

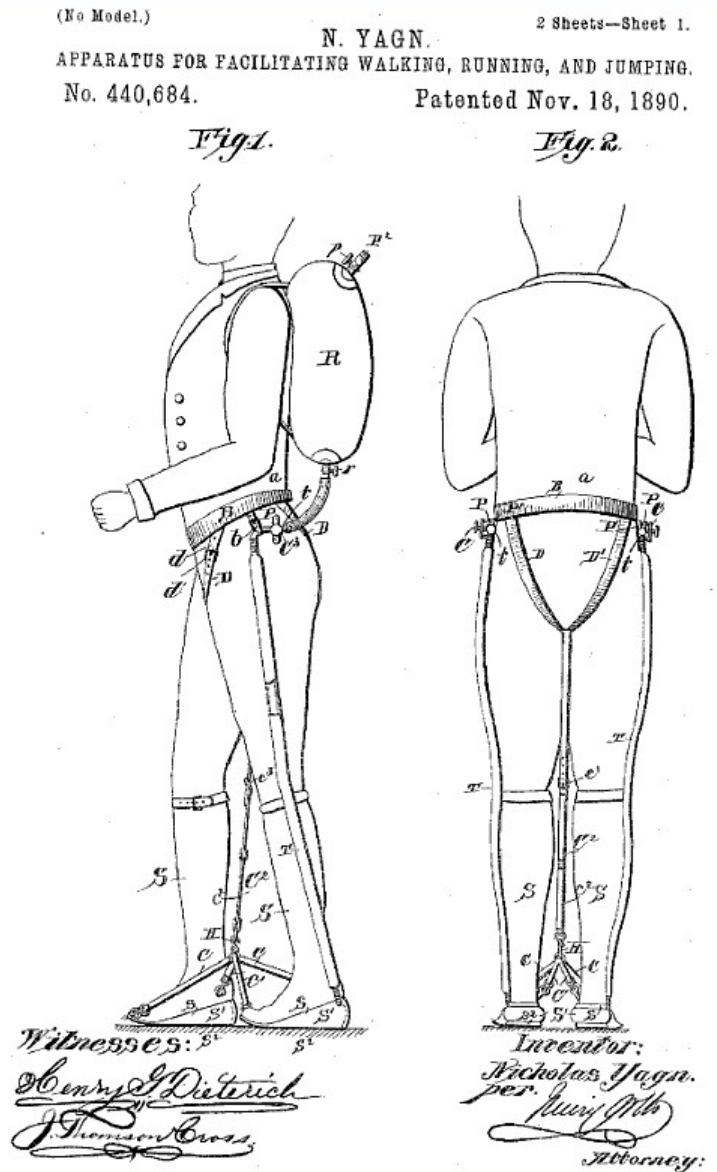
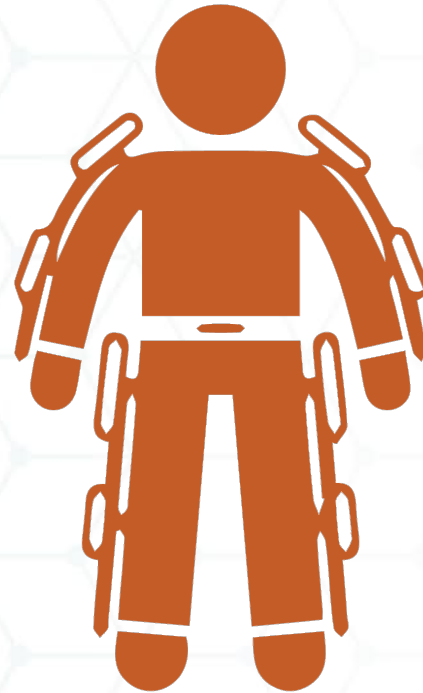


Exoskeletons!

Camila Shirota, PhD
Research Lead, HabITec
The Hopkins Centre

What is an exoskeleton?

