Identifying individual characteristics influencing post-adaptation of motor behavior in upper-limb exoskeleton users

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Introduction

Occupational exoskeletons, composed mostly of spring-based mechanisms to compensate for the weight of body parts or tools, have experienced a major leap forward in recent years. They are used especially in the industry to support hard and repetitive tasks [1].

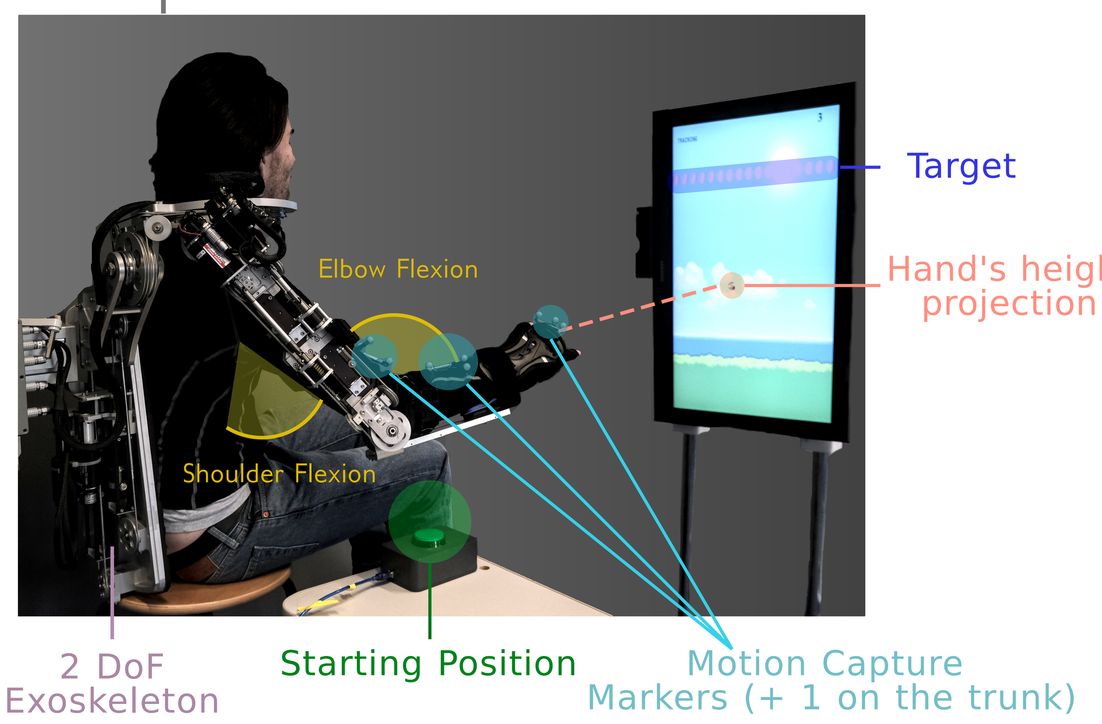
However, due to their close and distributed interaction with the human body, over an extended period of time, they act as a perturbation and can modify the inter-joint coordination [2]. Different patterns of adaptation have already been documented [3]. However, the specific reasons for these differences in adaptation remain little explored.

What are the factors and characteristics influencing the post-adaptation patterns in asymptomatic individuals ?

