CODYCO Whole-body Compliant Dynamical Contacts in Cognitive Humanoids

Understanding and modelling human whole-body behaviours in physical interaction (WP2)

Overview of work done during project year 2

Presented by:

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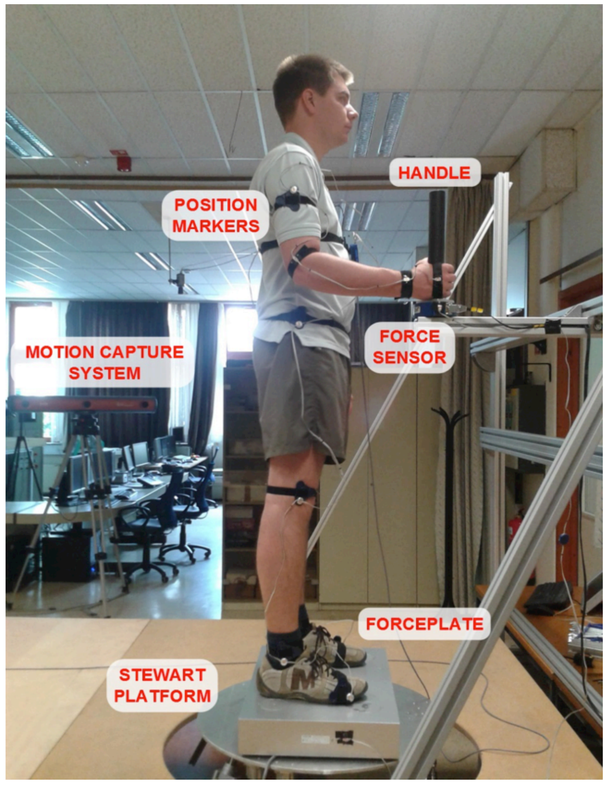
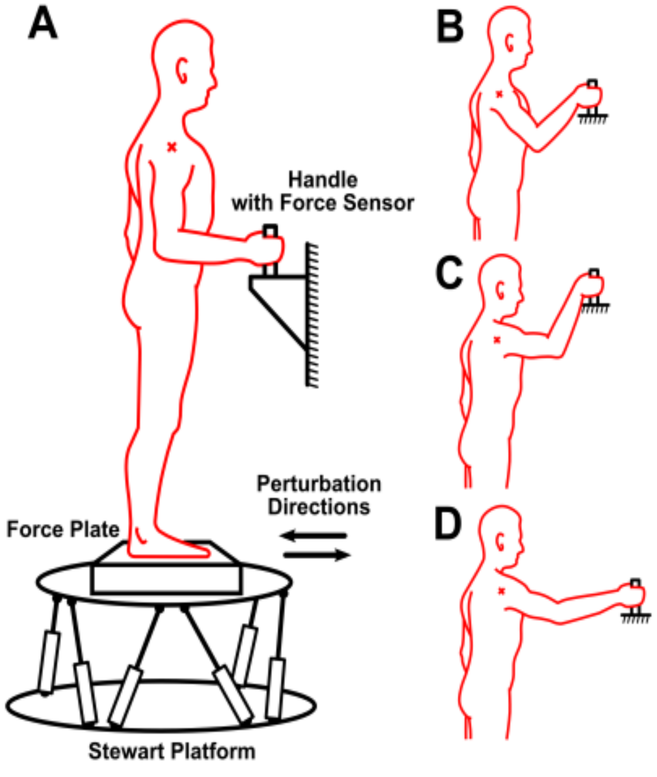
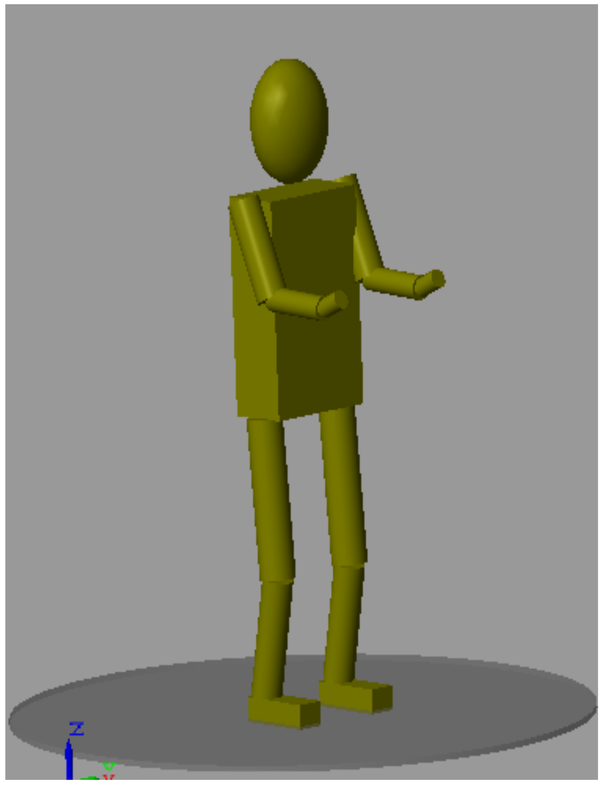
Overview of work done during project year 1

Review of human postural control and measures for stability assessment
Experimental setup and medical ethics committee approval
Experminets studying effects of rigid hand contact on human postural control
Robotic validation study







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Recommendations to WP2 from year 1 review

It can be helpful if they consider applying the concept of manipulability or effective mass on the reduced model to improve movement understanding in balancing.

The WP2 is very important for the success of the project to guide the development of learning of whole body motor control. This is why we recommend more interactions with other teams and WP3, 4, and 5.

The latent operational space is extracted from the data of WP2 and the operational space control laws can be learned without specifying the task-space manually. This is a very important step in the project and the connection between WP2 and WP4 is very promising and challenging.

Second year objectives

Task 2.2: To continue the work on **designing of models for human whole body motion in contact** where we aimed to form simplified models of high-level understanding of **how additional supportive contacts affect human motor control strategies** involved in balancing.

Task 2.3: To study **strategies that humans use in dealing with uncertainties in contact** where we aimed to go beyond the work performed in Task 2.2 by putting human subjects in situations where they had to perform **task oriented movements** by interacting with either stiff, compliant, or unpredictable supports.

Task 2.4: To get a deeper insight into **factors involved in human choice of contact utilization** and to investigate **how interaction through contacts can contribute to learning** of whole body motor control.

Overview

Role of supportive hand contact and associated changes in postural responses during continuous perturbations of stance (Task 2.2 and Task 2.4)

Manipulability of COM – metric of the effects of supportive contacts on the robot's stability (Task 2.2)

Human strategies of dealing with uncertainties in contact (Taks 2.3)

Hand contacts during goal directed actions – are supportive hand contacts planned or reactive? (Task 2.4)

Unifying speed-accuracy trade-off and cost-benefit trade-off: a motor control model (Task 2.2 and Task 2.3)

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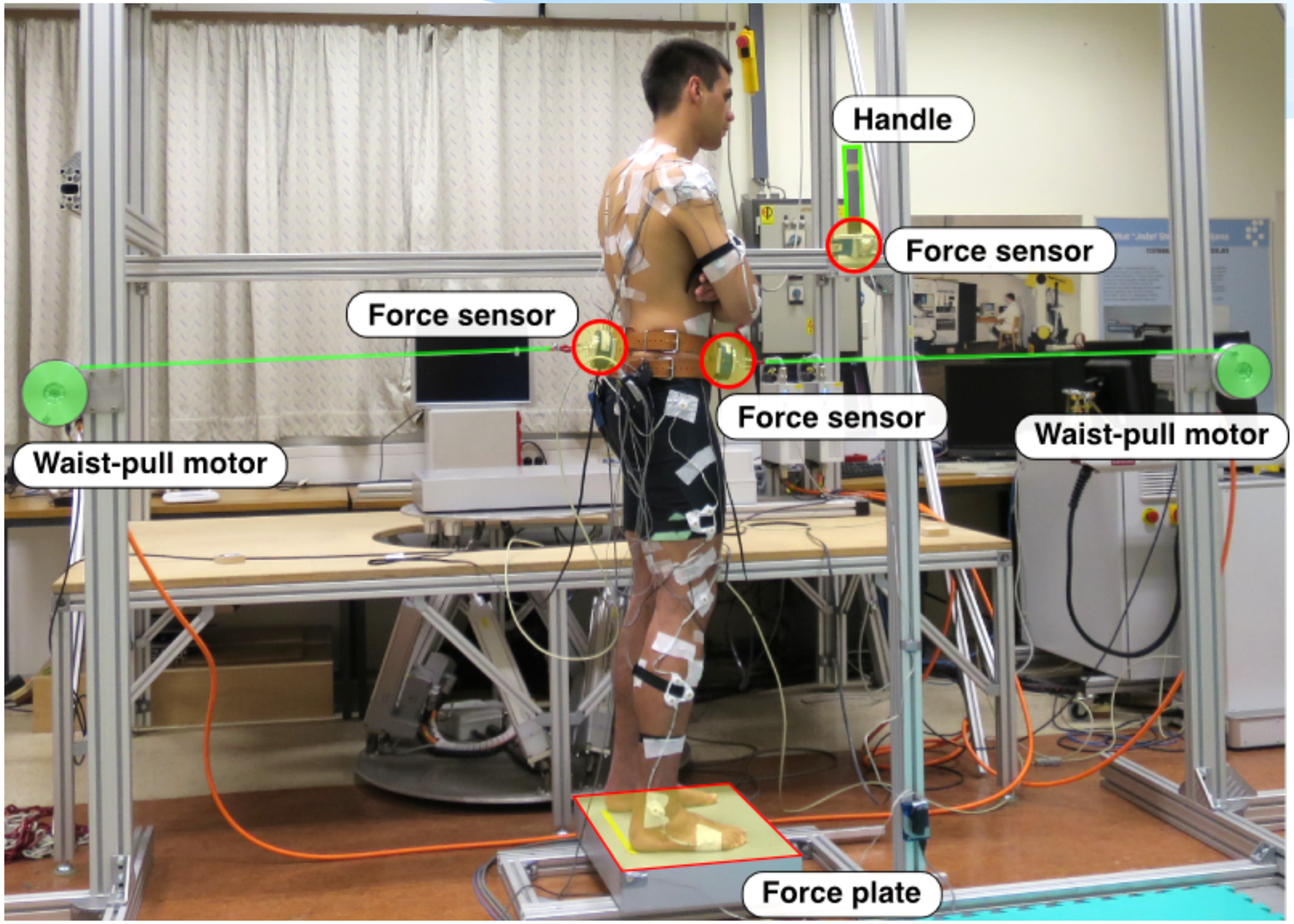
Role of supportive hand contact and associated changes in postural responses during continuous perturbations of stance