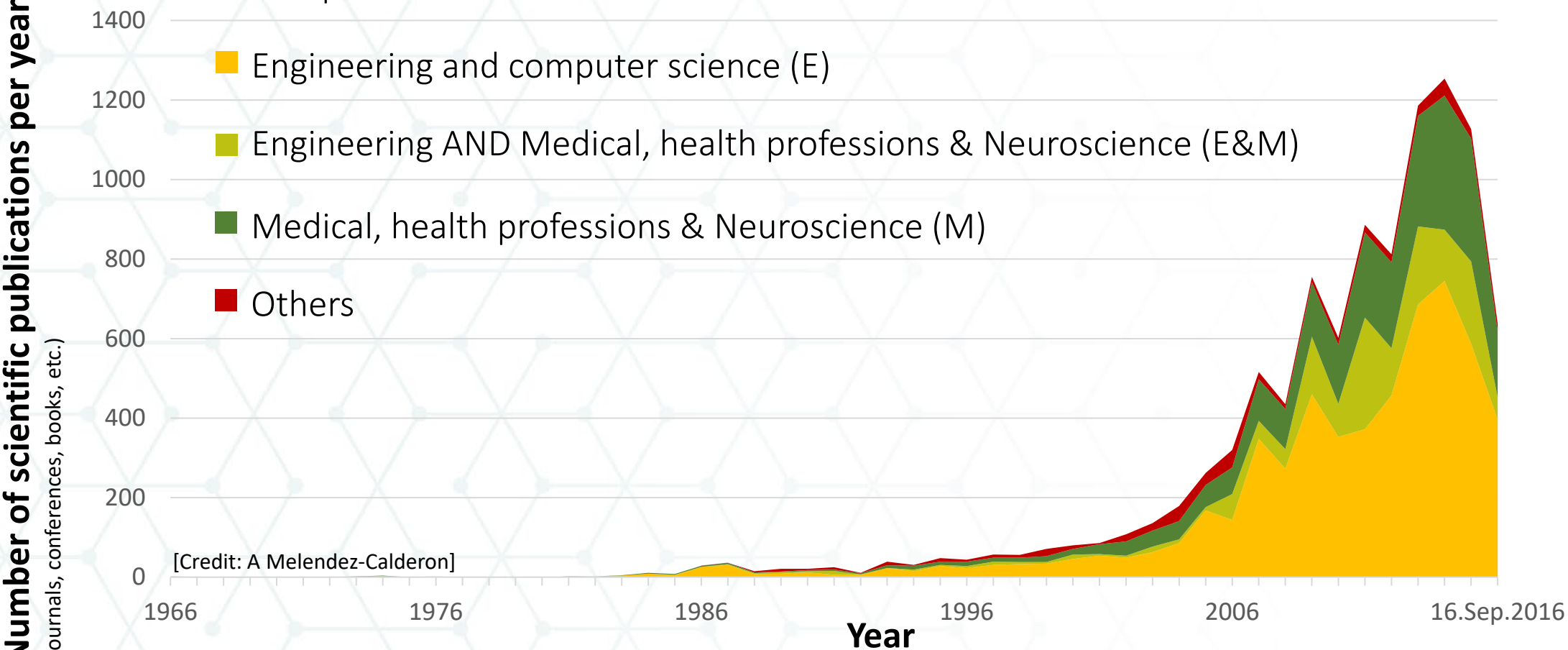
- ◆ Wearable device
- ◆ Works in parallel to user
- ◆ Augment, support or restore movement



[Source: cyberneticzoo.com]



Growing field



[Credit: A Melendez-Calderon]

Data source: Scopus

Search terms: rehabilitation" AND ("robot" OR "robotic" OR "electromechanical" OR "mechatronic" OR "virtual reality" OR "computer games")



Range of exoskeletons: applications

- ◆ Military
- ◆ Consumer
- ◆ Industrial
- ◆ Medical
- ◆ Research



[Source: Lockheed Martin]



[Source: Roam Robotics]



[Source: auxivo]



[Source: ReWalk]



[Source: Honda]

Range of exoskeletons: medical

- ◆ Shapes
- ◆ Body parts
- ◆ Intended uses



[Source: ReWalk]



[Source: Hocoma]



[Source: Honda]



[Source: Hocoma]



[Source: rexionics]



Challenge: safety

- ◆ Environment
- ◆ Training
- ◆ Access to third person
- ◆ It only takes 1 fall...

