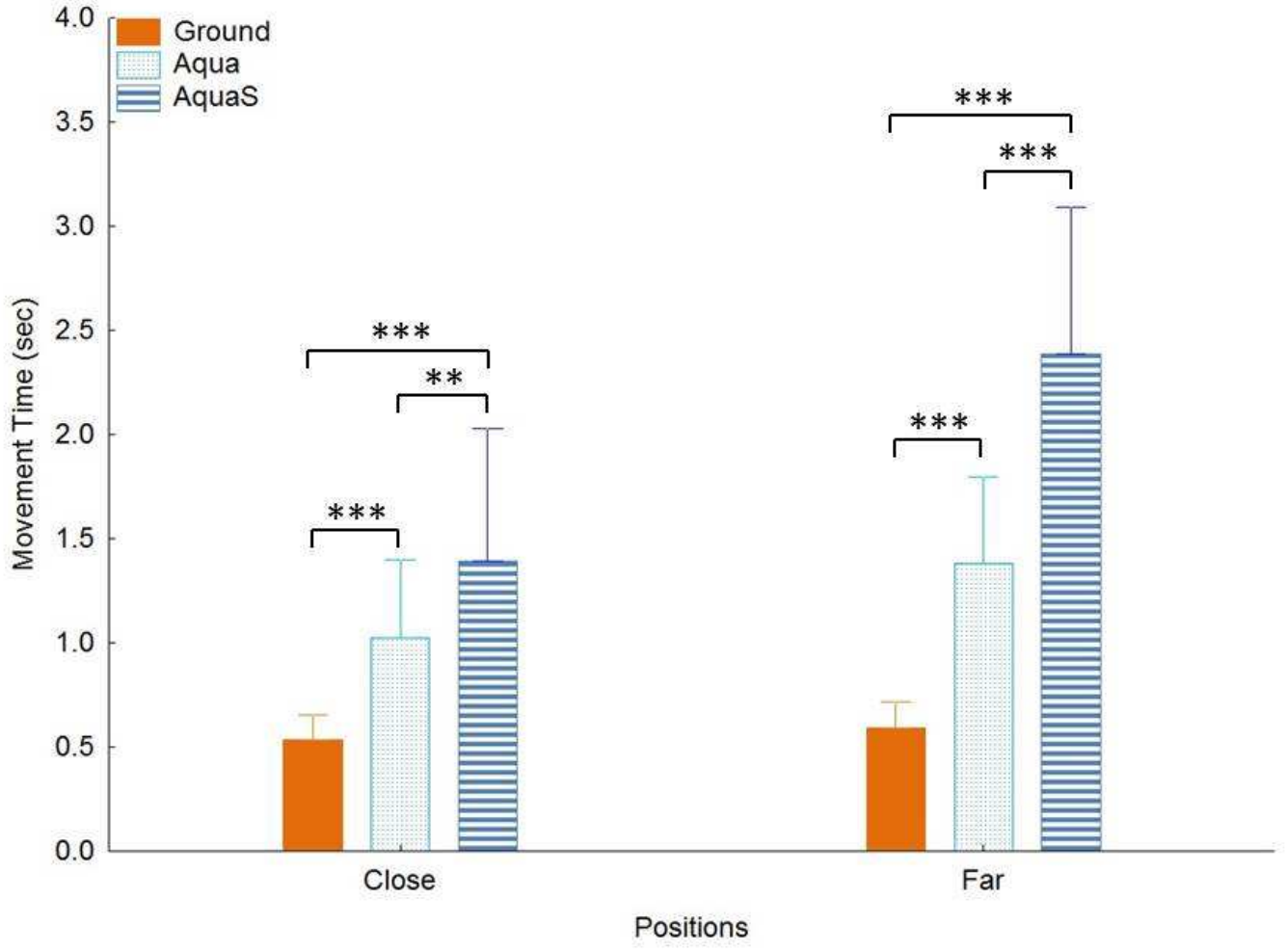


Success Rate & Final Accuracy

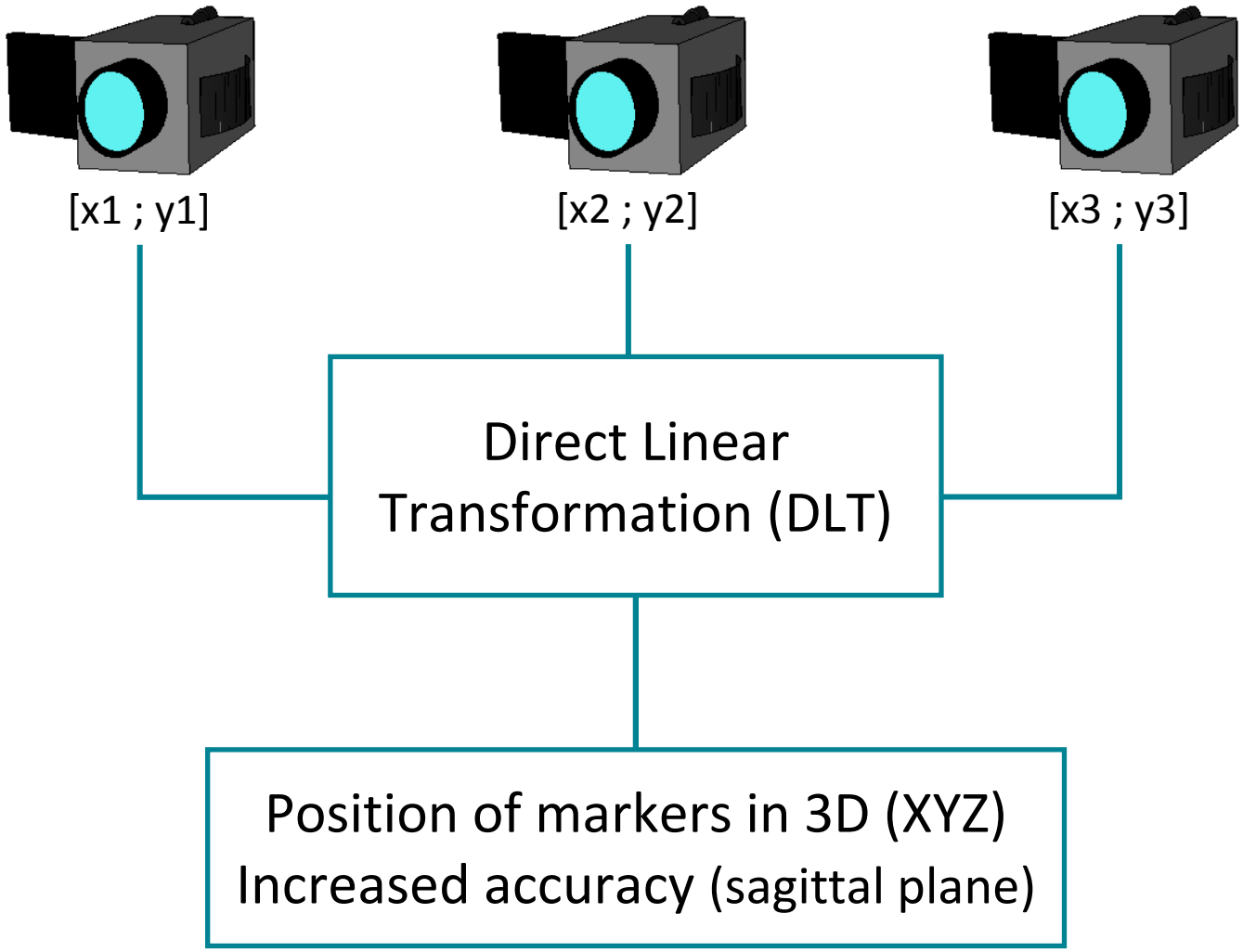




