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

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

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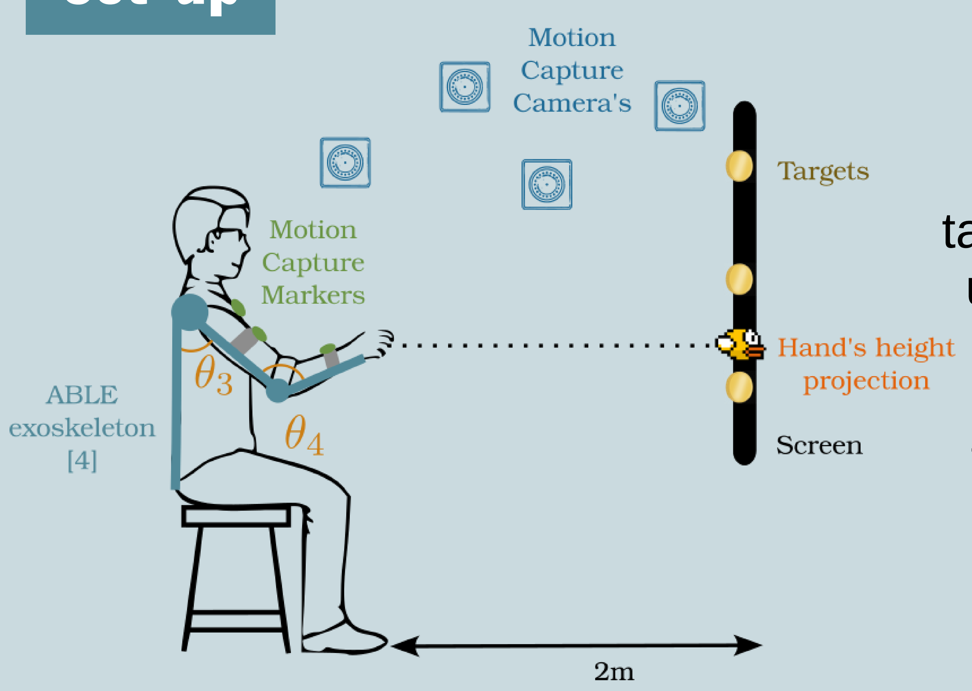
A low-magnitude perturbation applied by an exoskeleton at the joint level still alters joint coordination once the disturbance is removed, even though task performance is unchanged.

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.

Set-up



Task : reaching targets' height using only 2 DoF (θ3 : shoulder flexion and θ4 : elbow flexion)

Protocol

11 Subjects per force field (55 in total)

BEFORE		AFTER
Reach targets without the exoskeleton	→ Reach target with the exoskeleton →	Reach targets without the exoskeleton
Baseline	Transparent, Elastic, Viscous , Increase or Decrease of gravity mode 15 - 25 min	

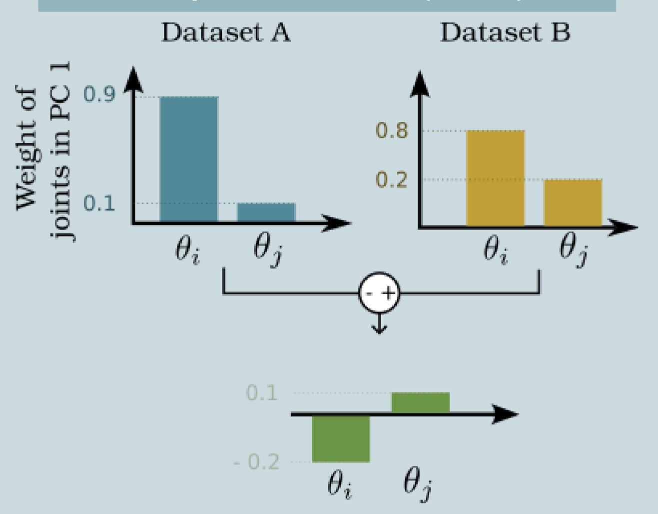
Metrics of inter-joint coordination [5]

Inter-joint coordination involves **spatial** and **temporal** coordination of joints

Spatial

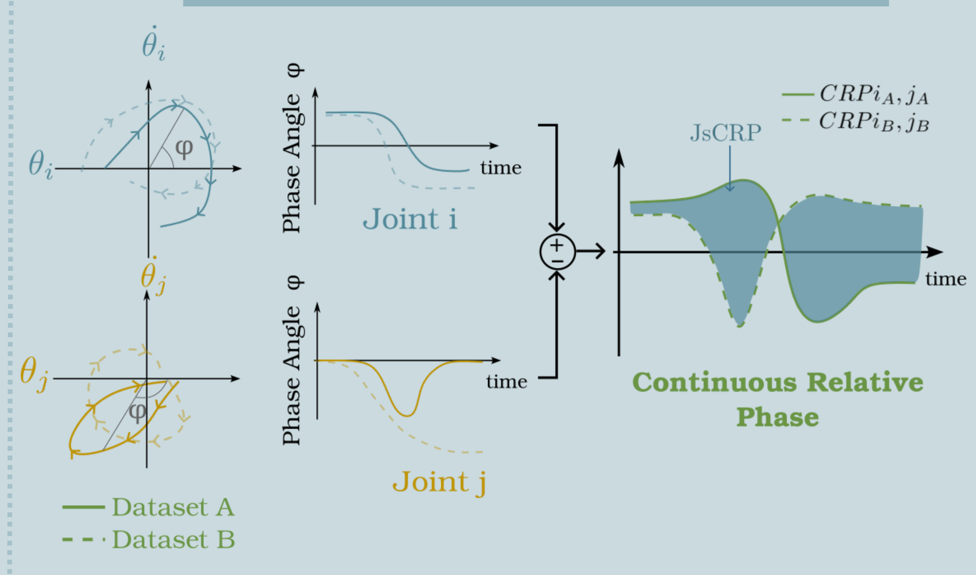
Temporal

Joint Contribution based on Principal Component Analysis (JcPCA)



