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Océane Dubois, Agnès Roby-Brami, Ross Parry, Nathanael Jarrasse

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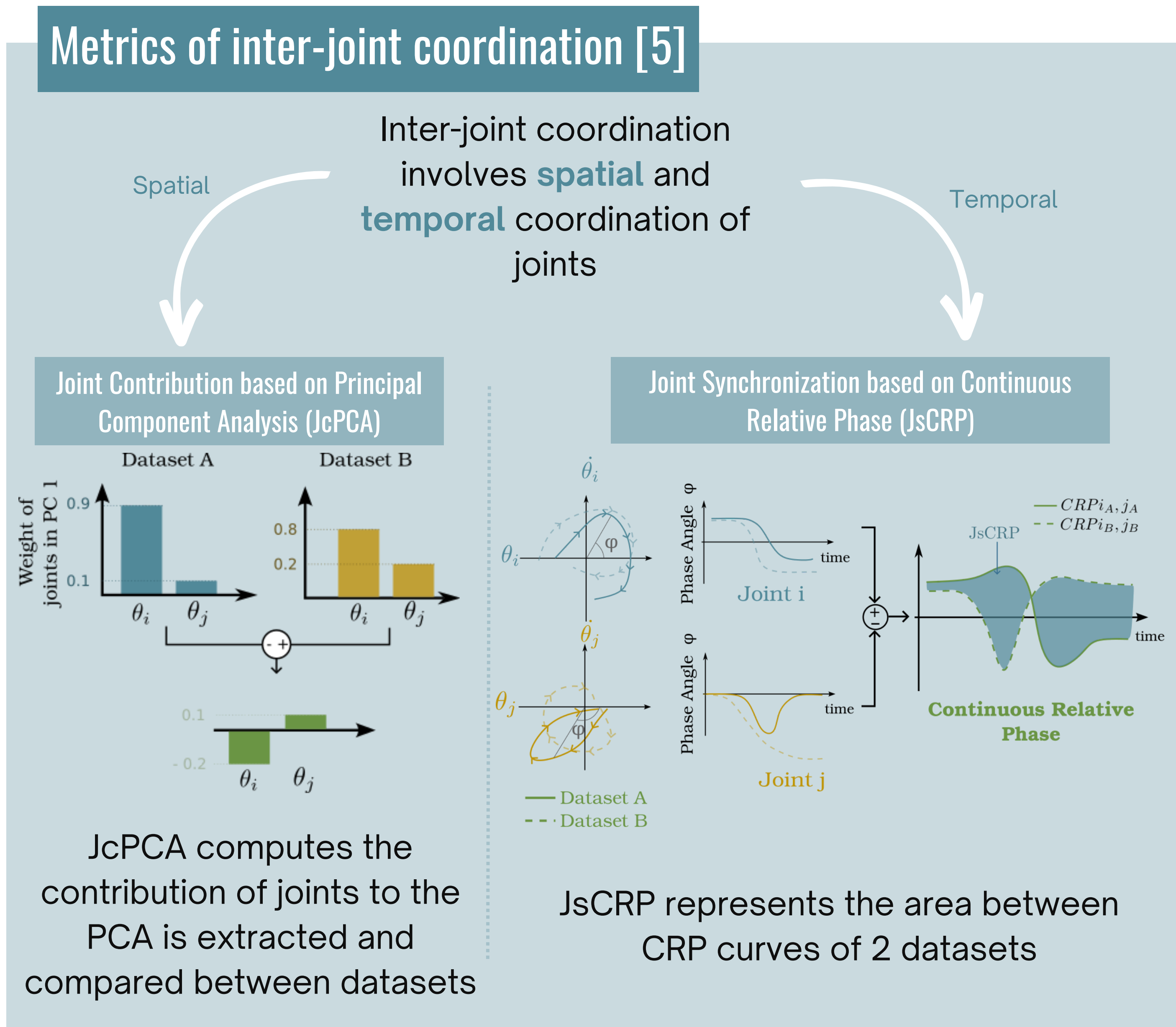
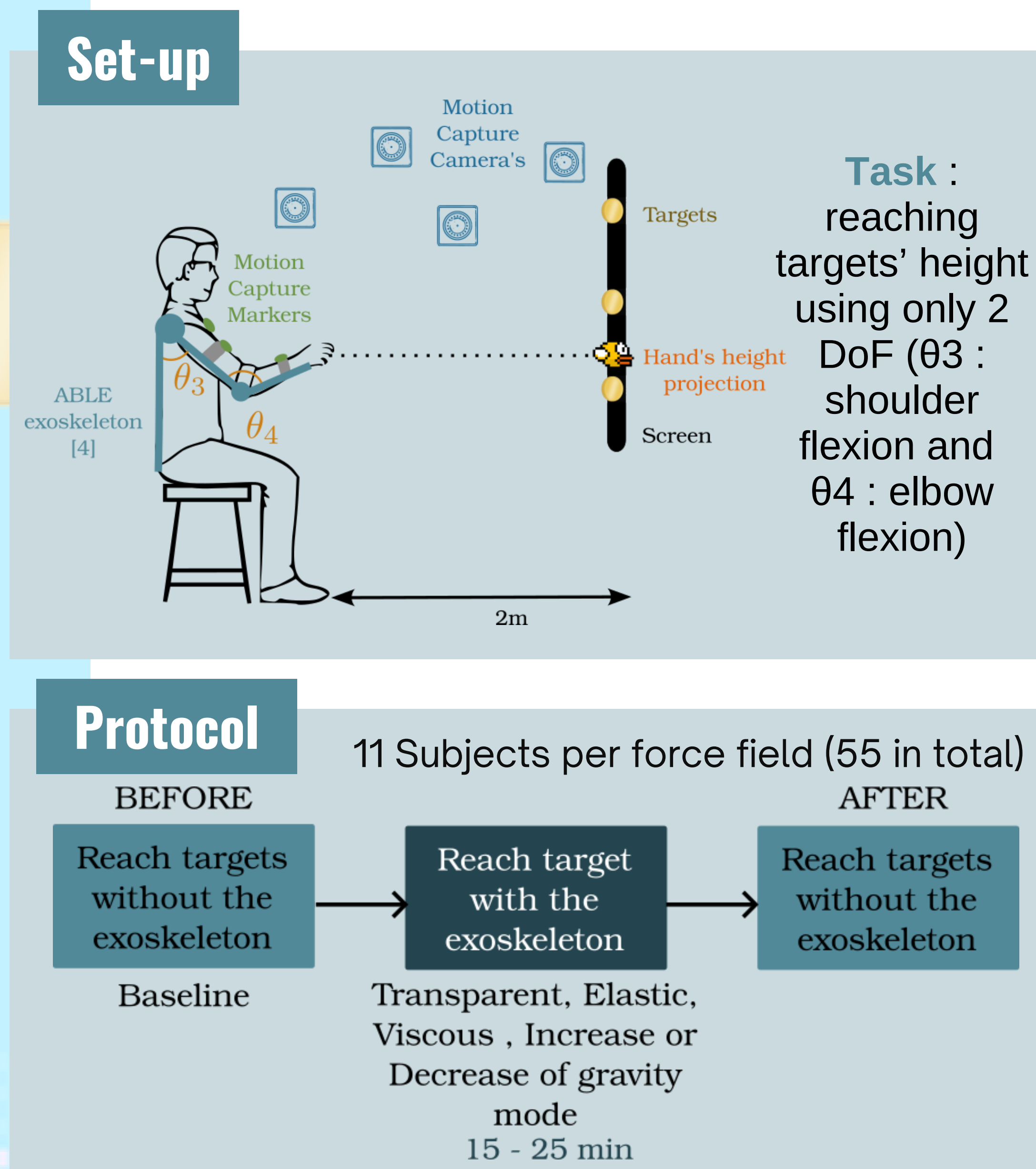


Does a small perturbation created by an upper-limb exoskeleton impact our coordination in reaching tasks ?