Clinical use



[Source: indego]

Therapy

Personal use



[Source: ReWalk]

Assistance

Challenge: safety

FDA INDICATION FOR USE

The Indego® orthotically fits to the lower limbs and the trunk; the device is intended to enable individuals with spinal cord injury at levels T3 to L5 to perform ambulatory functions with supervision of a specially trained companion in accordance with the user assessment and training certification program. The device is also intended to enable individuals with spinal cord injury at levels C7 to L5 to perform ambulatory functions in rehabilitation institutions in accordance with the user assessment and training certification program. Finally, the Indego® is also intended to enable individuals with hemiplegia (with motor function of 4/5 in at least one upper extremity) due to cerebrovascular accident (CVA) to perform ambulatory functions in rehabilitation institutions in accordance with the user assessment and training certification program. The Indego is not intended for sports or stair climbing.

Indications for Use (USA)

Ekso, and EksoGT, and EksoNR are intended to perform ambulatory functions in rehabilitation institutions under the supervision of a trained physical therapist for the following populations:

- Individuals with hemiplegia due to stroke (upper extremity motor function of at least 4/5 in at least one arm)
- Individuals with spinal cord injuries at levels T4 to L5 (upper extremity motor function of at least 4/5 in both arms)
- Individuals with spinal cord injuries at levels of C7 to T3 (ASIA D with upper extremity motor function of at least 4/5 in both arms)
- The therapist must complete a training program prior to the use of the device. The devices are not intended for sports or stair climbing.

Source: [FDA Part 21 CFR](#)

Indications for Use (EU)

- EksoNR is intended for use as a gait training device to improve walking function and independence in patients with a neurological or muscular injury, illness, or weakness.
- EksoNR is designed to be used in a controlled clinical or non-clinical setting under supervision of Ekso Certified Physical Therapist (or equivalent medical professional) and operated by a Trained Spotter.
- EksoNR is a device intended to help facilitate the restoration or improvement of ambulation for its pilots. The device is intended to serve multiple pilots over the duration of its life.
- EksoNR is used to manipulate the legs of a patient and move them through the normal walking gait, from the sit-to-stand position and from standing back to sitting.

Source: [Intended Use – Council Directive 93/42/EEC, Annex II](#)



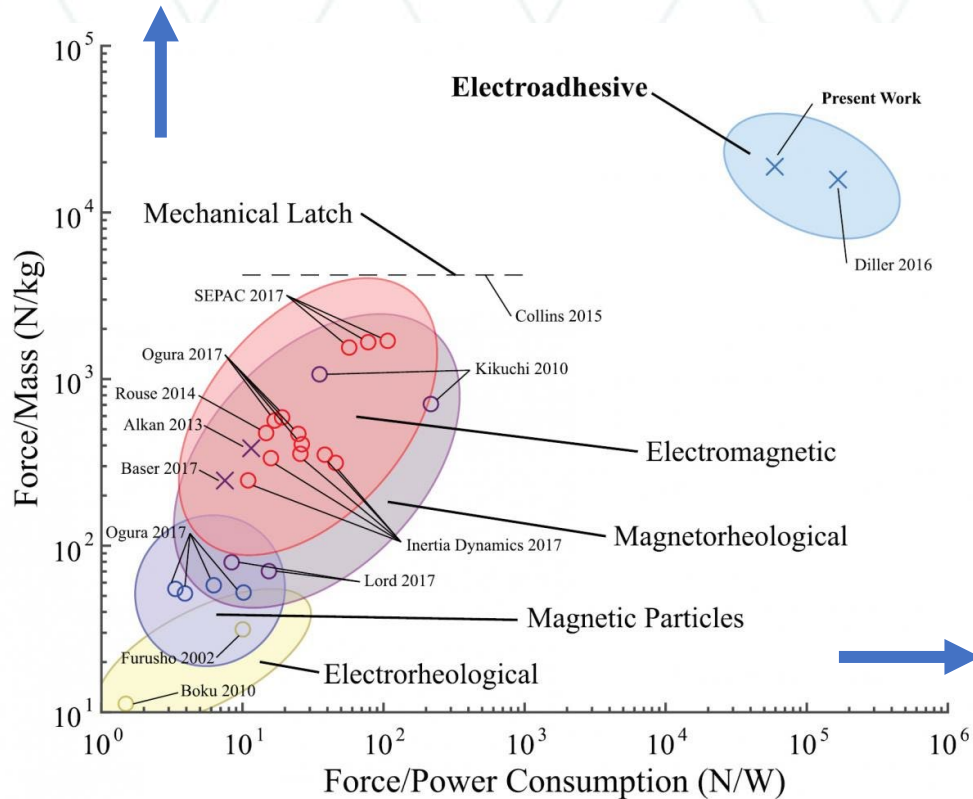
FDA Clearance for Clinical and Personal Use