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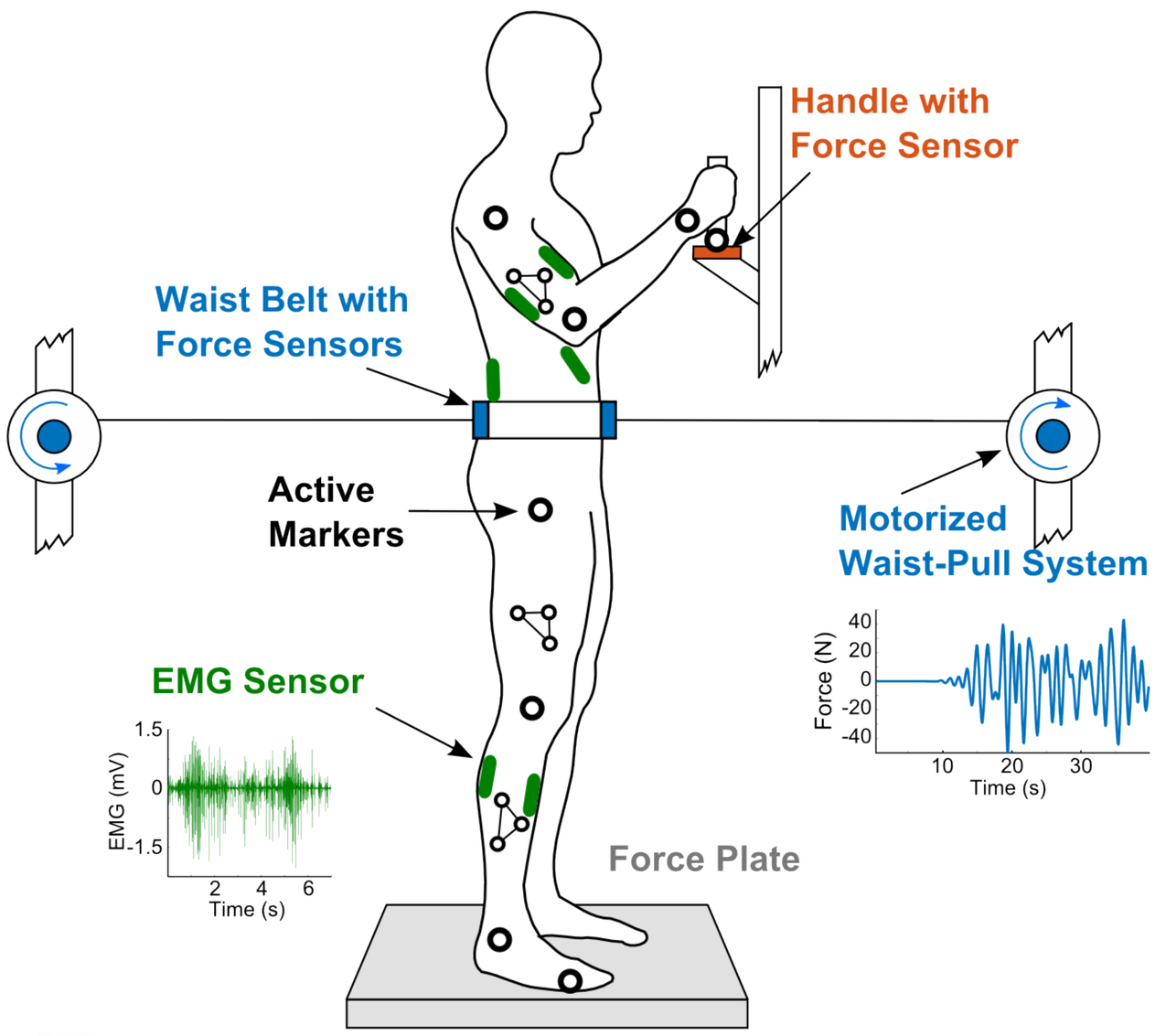
Experimental setup



Light continuous perturbations – filtered white noise (0.25 Hz – 1 Hz)

Whole body kinematics – 20 active markers

Muscle activity – EMG of arm, trunk, and leg muscles

Contact forces – force plate and force sensor in the handle

Analyses – Power Spectral Density (PSD)

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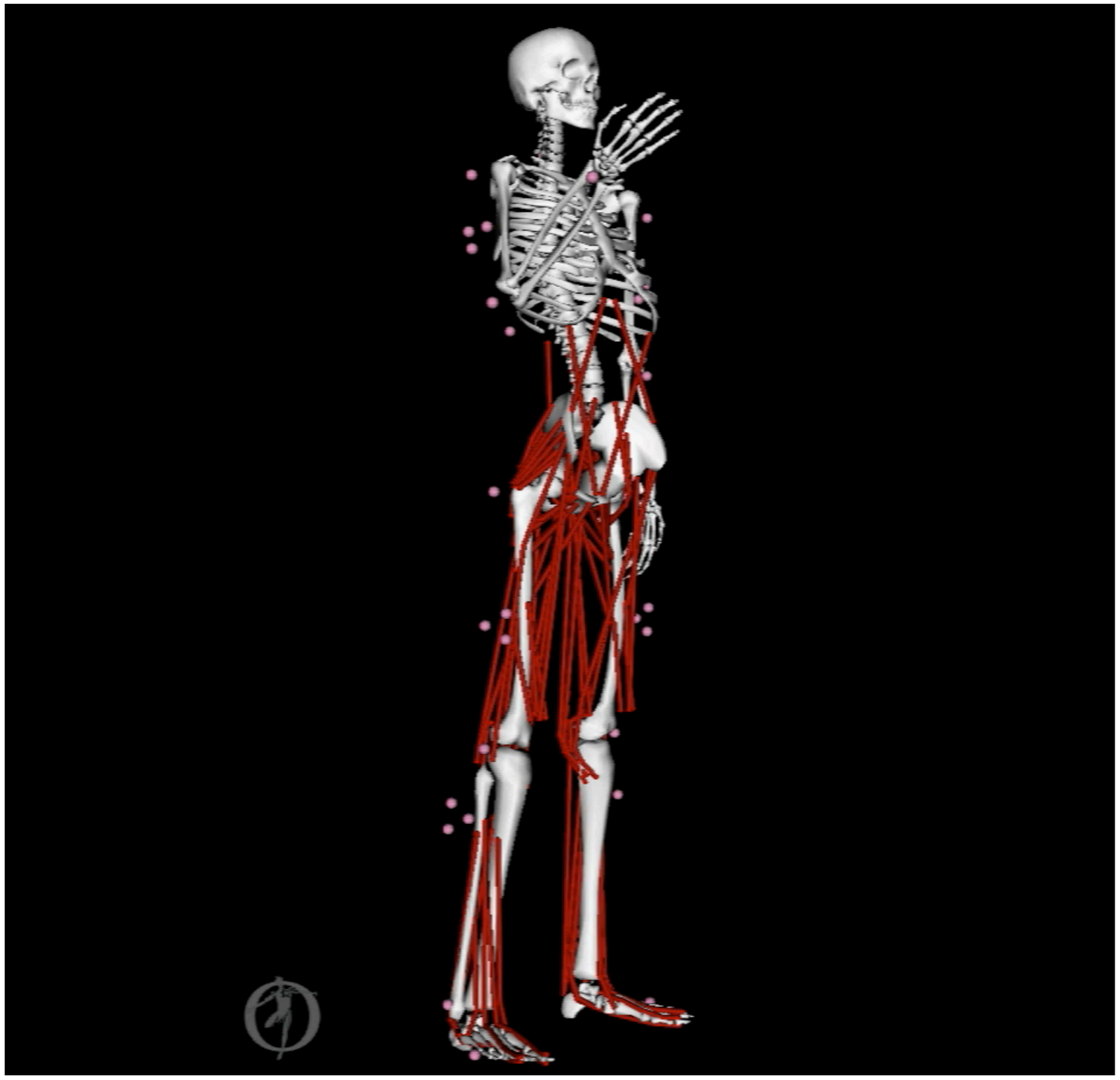
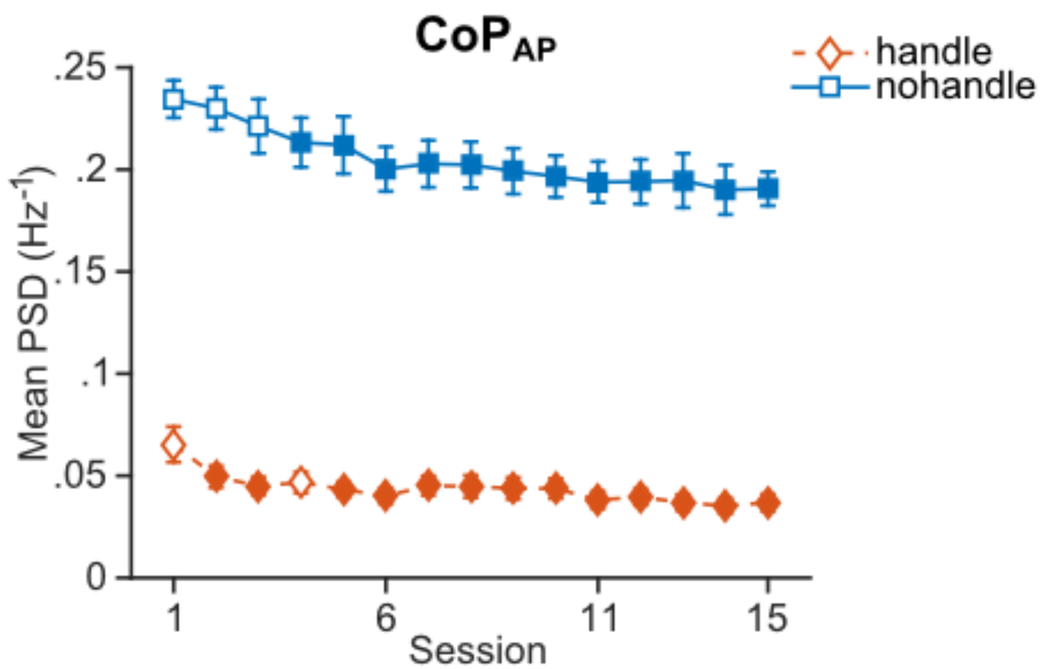
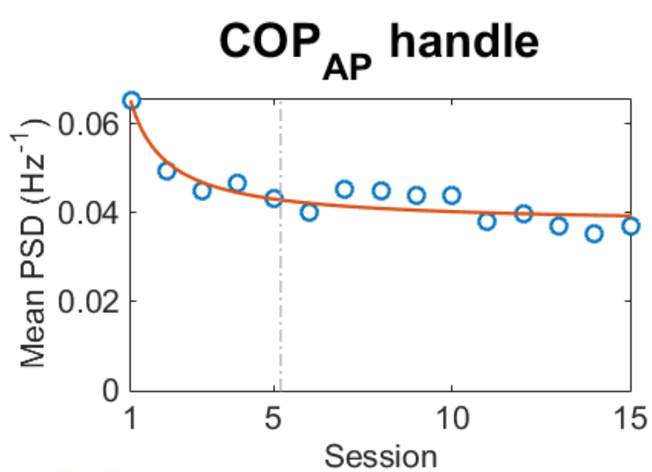
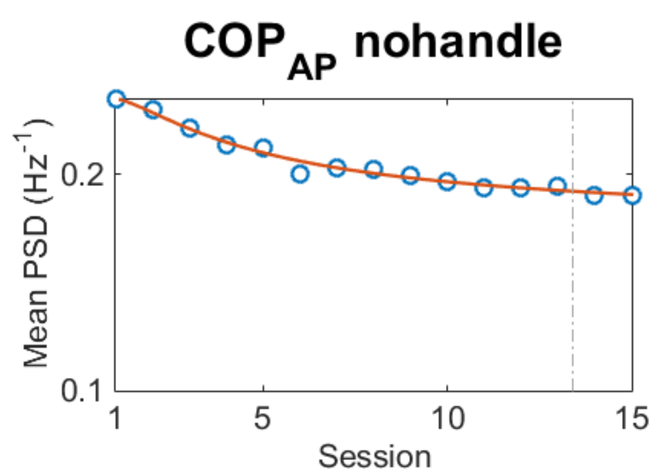
Whole-body analyses