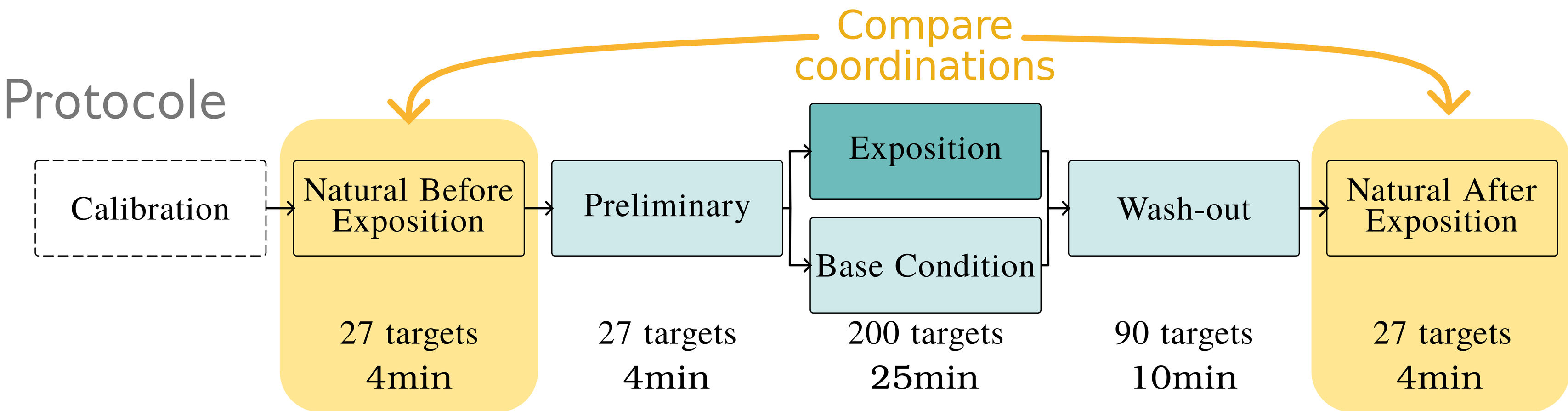
Ottobock Paexo

Materiel & Method

Set-up



Protocole

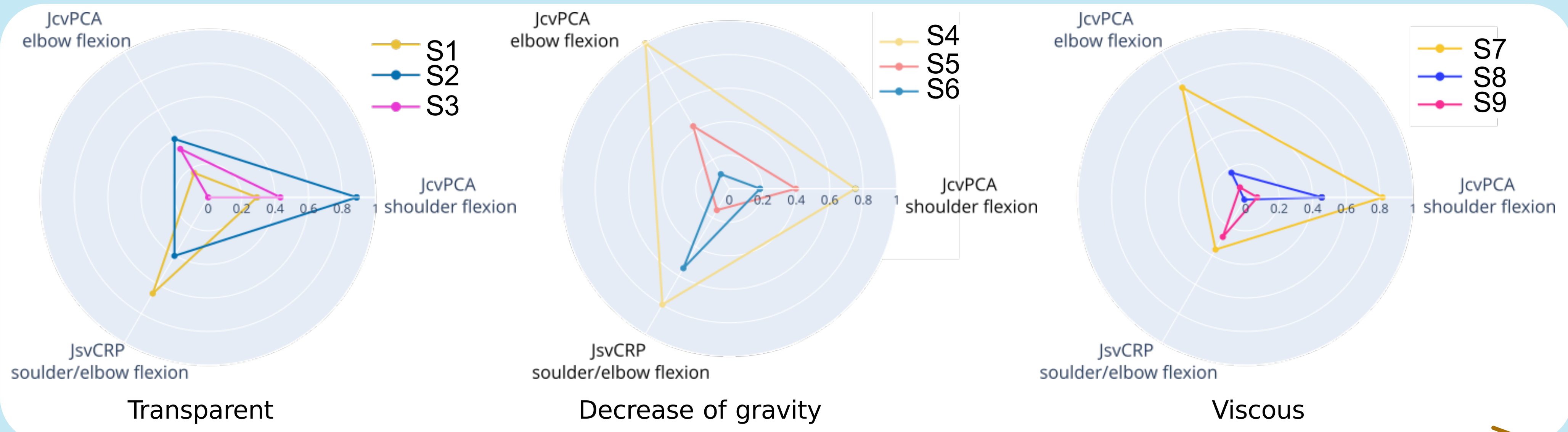


Participants

Conditions	Transparent (Gravity Compensation)	Increase of Gravity	Decrease of Gravity	Elastic	Viscous
Nb of Subjects	11	11	11	11	11
Sex (F/M)	4/7	3/8	3/8	4/7	6/5
Laterality	63.2 ± 36.0	69.7 ± 53.5	50.8 ± 59.3	54.2 ± 54.7	48.0 ± 62.5
Weight (kg)	67 ± 11	69 ± 10	68 ± 6	68 ± 11	67 ± 13
Height (cm)	175 ± 12	176 ± 8	175 ± 10	173 ± 8	173 ± 12