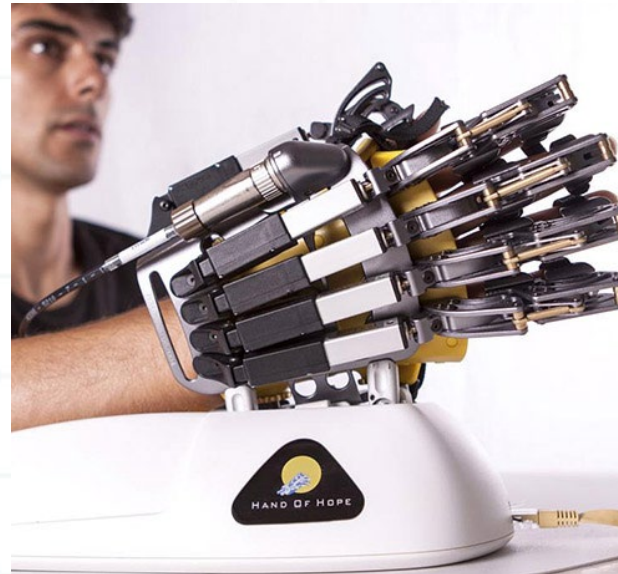


Challenge: weight vs power

more efficient



[Source: Diller, Collins, Majidi, 2016]



[Source: Hand of Hope]

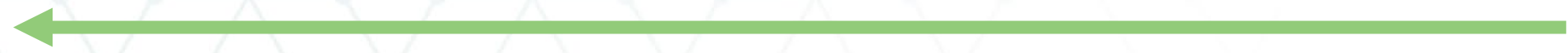


[Source: RELab, ETHZ]



Challenge: shared control

Robotic support



[Source: indigo]