Adaptation through time







Larger COP motion in nohandle condition

Adaptation happened in both conditions

Faster adaptation when using hand contact

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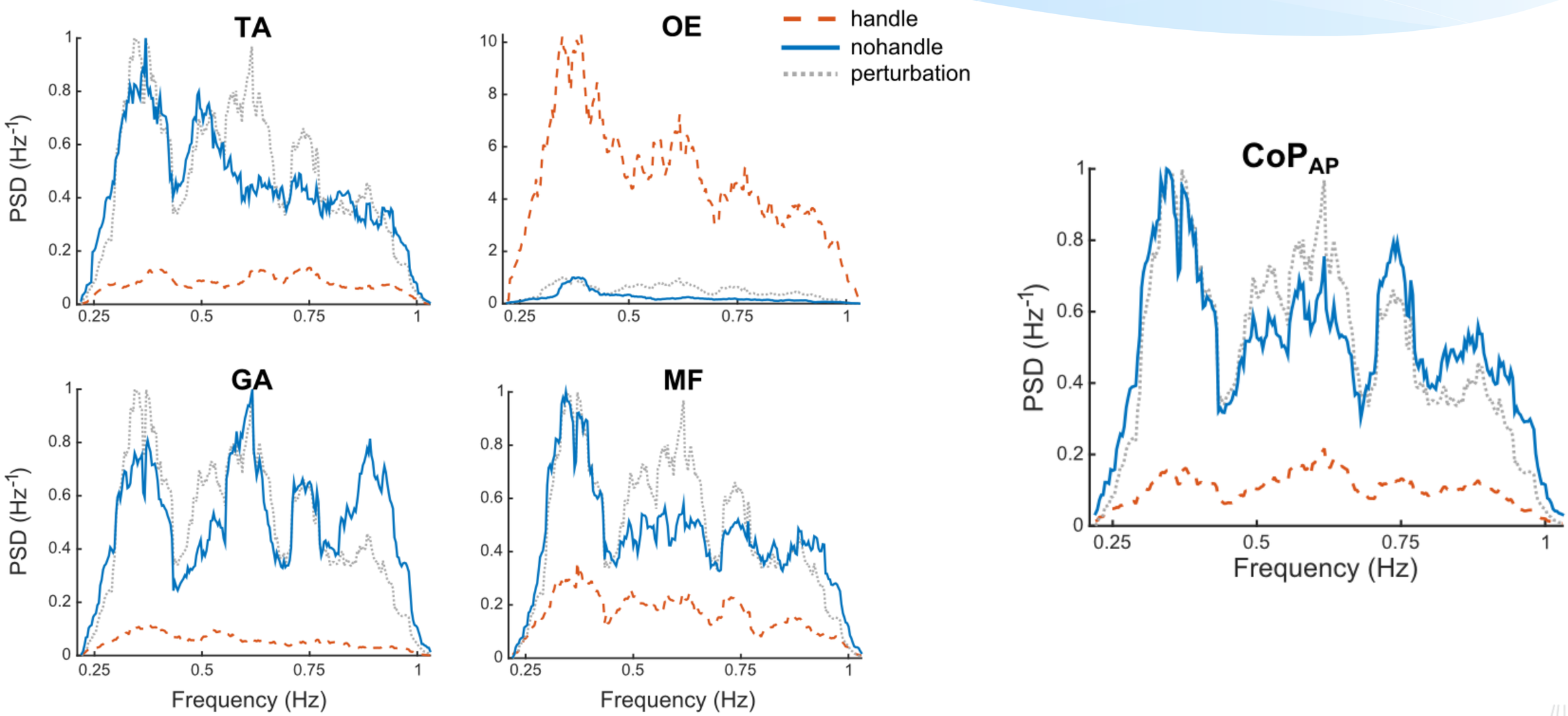
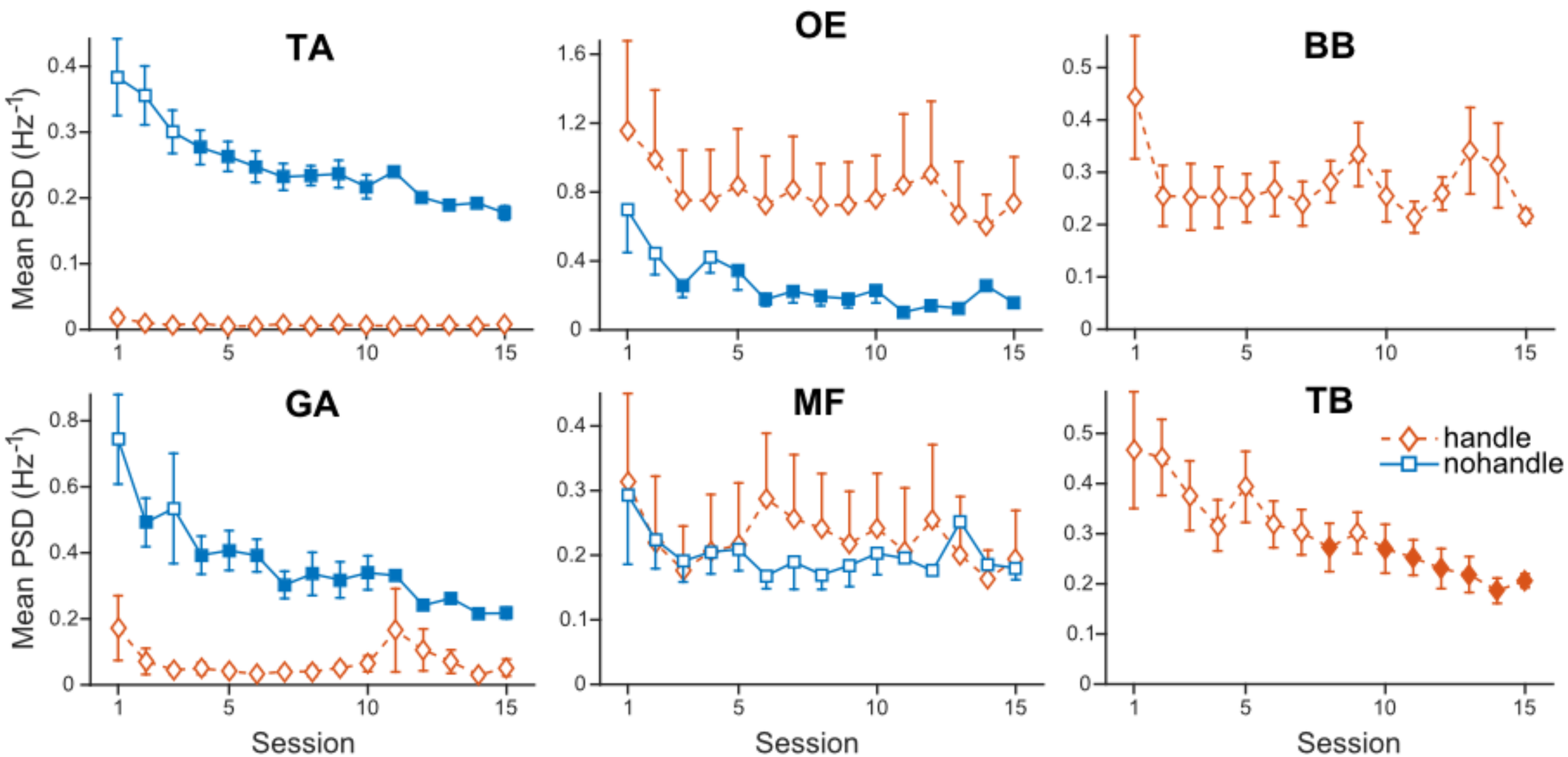
Effect of perturbation on muscle activity



leg

trunk

Adaptation of muscle activity through time



leg trunk arm

Effect of holding the handle

session	MF	OE	TA	GA
1	0	0	1	1
5	0	0	1	1
10	0	0	1	1
15	0	1	1	1

Low (0.25-0.5Hz) **M**edium (0.51-0.75Hz) **H**igh (0.76-1.00Hz)

session	MFL	MFM	MFH	OEL	OEM	OEH	TAL	TAM	TAH	GAL	GAM	GAH
1	0	0	0	0	0	0	1	1	1	1	1	1
5	0	0	0	0	0	0	1	1	1	1	1	1
10	0	0	0	0	0	0	1	1	1	1	1	1
15	0	0	0	0	1	1	1	1	1	1	1	1

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Conclusions

Adaptation occurs in spite of the randomness of the perturbations

Leg muscles become inactive with hand contact

Possible synergy between belly muscle and arm muscles at higher frequencies

Submitted for publication to **Journal of Biomechanics**

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Metric of the effects of supportive contacts on the robot's stability

