



# Digital Science for Disability Overview of the initiatives undertaken by Inria

Christophe Biernacki

## ► To cite this version:

Christophe Biernacki. Digital Science for Disability Overview of the initiatives undertaken by Inria. Inria/IIT DELHI workshop, Oct 2023, New delhi, India. hal-04370905

**HAL Id: hal-04370905**

**<https://inria.hal.science/hal-04370905>**

Submitted on 3 Jan 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Inria/IIT DELHI  
WORKSHOP  
October 25, 2023

# Digital Science for Disability *Overview of the initiatives undertaken by Inria*

**Christophe Biernacki**, *deputy scientific director*

## General overview

Researchs involved in disability initiatives @Inria

The Inria logo is written in a red, cursive script font.The Inria logo is written in a red, cursive script font.

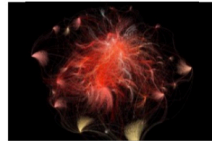
# Inria

- French National Research Institute for Digital Sciences and Technologies
- "Scientific Excellence and Transfer"
- Computer Science and Applied mathematics

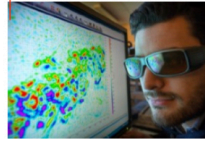
## ALGORITHMS & PROGRAMMING



## DATA SCIENCE & KNOWLEDGE ENGINEERING



## MODELING & SIMULATION



## OPTIMIZATION & CONTROL



## ARCHITECTURE, SYSTEMS & NETWORKS



## SECURITY & PRIVACY



## INTERACTION & MULTIMEDIA



## ARTIFICIAL INTELLIGENCE & AUTONOMOUS SYSTEMS



## Disability

It is associated with a very strong heterogeneity between people, therefore no single solution

We must remain vigilant in the face of stereotypes! Example: “disabled people reject/love technology”

## Objectives of our research

Improving the quality of life of people with disabilities

Increase their autonomy

Respect and develop their self-determination

## Disability@Inria

About 20 teams have an activity in link with disability

## Gait and posture

Avoiding “technological solutionism”

Involve stakeholders upstream and downstream

Take into account constraints (costs, logistics, intrusiveness)

Take ethical aspects into account

Be concerned about the impact: effective implementation, startups as a preferred vector of transfer

## **Diversity of topics involved in numerical science**

Machine learning, Signal processing, Control theory, Automatic language processing, Medical imaging, Sensors, Robotics, Human Machine Interface, Cryptographic protocols...

## **To keep in mind for having impact**

Absolute need for multidisciplinary approaches

Work on needs, practical constraints, acceptability, etc.

## **Despite several projects, area still underinvested...**

**FLOWERS** A set of educational technologies to promote inclusion for children with Autism Spectrum Disorder (ASD)

**ALMANACH** Develop Cap'FALC, a text simplification algorithm, for people suffering from disabilities and for non-native speakers learning a given language

**CAMIN** Neuroprosthesis user interface based on residual motor skills and muscle activity in persons with upper limb disabilities

**DEFROST** Developing wearable soft exoskeletons with variable damping or stiffness for helping disable people (new soft exoskeletons that may become hard at the period of supporting weight and transferring power, and then become soft at the working mode)

**EMPENN** Study the impact of lesion damages along the whole motor pathways on disability in multiple sclerosis



**Teams**

**HEPHAISTOS** Robotized devices for assistance, including smart objects, that may aid disabled or elderly people in their personal life

**HYBRID** Assistive Robotic Technologies for Next-Generation Smart Wheelchairs: Codesign and Modularity to Improve Users' Quality of Life

**MFX, POTIOC, RAINBOW** The DORNELL project as a multimodal, shapeable haptic handle for mobility assistance of people with disabilities

**MIND** Project LargeSmallBrainNets on the learning process for children with mathematical disabilities

**MULTISPEECH** Voice assistants tool for senior or disabled people, especially for those who are unable to use other interfaces due to lack of hand dexterity, mobility, and/or good vision



*Teams*

**POTIOC** Accessible applications targeted at users with special needs including people with sensori-motor and/or cognitive disabilities (personalization with Artificial Intelligence)

**RAINBOW** Using cutaneous haptics for helping the navigation of people with sensory disabilities (vibrotactile sensations, tap stimulations, sensory illusions)



## NEURINNOV

Control of movements of paraplegic patients

Sensory feedback: above-knee amputees

Challenges: coordinated stimulation to restore function or regain sensation

Startup



CYBATHLON 2016



## Uilo

Treatment of anxiety,...