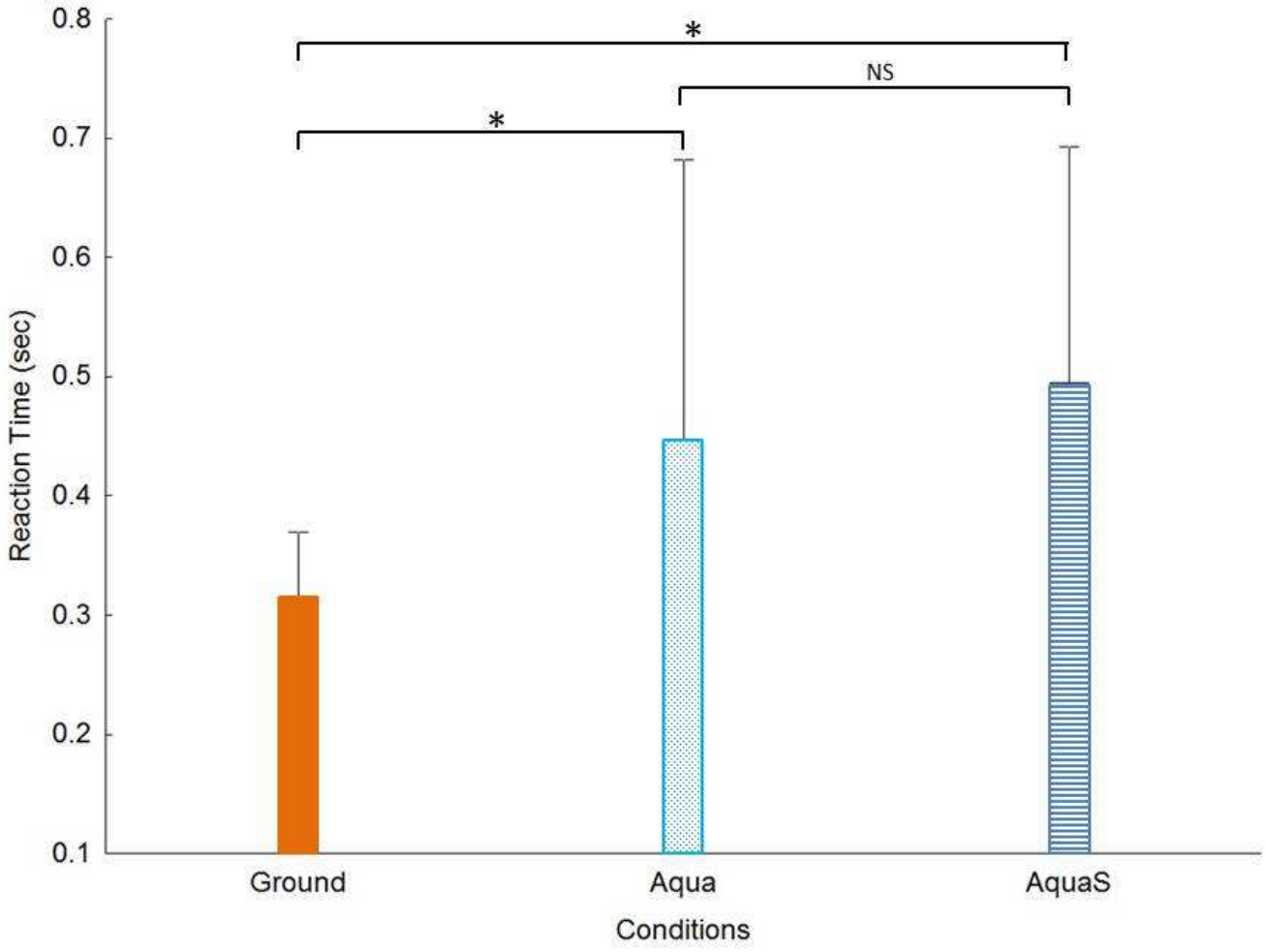
Movement Time



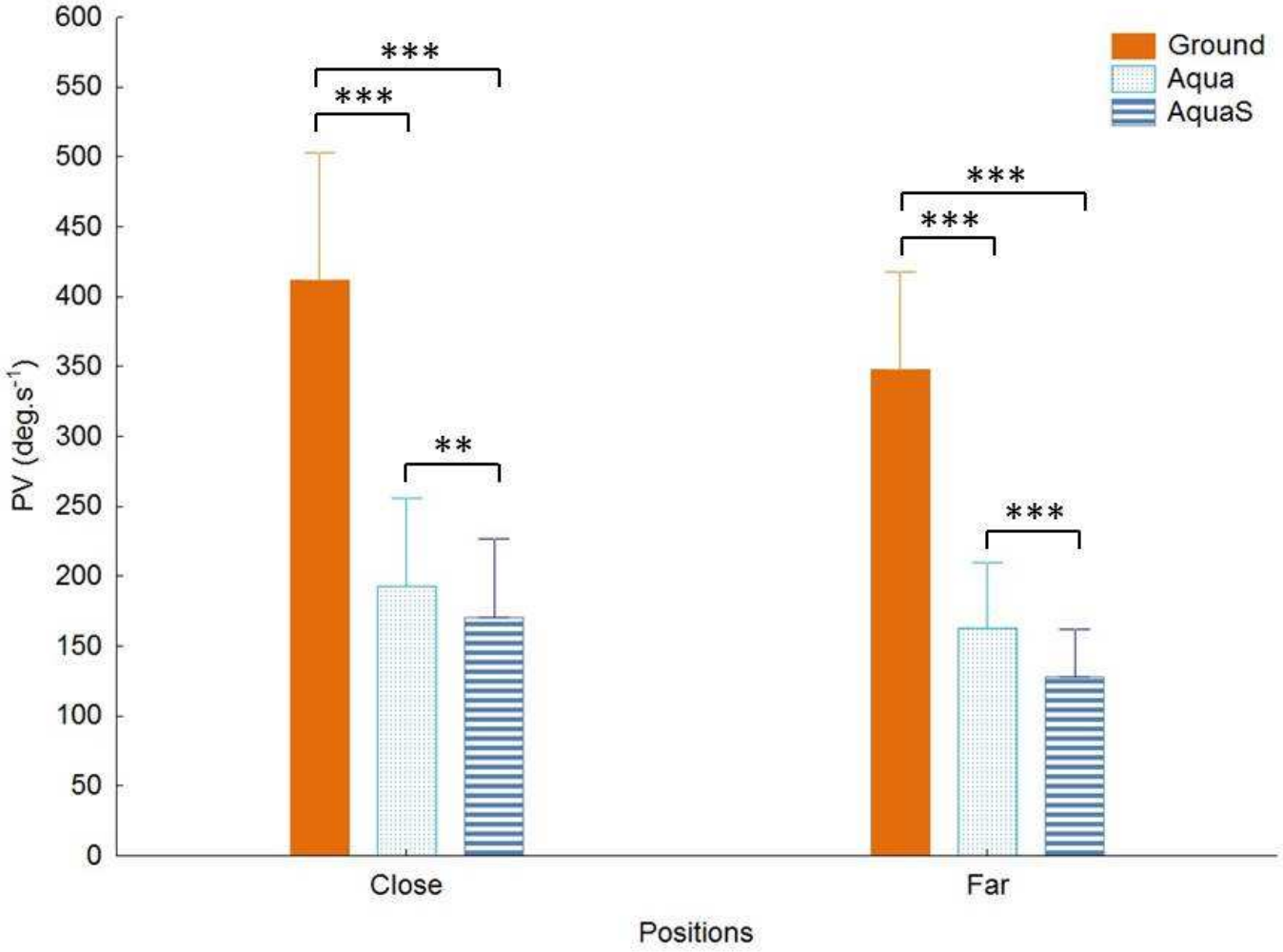
Video acquisition system