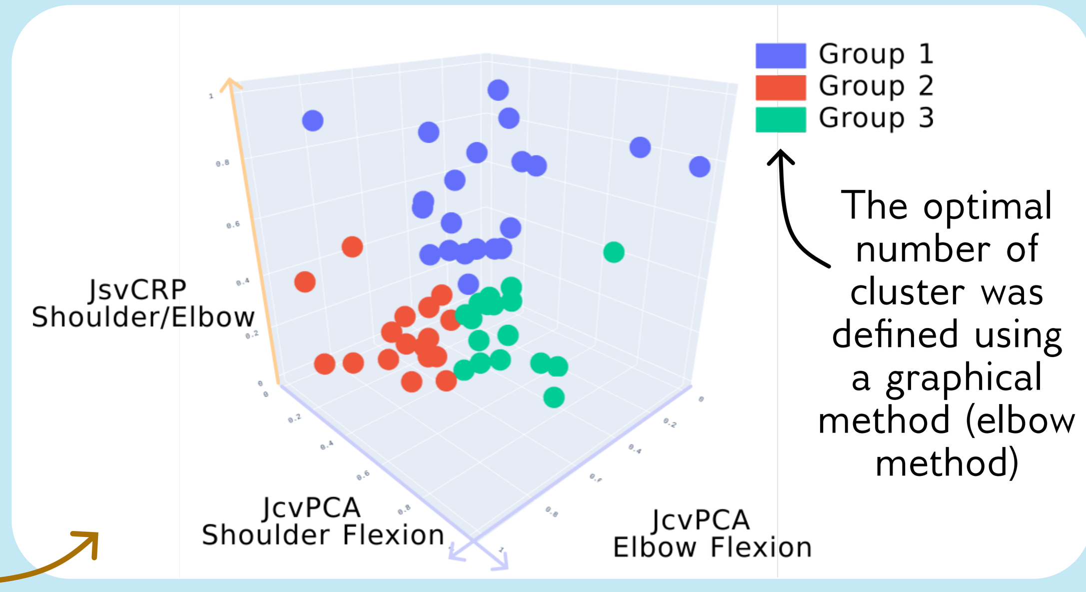
Patterns of adaptations have been quantified using 2 metrics : **JcvPCA** (variation of the **conbtribution** of joints) and **JsvCRP** (variation of the **temporal coordinations** between joints) [4]

POST-ADAPTATION BEHAVIOUR EXPLORATION



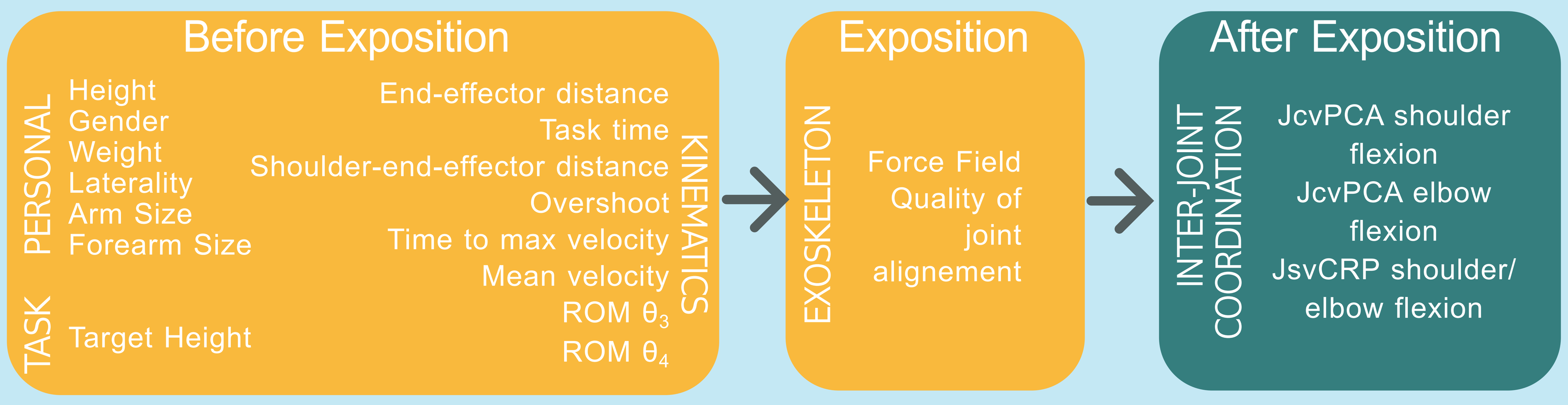
Different post-adaptation behaviors for participants exposed to a same force field.