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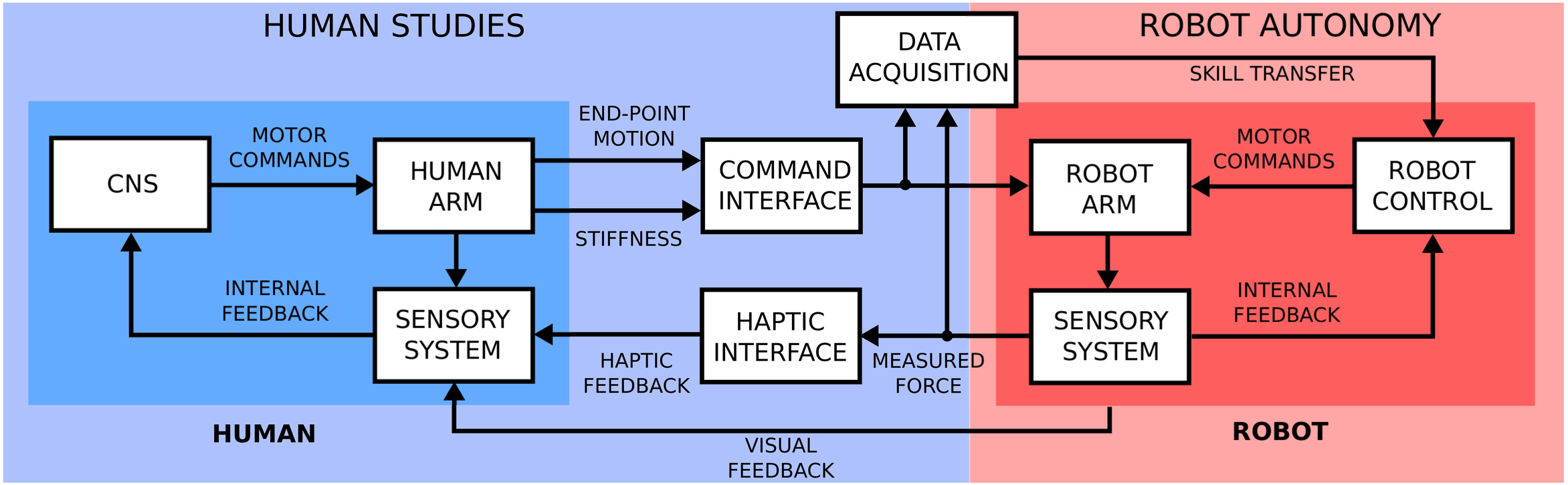
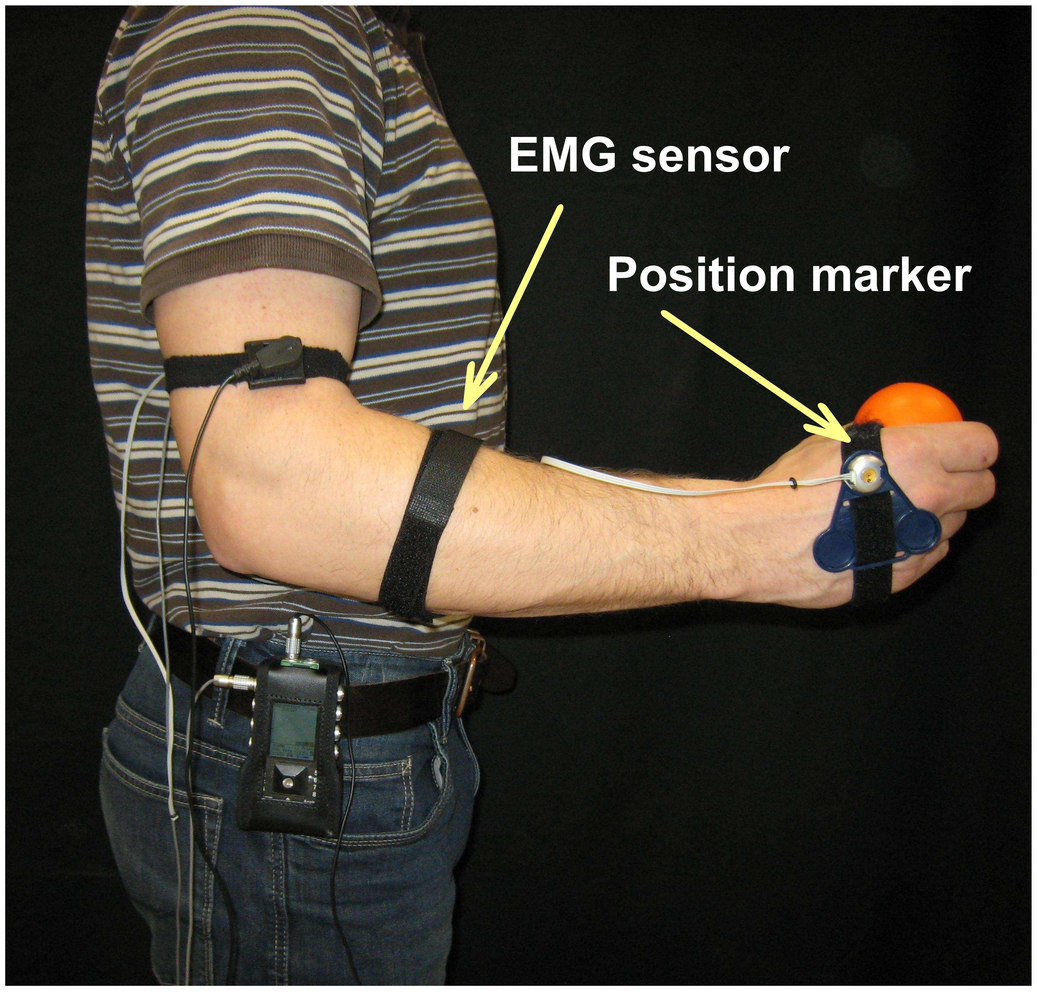
Human strategies of dealing with uncertainties in contact



Modulation of impedance



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HUMAN-IN-THE-LOOP TEACHING USING HAPTIC INTERFACE AND IMPEDANCE CONTROL INTERFACE

Are supportive hand contacts planned or reactive

Reaching for a far target on the screen

20 subjects

Trunk and arm kinematics – 17 active markers

Contact forces – 2 force plates for GRF and table forces

Analyses – novel environment, catch trials, aftereffects, correlation of motion of arms and trunk

Work spanning WP2, WP3 and WP4; collaboration between JSI, UPMC, TUD

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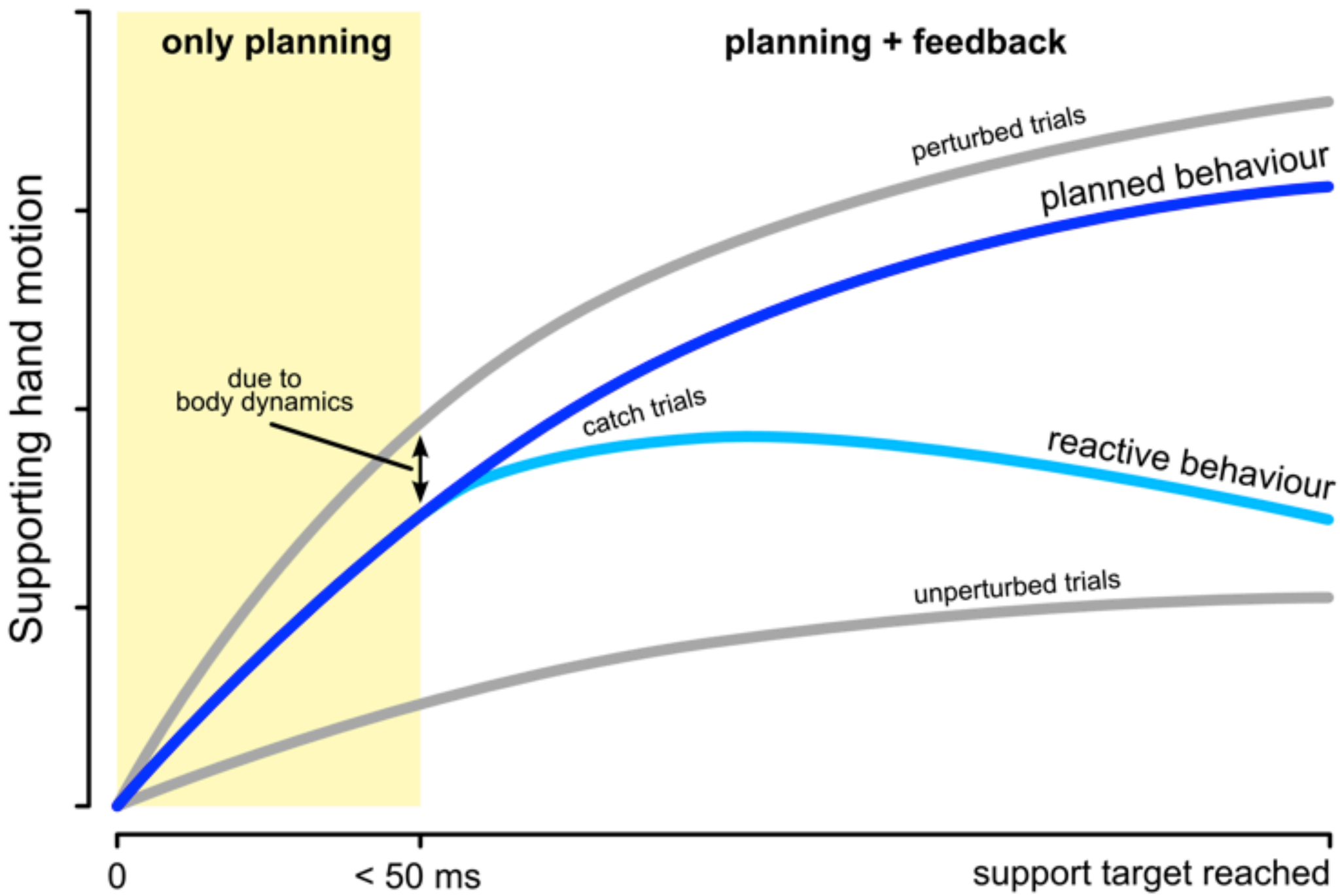
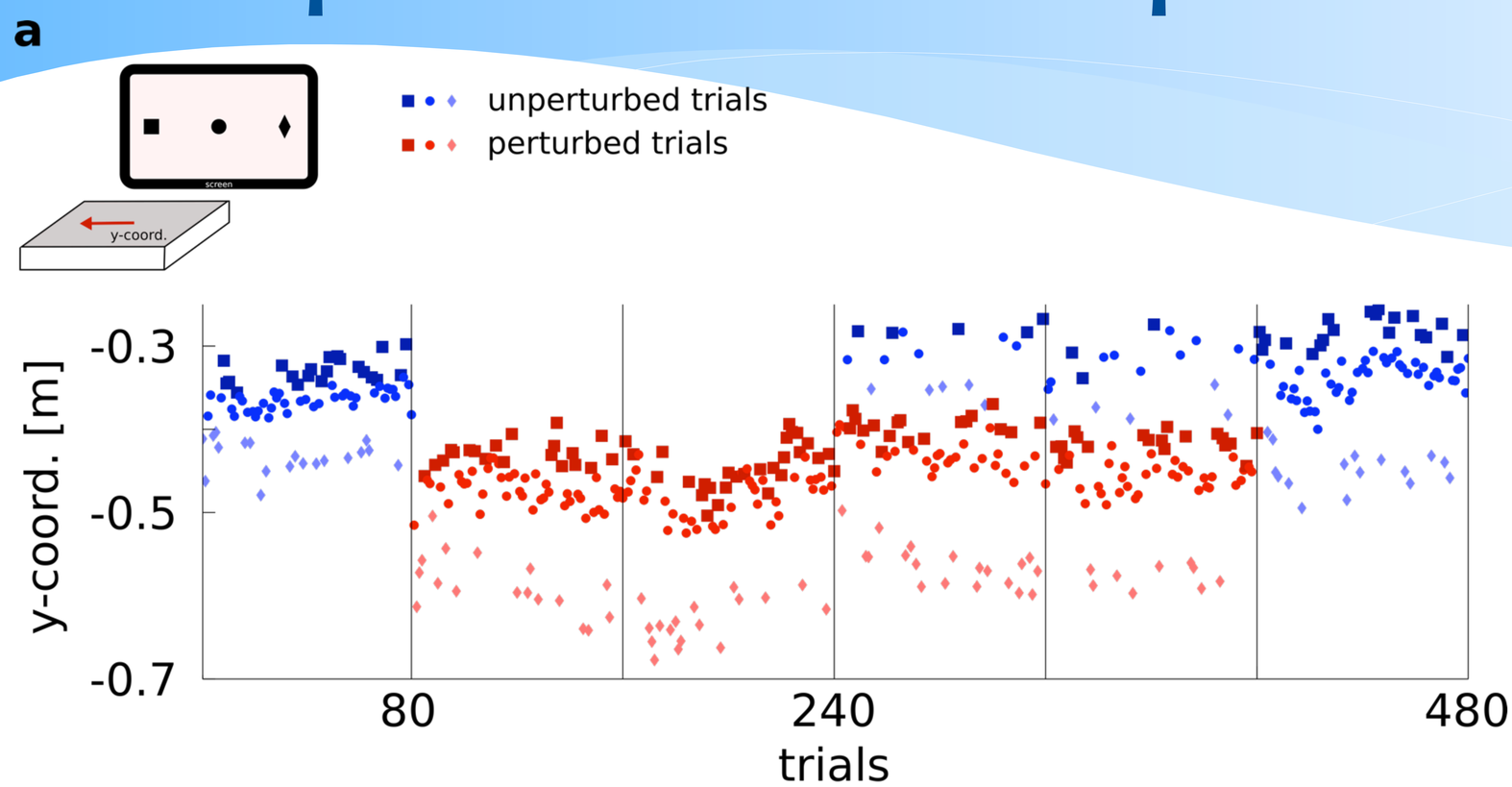
Experiments