Solutions combining augmented reality, sensory stimulation and breathing exercises

Tested then deployed within EHPADs (elderly people)

Startup





## HumanLab

Collaborative digital manufacturing or repair spaces of objects, open to people with a disability to appropriate the technology for their own use.

Complementary with the equipment and a medical approach not the replace !

## HumanLab@Inria

Create a model of collaboration between Inria and the network of HumanLab

Contribute to meeting the needs expressed by individuals people with disabilities

Frugal innovation approach, open-source



## Focus n°1

Electrically stimulate the system peripheral nerve  
to restore lost motor functions



## Electrically stimulate nervous tissues to

Explore & model the neurophysiological mechanisms

Assist and restore lost functions (gripping, standing, walking, etc.)

## Methods

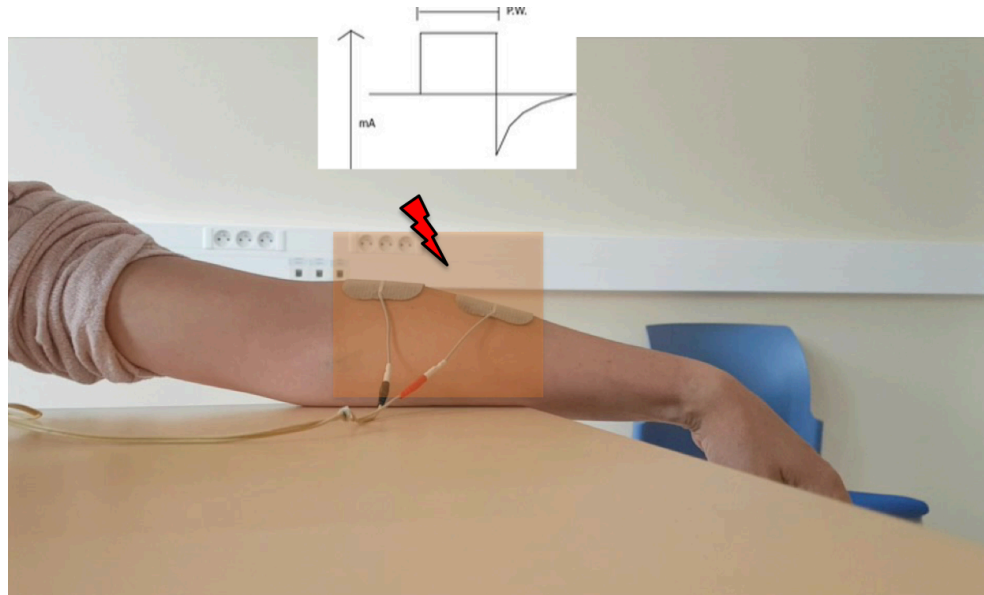
Surface or implanted electrodes

Experiments in humans and animals



# Functional Electrical Stimulation (FES)

Artificially trigger a muscle contraction



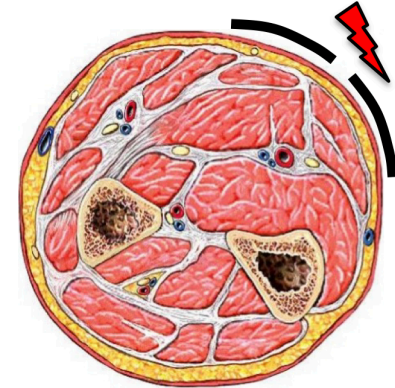
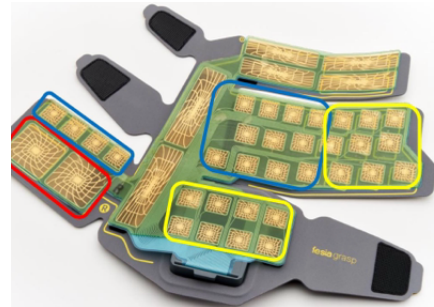
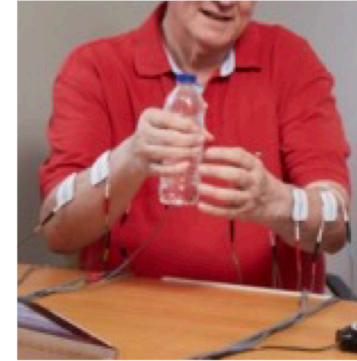
# Application of SEF to restoration of grip

## Approach 1 - Surface electrical stimulation

But surface electrodes are not very selective, tedious positioning, movements of the skin during contractions...