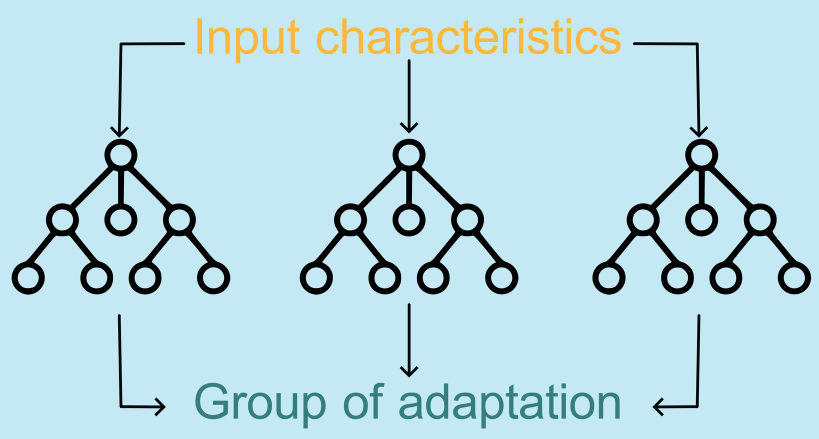
Extract groups of post-adaptation behaviors



Spectral Clustering Algorithm on inter-joint coordination data.