Hypotheses

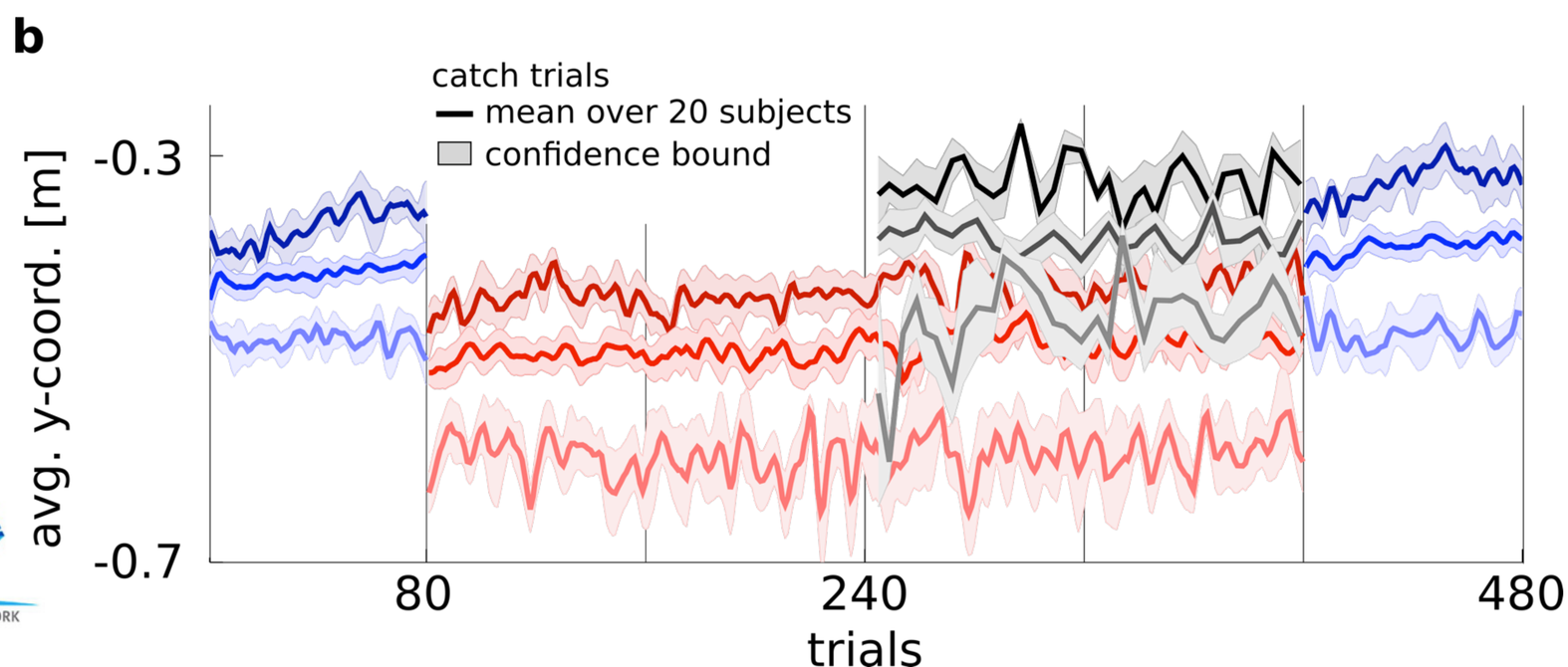

only planning
planning + feedback
perturbed trials
planned behaviour
due to
body dynamics
catch trials
reactive behaviour
unperturbed trials
Supporting hand motion
0
< 50 ms
support target reached

Catch trials: Switching back to policies of unpertb. trials



unperturbed

perturbed



20 male subjects

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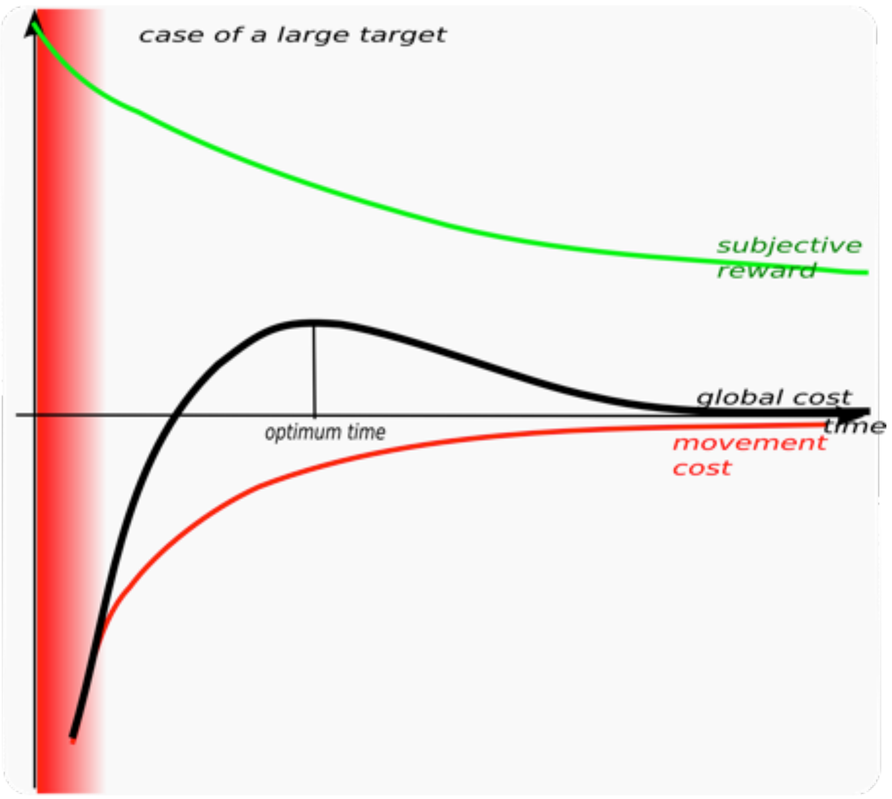
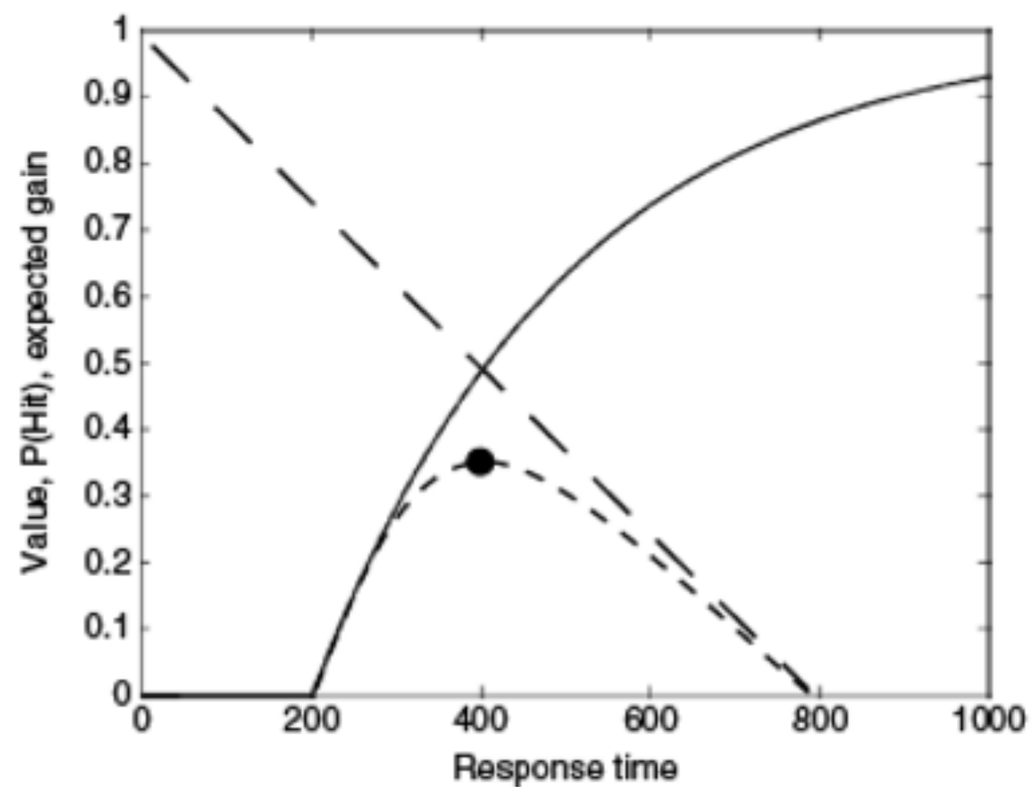
Unifying speed-accuracy trade-off and cost-benefit trade-off