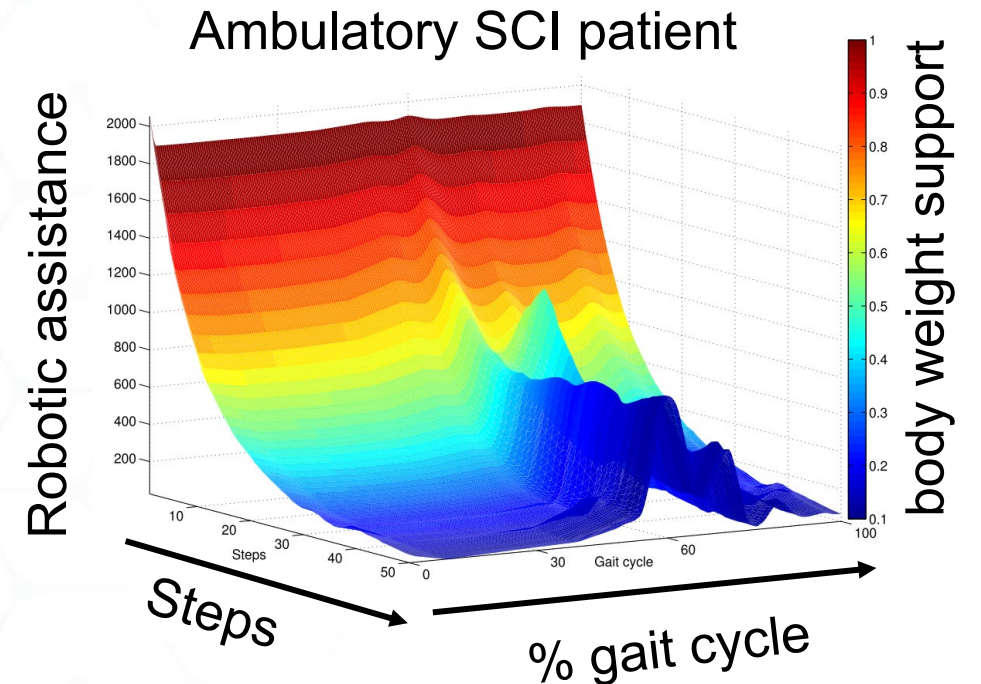


User autonomy

Challenge: shared control



[Source: Maggioni, Melendez-Calderon, et al.]