JcPCA computes the contribution of joints to the PCA is extracted and compared between datasets

Joint Synchronization based on Continuous Relative Phase (JsCRP)



JsCRP represents the area between CRP curves of 2 datasets

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 **Visous** 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

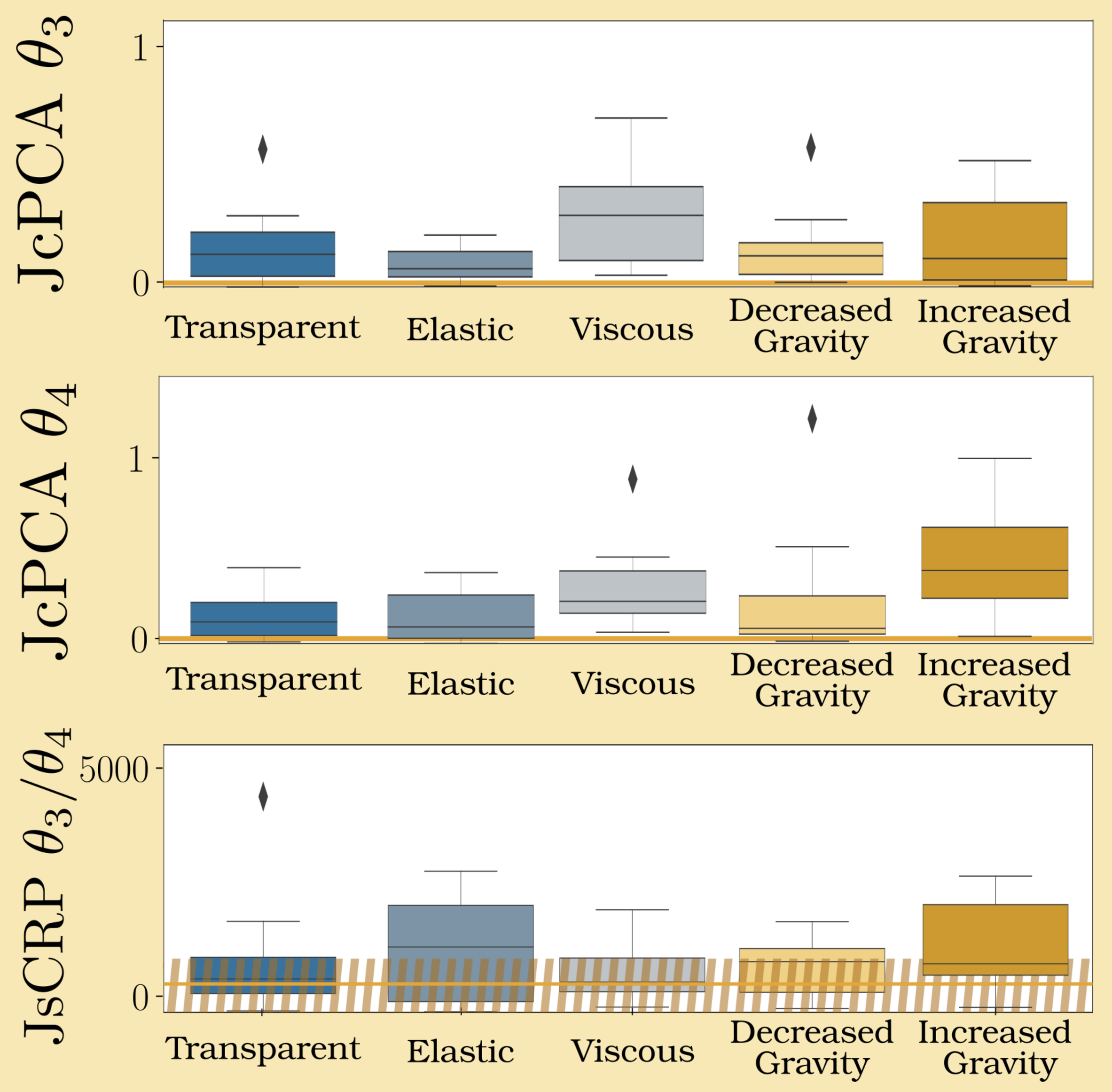
FORCE FIELDS HAVE NO IMPACT ON THE TASK'S PERFORMANCE ...

Inter-joint coordination results

	Transp.	Elastic	Viscous	Decr.	Incr.
JcPCA θ_3	8	7	10	11	8
JcPCA θ_4	6	8	9	6	9
JsCRP θ_3/θ_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 θ3 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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