# A low-magnitude perturbation applied by an exoskeleton at the joint level still alters joint coordination once the disturbance is removed, even though task performance is unchanged.

Océane Dubois  
Agnès Roby-Brami  
Ross Parry  
Nathanaël Jarrassé

The impact of **perturbations** applied at the human end-effector level has been widely studied as well as the **learning process** which results from it [1]. However, the effect of **perturbations at the joint level** and the learning process related to it has been poorly investigated [2] [3]. Indeed, due to the redundancy of human limbs, perturbations at the joint level **do not necessarily affect the task** and therefore, the central nervous system might adapt differently. This study investigates **the impact of a low-amplitude joint-level perturbation on our coordination strategies** while performing a reaching task.



## Comparing movements before and after being exposed to the force field in the exoskeleton.

### End effector and joints results

- **No significant differences** on the **end-effector** metric nor on **range of motions** of joints.
- Only the **Viscous** Force Field is statistically significant (\*) for the **overshoot** metric and **joint range of motion 3**

	End-effec. distance (%)	Overshoot (%)	Maximum End-effec. velocity (%)	Task Time (%)	Time to maximum velocity (%)
Transp.	-0.1±0.16	-0.97±2.48	0.00±0.34	-0.05±0.23	-0.03±0.33
Elastic	-0.04±0.17	-0.20±0.74	0.10±0.46	-0.06±0.33	-0.06±0.28
Viscous	0.07±0.17	0.5±0.4*	0.01±0.51	-0.13±0.22	-0.16±0.35
Decr.	-0.15±0.18	-0.63±1.35	-0.17±0.63	-0.08±0.24	0.03±0.23
Incr.	-0.04±0.18	-0.23±1.47	-0.65±2.32	-0.01±0.18	0.06±0.18

	ROM 1 (%)	ROM 2 (%)	ROM 3 (%)	ROM 4 (%)
Transp.	-0.39±0.87	-0.03±0.13	-0.20±0.55	0.08±0.31
Elastic	-0.48±0.95	-0.02±0.21	0.15±0.23	-0.05±0.38
Viscous	0.09±0.37	-0.18±0.33	0.40±0.27*	-0.45±0.57
Decr.	-0.57±0.81	-0.05±0.31	-0.18±0.44	0.00±0.36
Incr.	-1.28±2.11	-0.06±0.47	0.10±0.56	-0.18±0.75