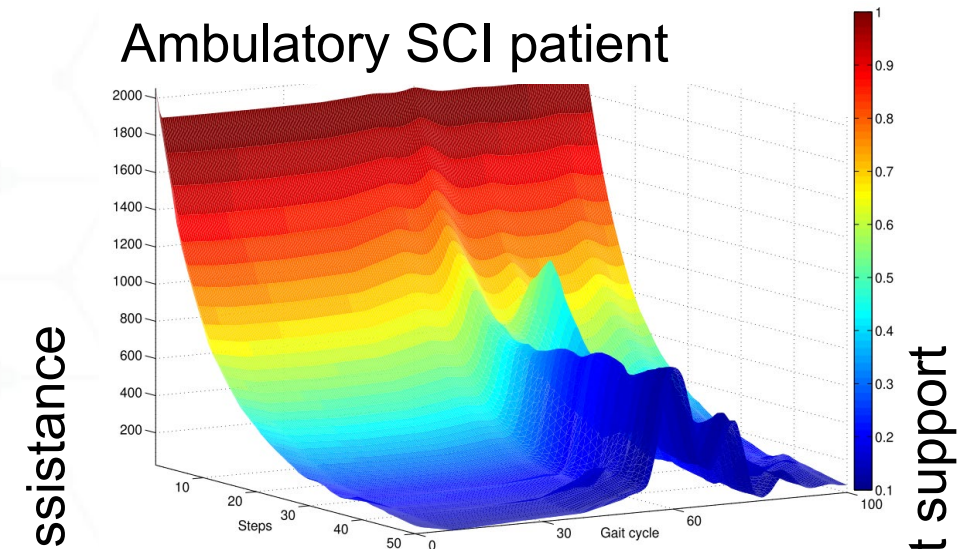


Challenge: shared control

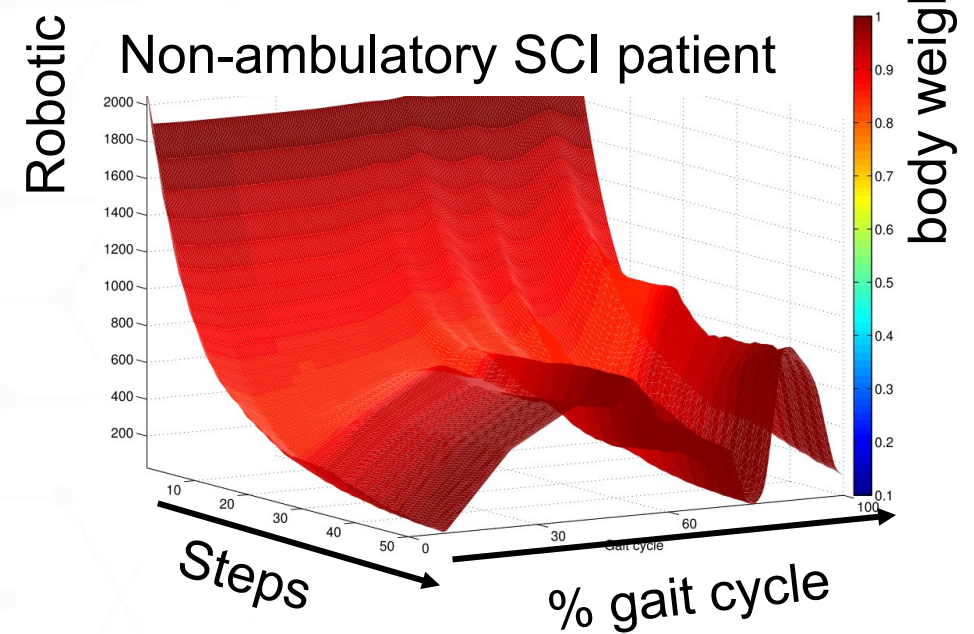


[Source: Maggioni, Melendez-Calderon, et al.]