speed – accuracy trade-off



cost – benefit trade-off



Work spanning WP2, WP3; collaboration between JSI, UPMC

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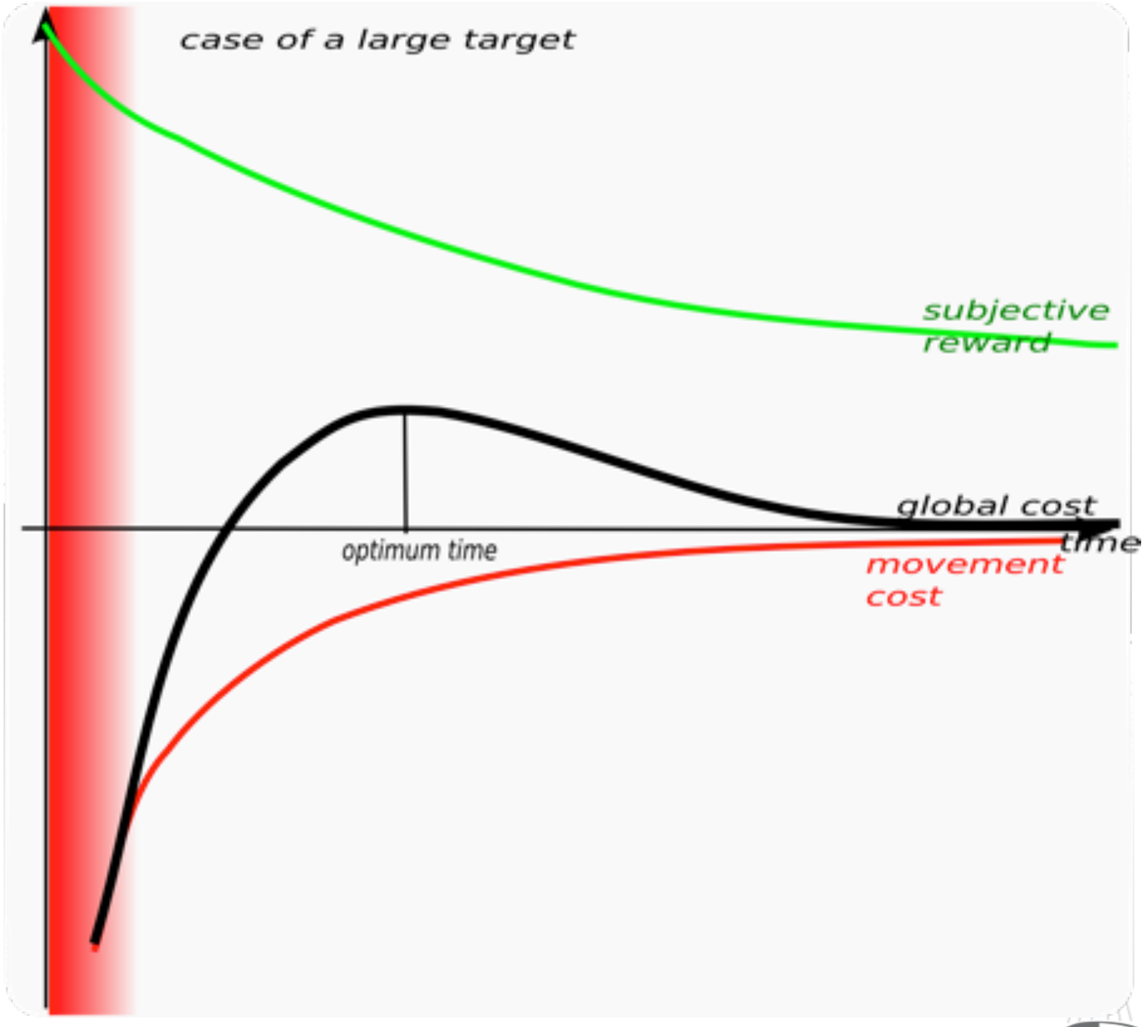
Cost-Benefit Tradeoff (CBT) model

- Proposed by Rigoux and Guigon (2012)
- Reaching time is determined by optimization of CTB

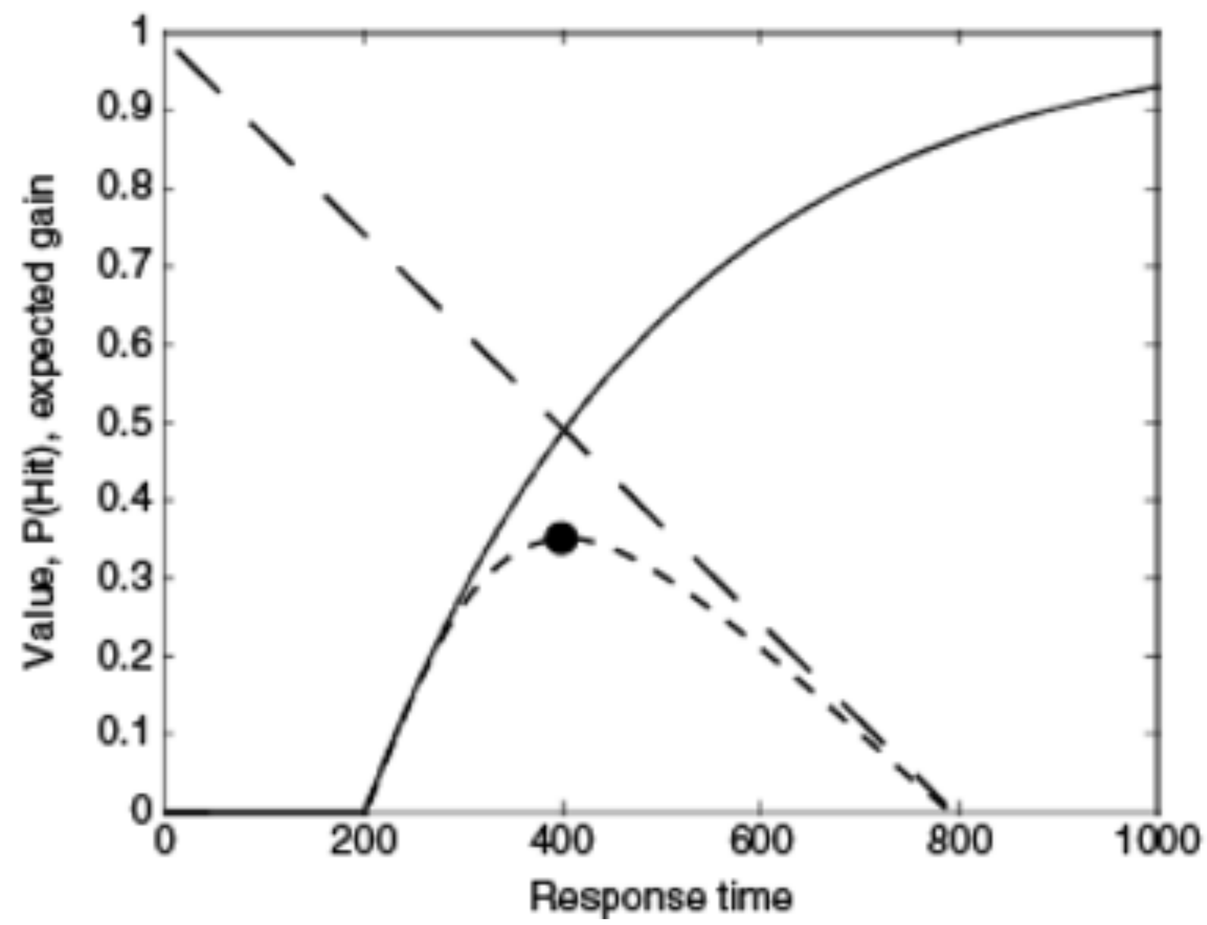
$$J(\vec{u}) = \int_0^\infty e^{-t/\gamma}[\rho R(\vec{s}_t) - \nu L(\vec{u}_t)]dt$$

$$L(\vec{u}_t) = ||u_t^2||$$



Speed-Accuracy Tradeoff (SAT) model

- Proposed by Dean et al. (2007)
- The value of a hit on the target decreases linearly with time (dashed line)
- SAT: increase of movement duration results in decreased end-point variance
- Duration corresponding to maximum expected gain (circle)