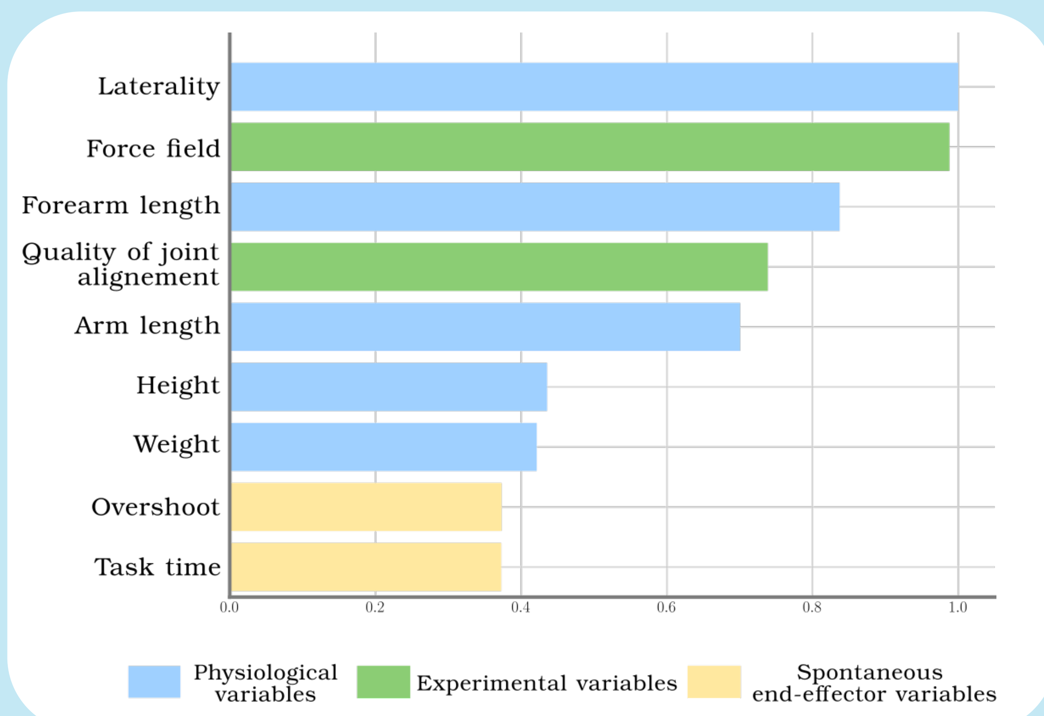
RELATION BETWEEN ADAPTATION PATTERN AND USER'S CARACTERISTICS





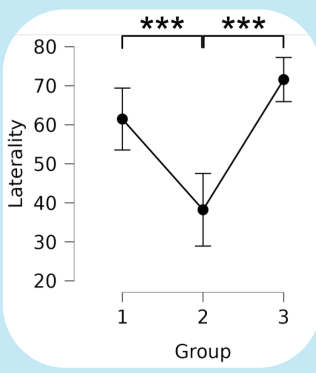
The Random Forest Classifier predicts with an **accuracy of 97%** the adaptation pattern group.

The **weight of the main variables** used to predict the inter-joint adaptation pattern are :

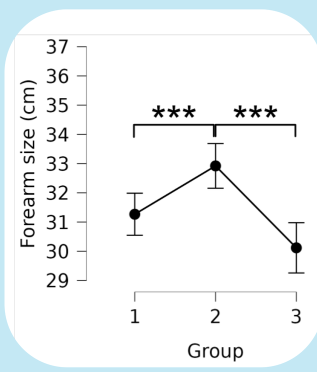


CHARACTERISTICS REPARTITION PER GROUPS

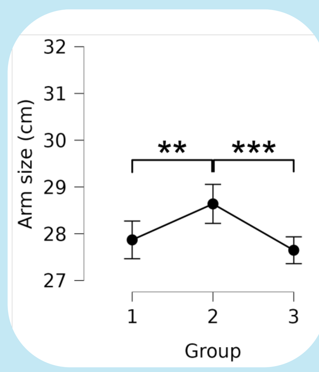
Examination the repartition of characteristics among groups with Kruskall-Wallis test



People with a lower laterality score (i.e. that tends to be left-handed) are more likely to adapt as the Group 2



People that have a long forearm are more likely to adapt as the Group 2



People that have a long arm are more likely to adapt as the Group 2

Conclusion

- Adaptation patterns of inter-joint coordination **after** being exposed to a force field can be **predicted** based on different **physiological, spontaneous kinematics and exoskeleton variables.**
- The dominant arm is the most important factor when predicting post-adaptation patterns. Adjusting differently the dominant and non-dominant arm (depending on the participant's laterality) is an interesting approach to **reduce the appearance of asymetrical behaviours.**
- Future work should focus on how can the exoskeleton be **personalized** considering thoses factors in order to **minimize the exoskeleton impact** on motor behavior.

References

[1] Iranzo, S., Piedrabuena, A., García-Torres, F., Martinez-De-juan, J. L., Prats-Boluda, G., Sanchis, M., & Belda-Lois, J. M. (2022). Assessment of a Passive Lumbar Exoskeleton in Material Manual Handling Tasks under Laboratory Conditions. Sensors, 22(11), 1–29.

[2] Dubois, O., Parry, R., Roby-Brami, A., Jarrassé, N., (2024) Short term after-effects of small force fields applied by an upper-limb exoskeleton on inter-joint coordination. Proceedings of ICRA 2024

[3] Proietti, T., Guigon, E., Roby-Brami, A., & Jarrassé, N. (2017). Modifying upper-limb inter-joint coordination in healthy subjects by training with a robotic exoskeleton. Journal of NeuroEngineering and Rehabilitation,

[4] Dubois, O., Parry, R., Roby-Brami, A., Jarrassé, N., JcvPCA and JsvCRP : a set of metrics to evaluate changes in joint coordination strategies (2024), submitted for publication to PLOS ONE

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