Ambulatory SCI patient

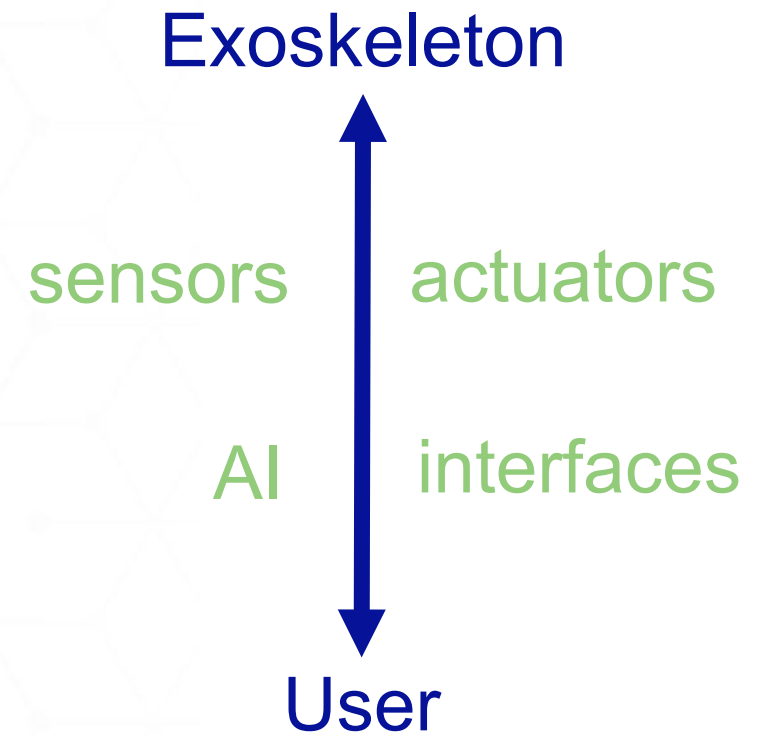
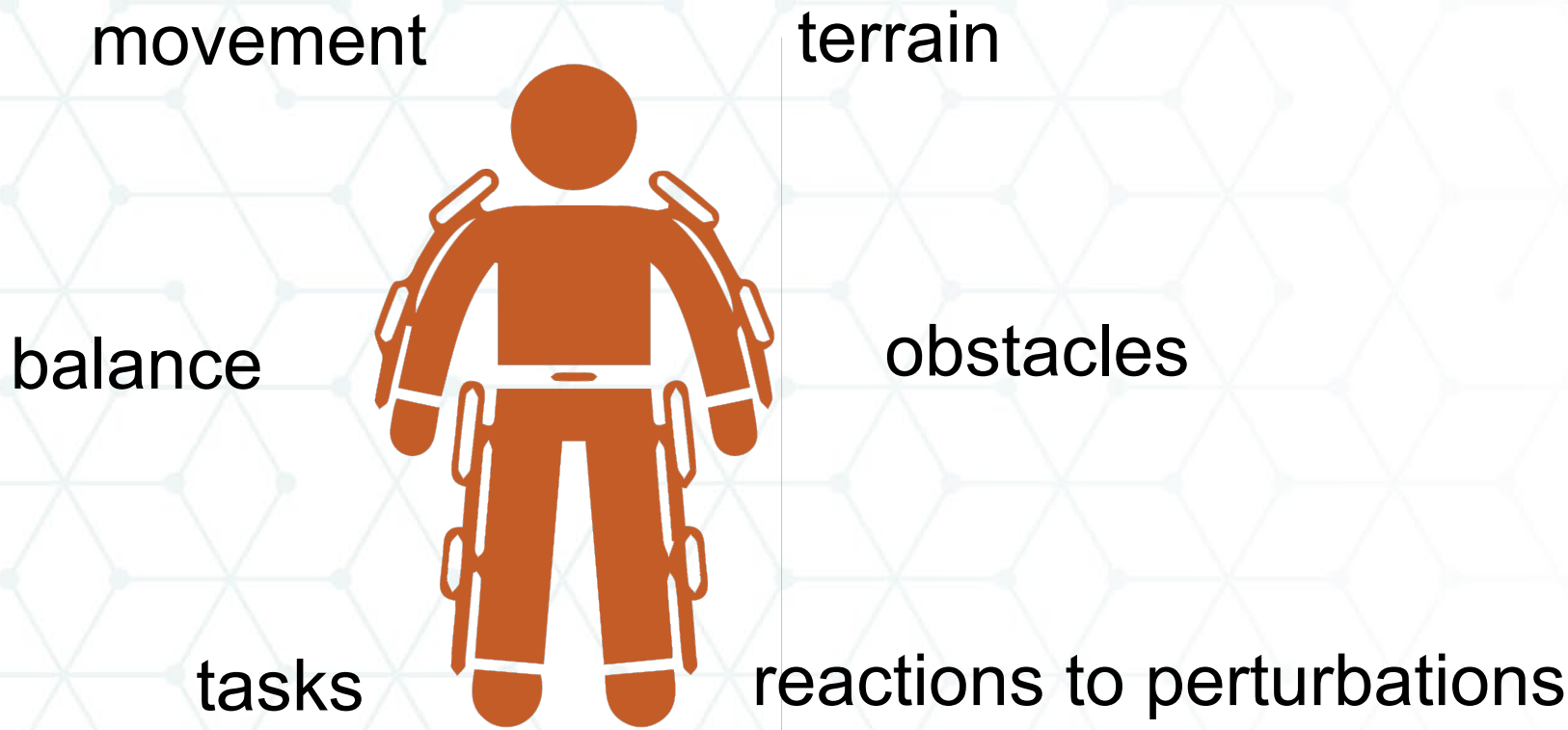