Proposed model

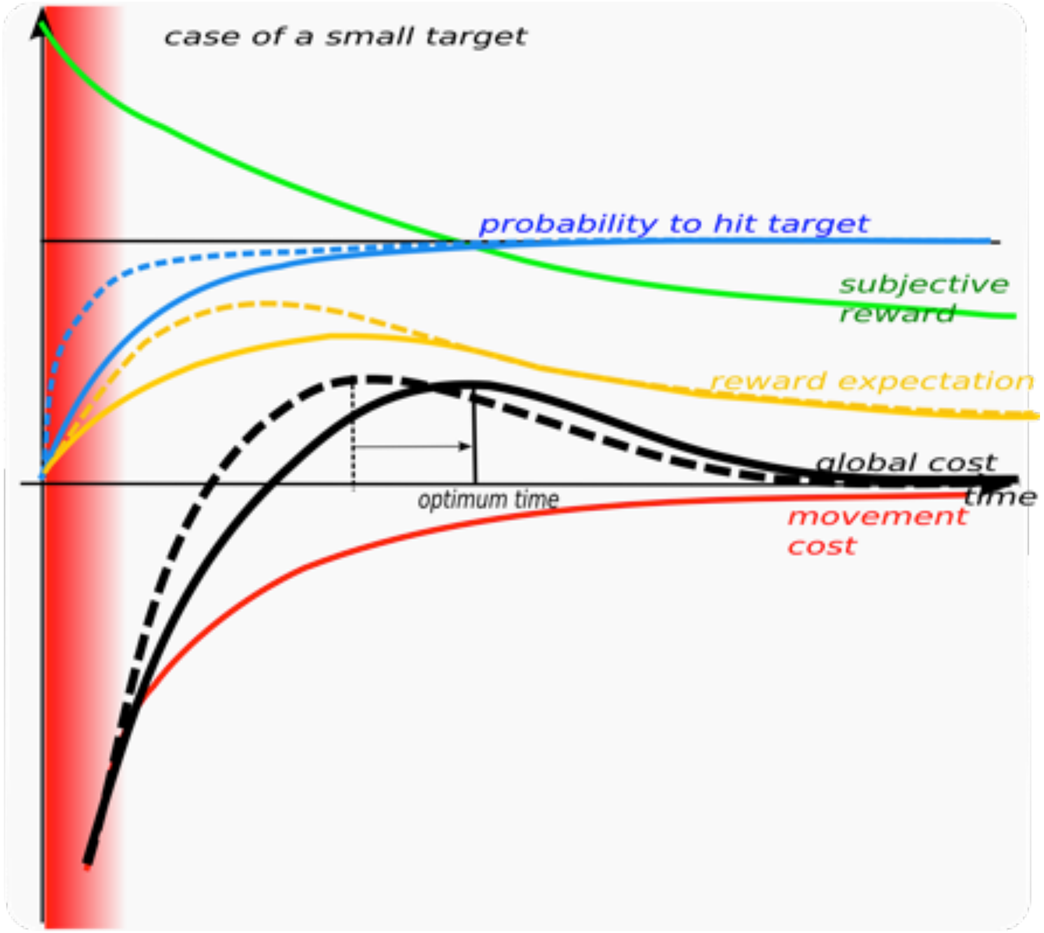
For small targets and fast movement, the target may be missed

reward -> reward expectation

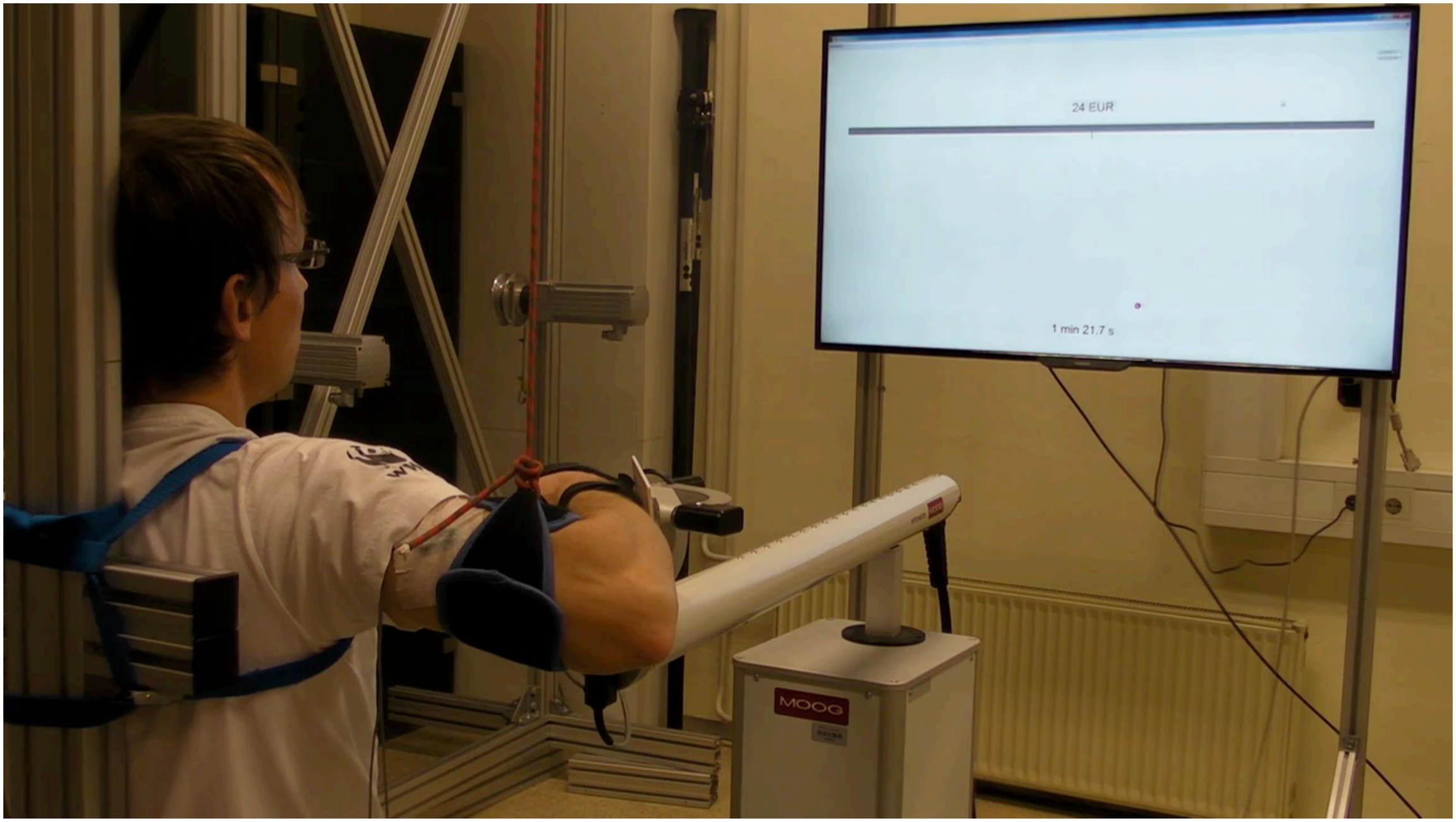
$$J(\vec{u}) = \int_0^\infty e^{-t/\gamma} \mathbb{E}[\rho R(\vec{s}_t) - \nu L(\vec{u}_t)] dt$$

SAT emerges from the optimization criterion

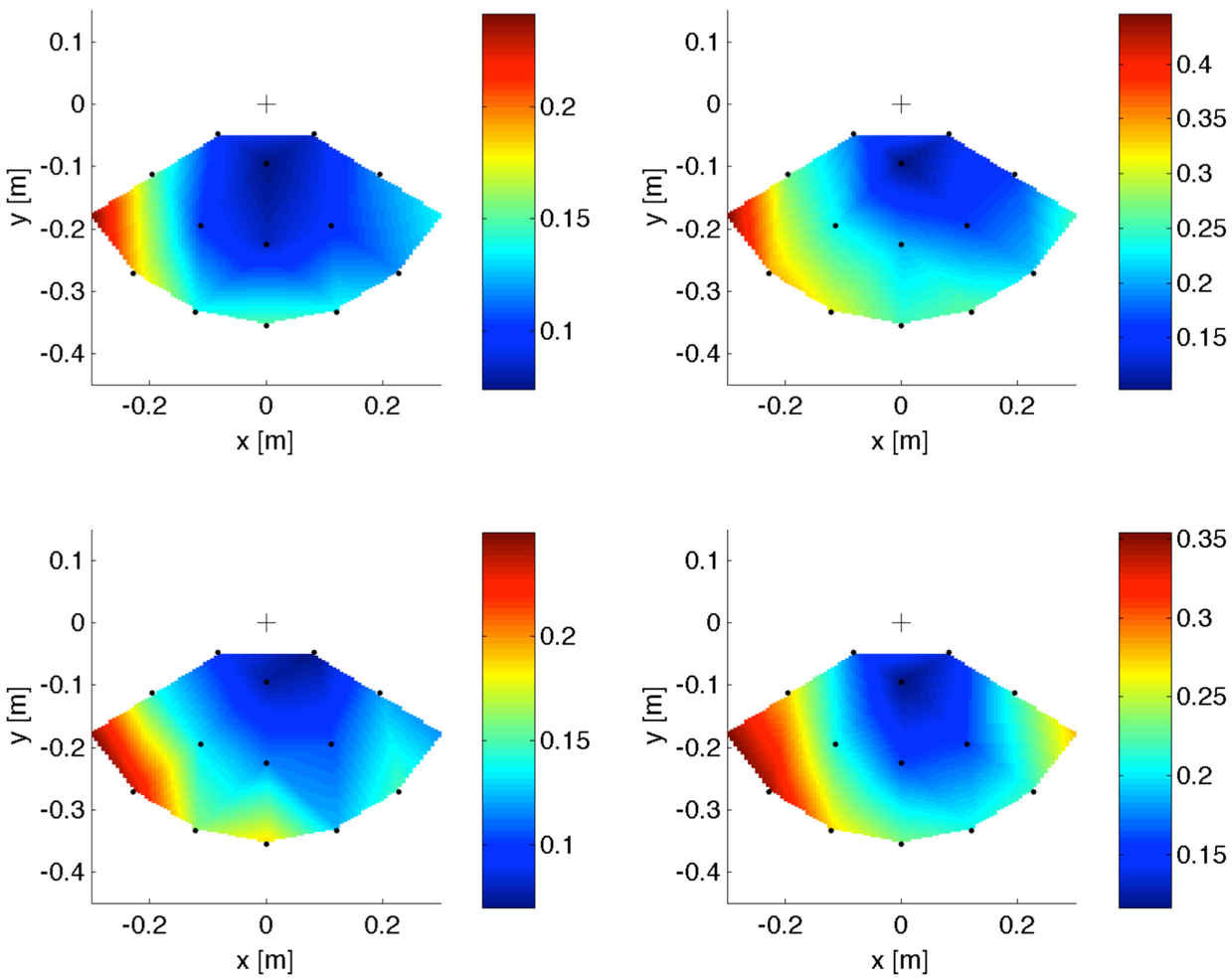
Movement time emerges from the combination of CBT and SAT