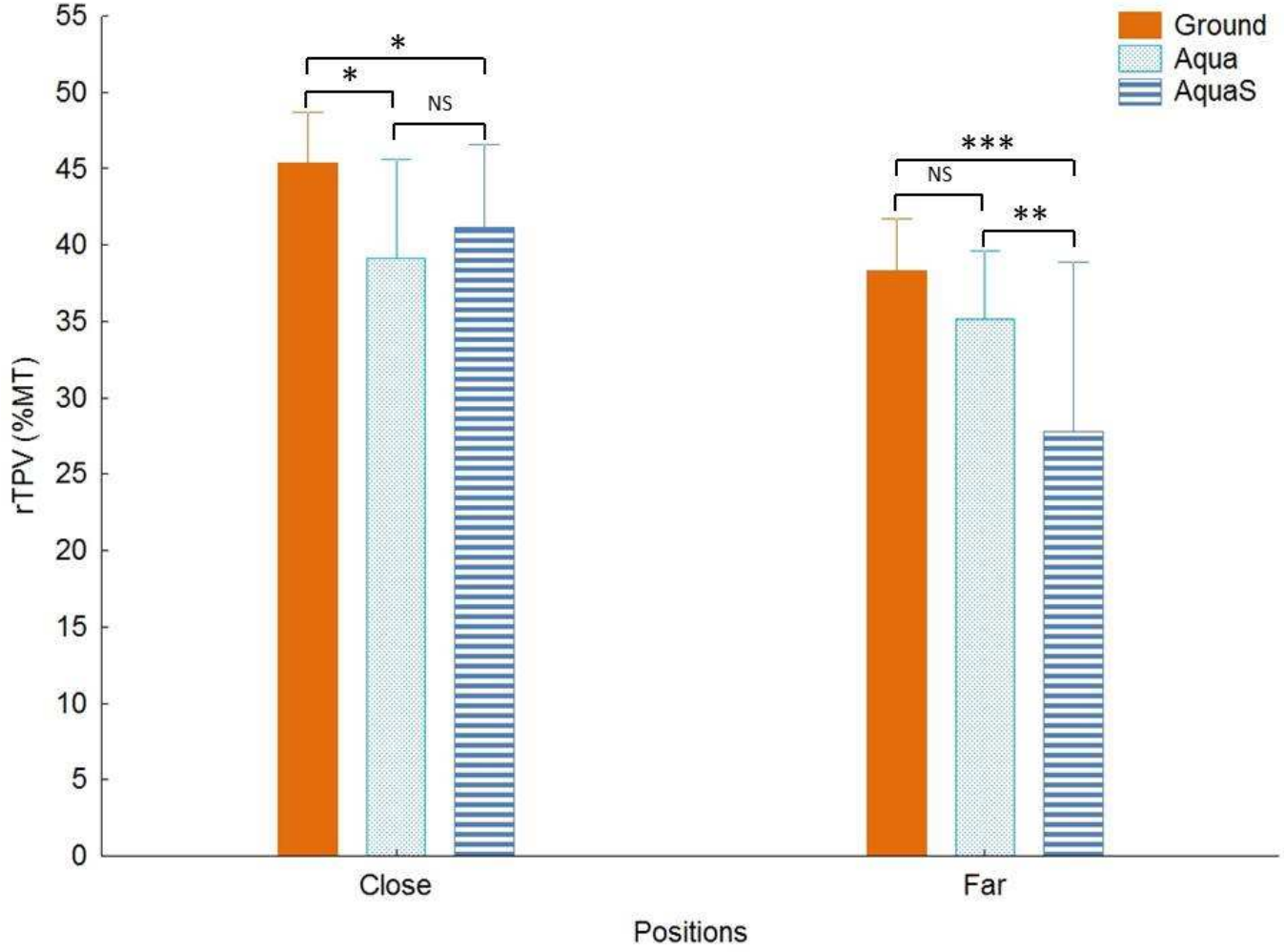
Reaction Time



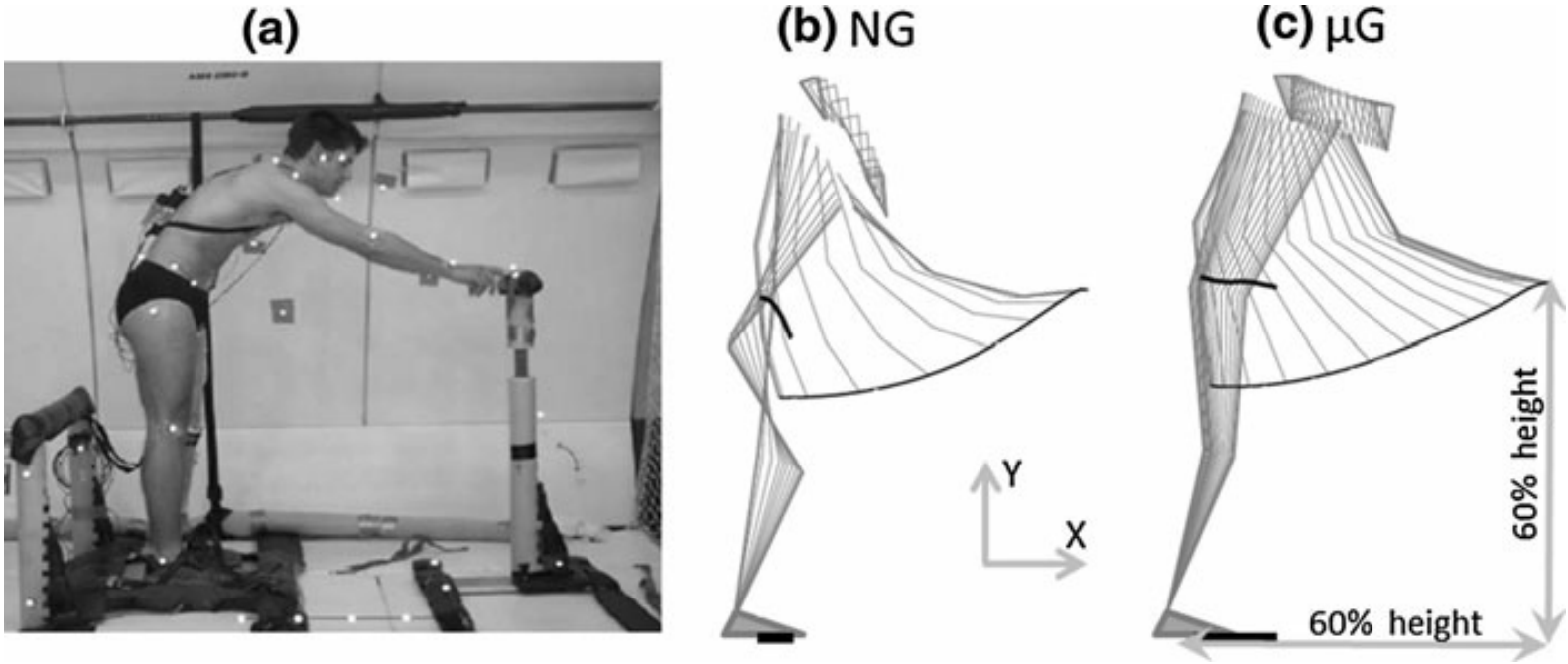
Peak Velocity