**FORCE FIELDS HAVE NO IMPACT ON THE TASK'S PERFORMANCE ...**

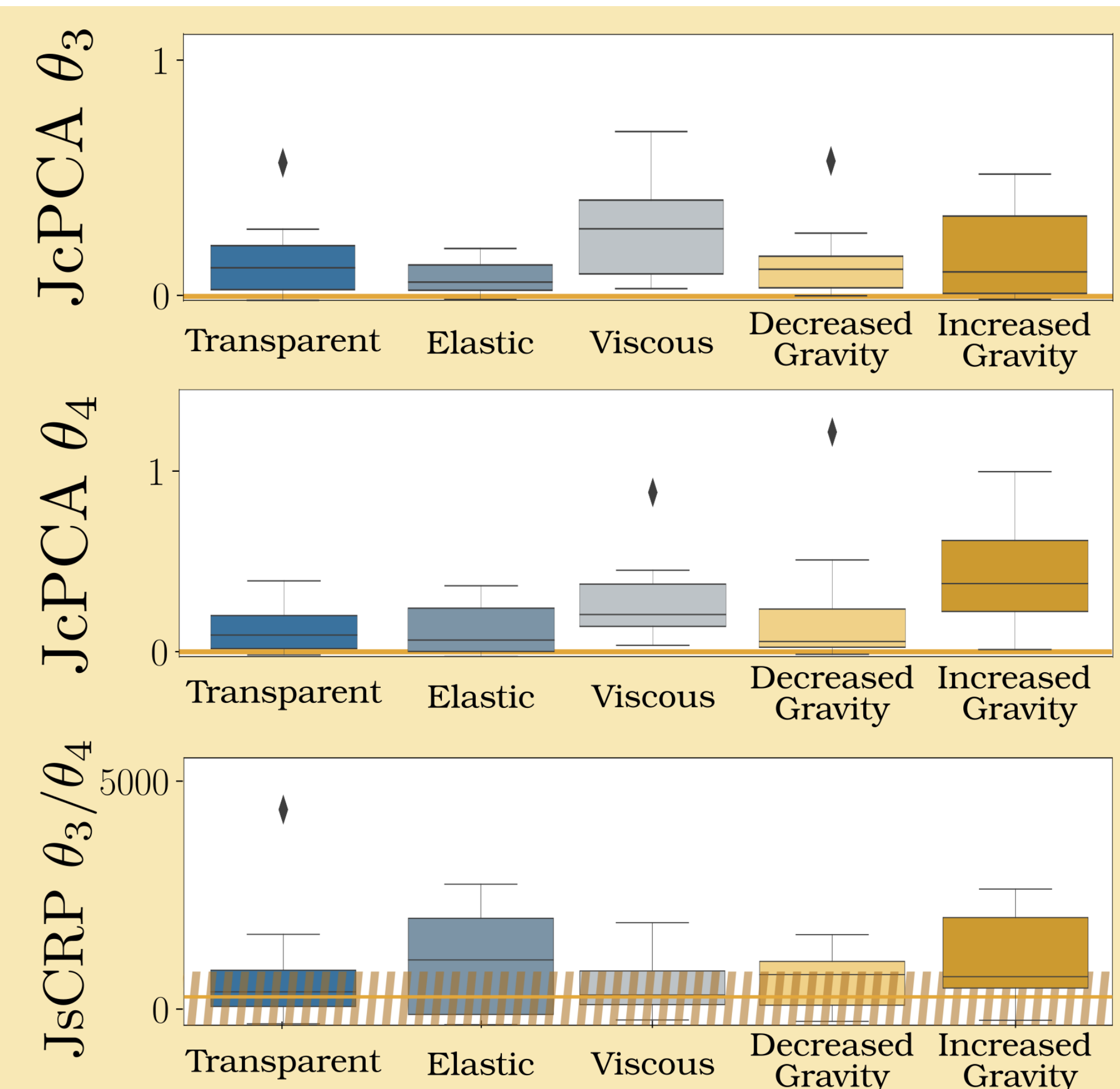
### Inter-joint coordination results

	Transp.	Elastic	Viscous	Decr.	Incr.
JcPCA $\theta_3$	8	7	10	11	8
JcPCA $\theta_4$	6	8	9	6	9
JsCRP $\theta_3/\theta_4$	7	7	4	7	9

Table 1: Number of participants (out of 11 per group) that modified their coordination strategy to each force field

- **Viscous** and **Decrease of gravity** are the force field with the most important effect on  $\theta_3$  contribution.
- **Increase of gravity** is the field that creates the greater change of inter-joint coordination both for spatial and temporal organization of joints.
- **Elastic** force field impacts essentially the joint synchronization
- Even the **Transparent** force field affects most of the subjects.

**... BUT THE COORDINATION STRATEGIES CHANGED !**



- The crosshatching area is the natural variability of all subject (i.e. their variability within the Natural Before Exposition Condition)

### Conclusion & Discussion

#### SHORT EXPOSITION OF LOW-MAGNITUDE FORCE FIELD IMPACTED COORDINATION STRATEGIES !

- There is **no differences** in the task performance before and after exposition to the force field regarding the **end-effector** and the joints ROM.
- The coordination strategies is **most impacted** by the **viscous** force field. The **Increase of gravity** force field created **greater change in the coordination strategies** for more than half of the subjects.
- **Long term effect** of those force fields should be investigated.
- The **evolution of the coordination strategy** during the **exposition** to the force field could be explored.
- The **exploration of the individual characteristics** (fatigue generated, vigor, etc.) could explain why did some subjects adapt or not to the force fields

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