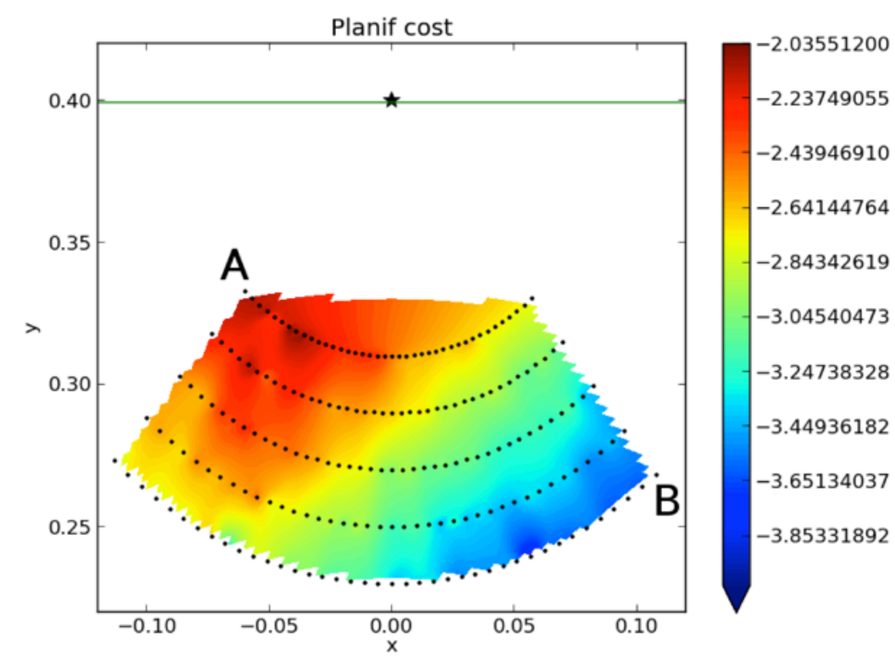


Experiments



Cost of reaching motions





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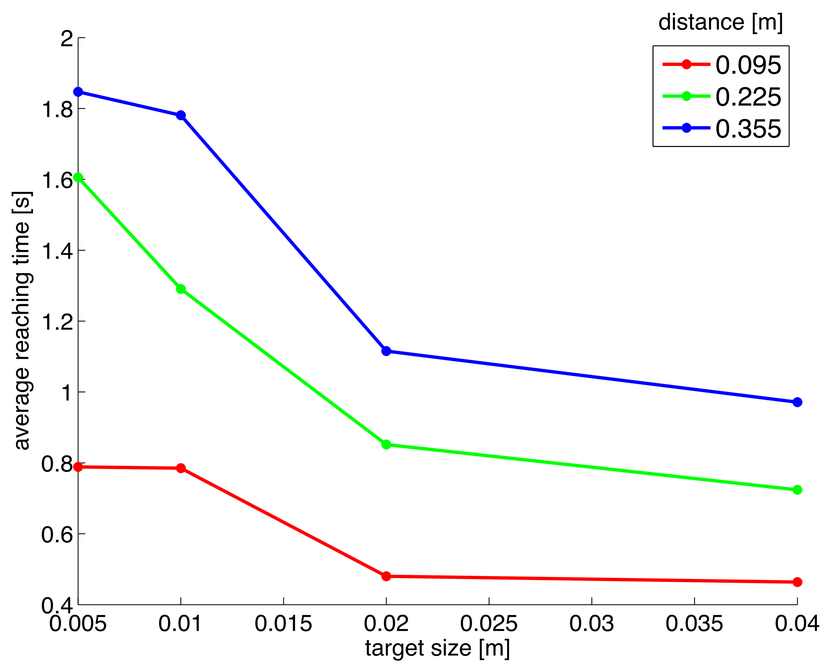
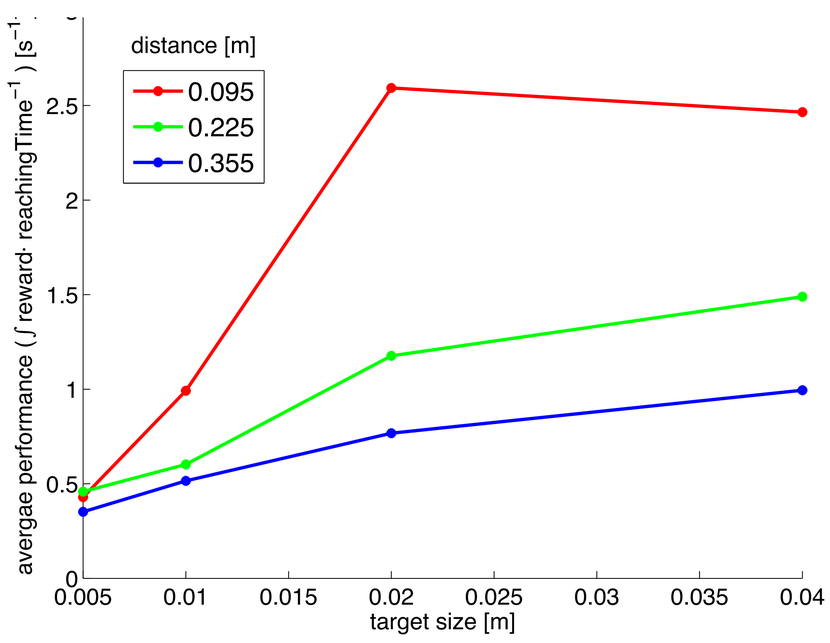
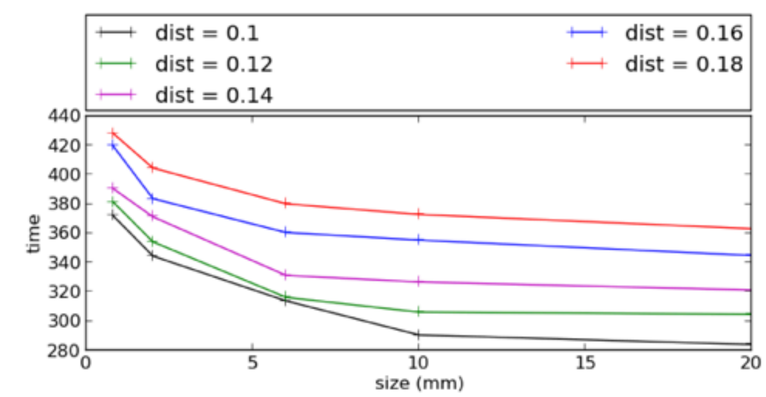
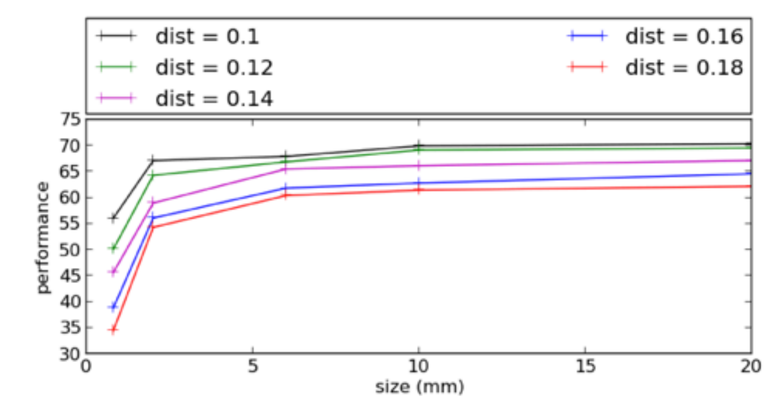
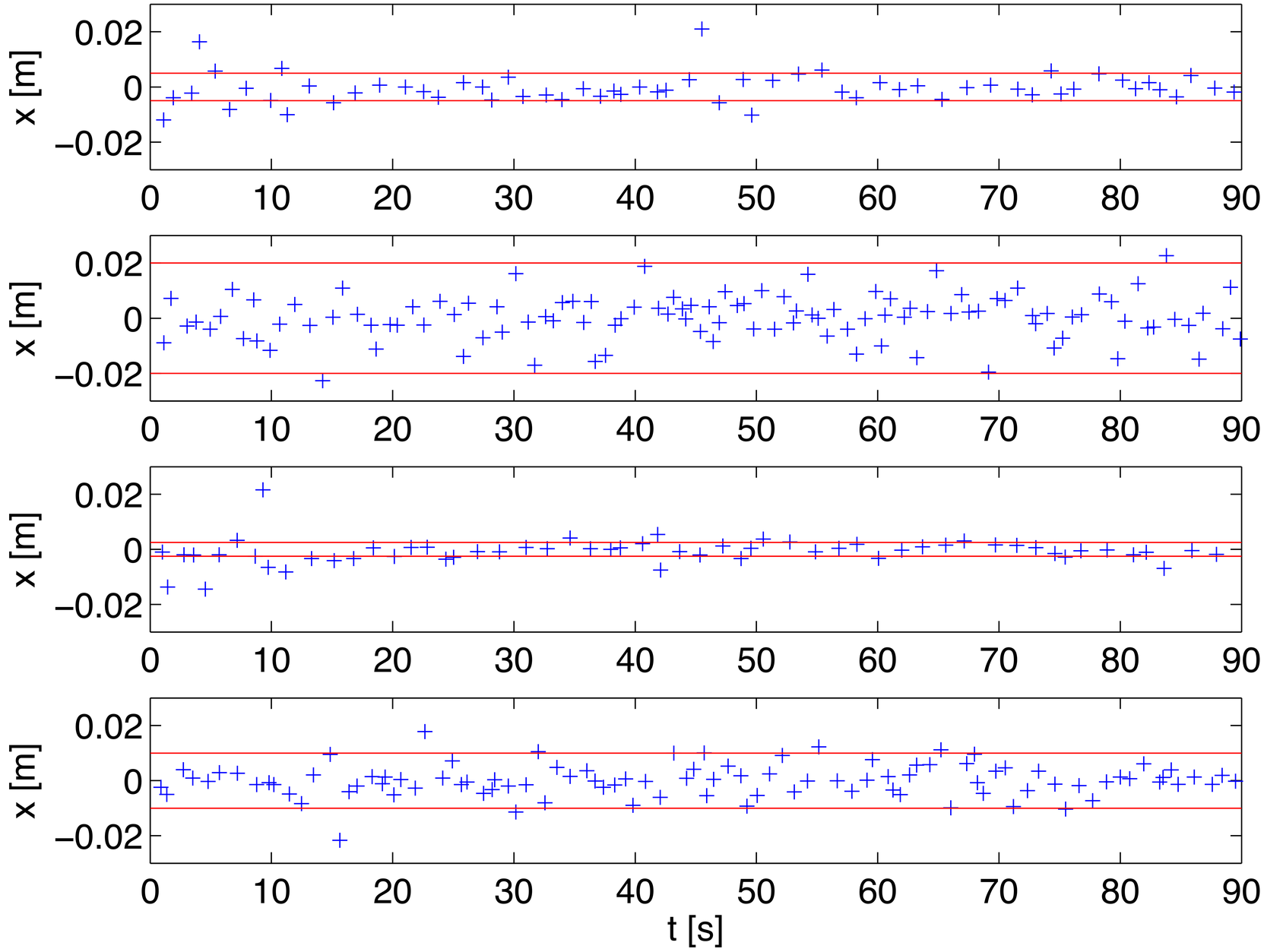
Reaching time and performance









Dispersion of target hits