Relative Time to Peak Velocity



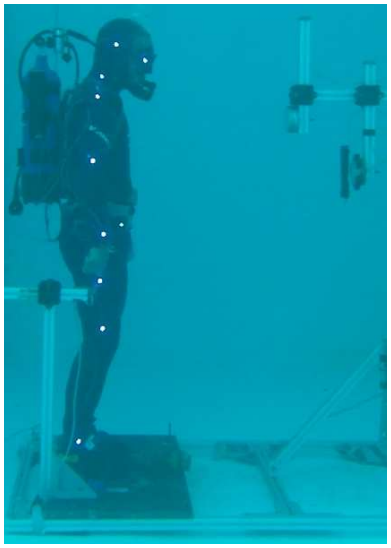
Casellato et al., 2012



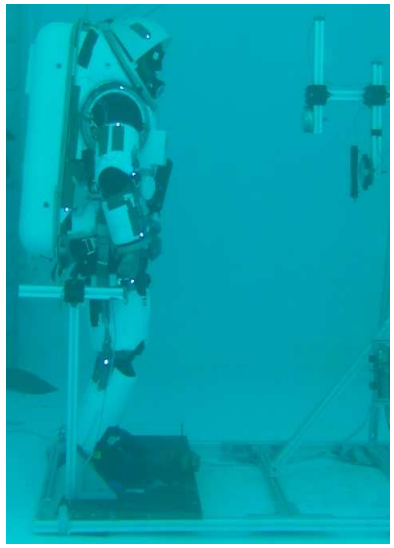
Procedure and experimental setup

3 environments
repeated measures
n=8

« Ground »

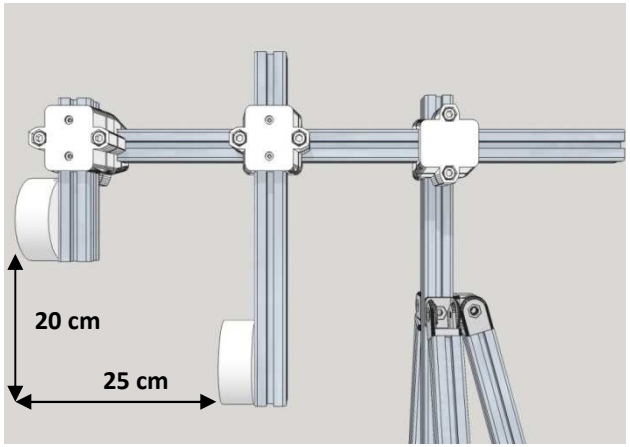


« Aqua »



« AquaS »

2 positions: -
Close
-Far



2 sizes:
-Small 5cmØ
-Large 10cmØ