Non-ambulatory SCI patient



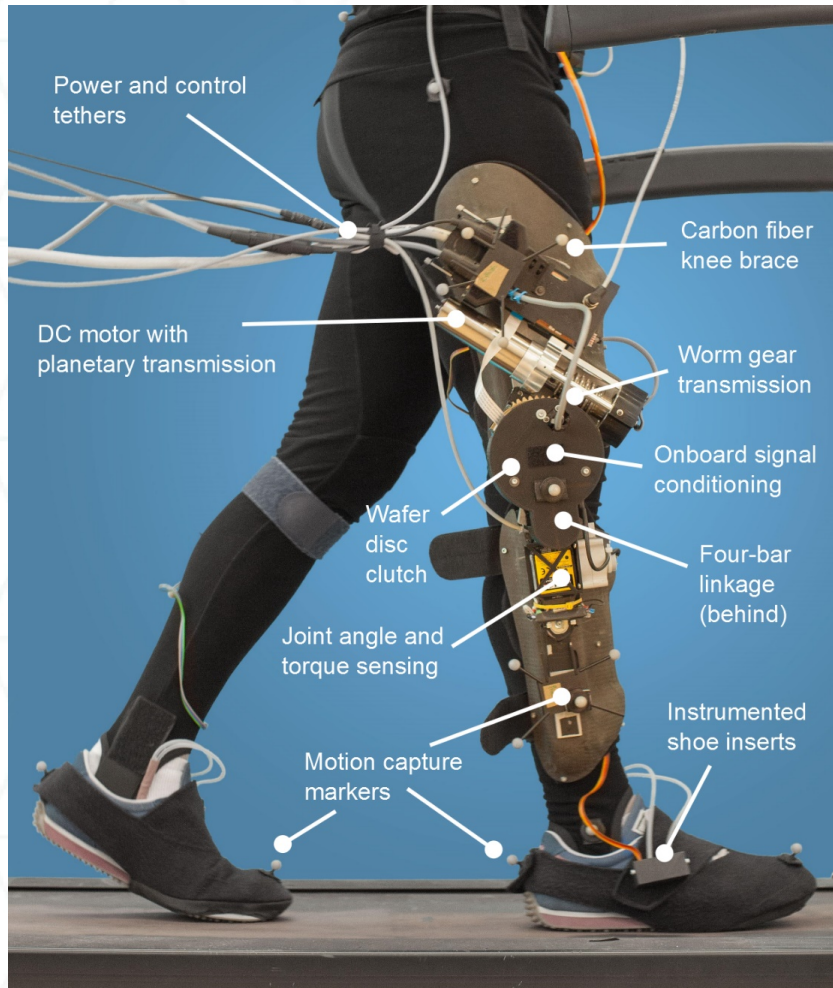
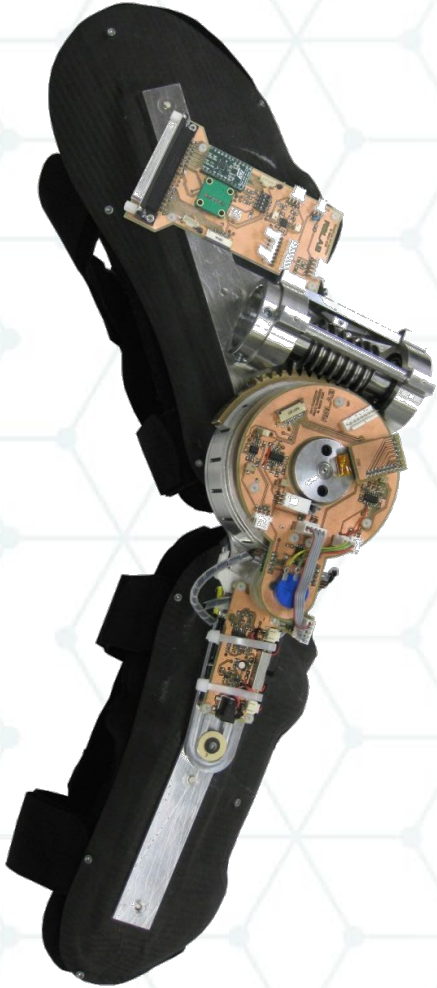


Challenge: shared control





Challenge: shared control



Tucker et al., ICORR, 2013
Tucker et al., TBME, 2017

The ETH Knee Perturbator: Active perturbation experiments

<https://www.youtube.com/watch?v=gGw52WkqjHM>



Clinical implications

- ◆ Improvements in bone density, bowel function, spasticity
- ◆ “People who receive electromechanical and robot-assisted arm training after stroke might improve their activities of daily living, arm function, and arm muscle strength. However, the results must be interpreted with caution although the quality of the evidence was high, because there were variations between the trials in: the intensity, duration, and amount of training; type of treatment; participant characteristics; and measurements used.”

[Mehrholz et al., 2018]



Take-home message

- ◆ Growing area
- ◆ Huge potential
- ◆ High expectations
- ◆ Complex systems
- ◆ Exos are only tools to enable different interventions!



Source: https://www.youtube.com/watch?v=xq8c_hgMOZ8