### Solution 1 - Matrix electrodes: selective

Simplified positioning and adjustments, rehabilitation / replacement (control methods)

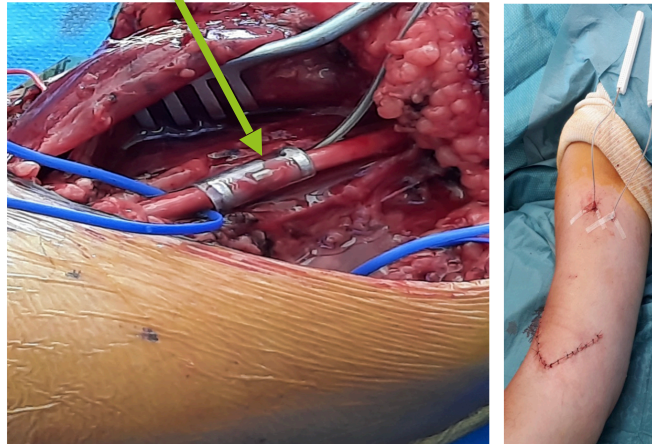


# Application of SEF to restoration of grip

## Approach 2 - Implanted electrical stimulation

### Solution 2 - implanted electrodes

Selectivity and increased efficiency, stability / invasiveness



## Basic functional movements

Implantation of 2 electrodes for 28 days



# STARS



UNIVERSITÉ  
CÔTE D'AZUR

Aix\*Marseille  
université  
Initiative d'excellence



Inserm

## Focus n°2

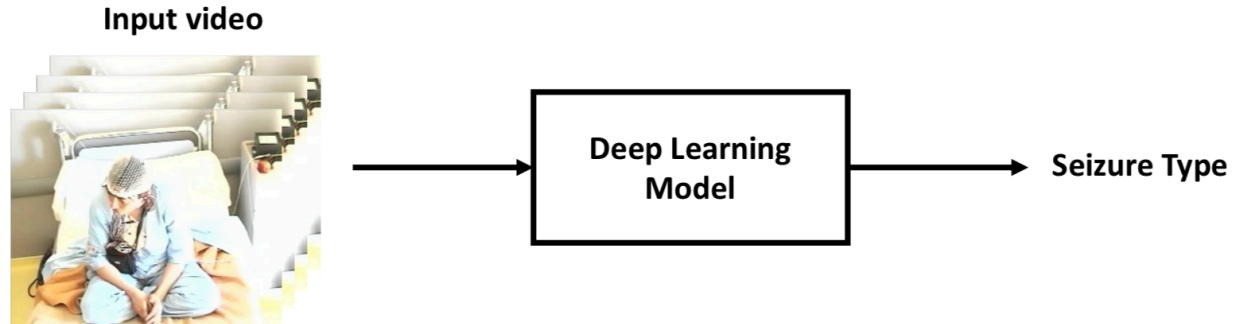
### Video-based identification of epileptic seizures

*Inria*



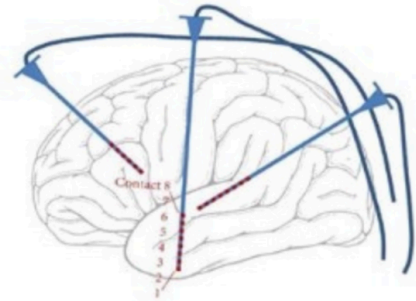
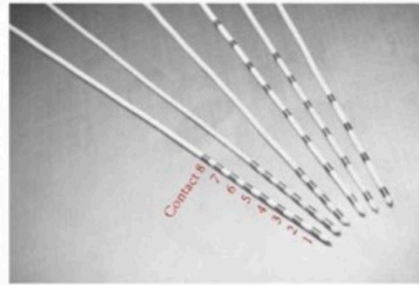
# Goal

- Classify **epileptic seizures** and non-epileptic seizures based on videos.



# What are epileptic seizures (ES)

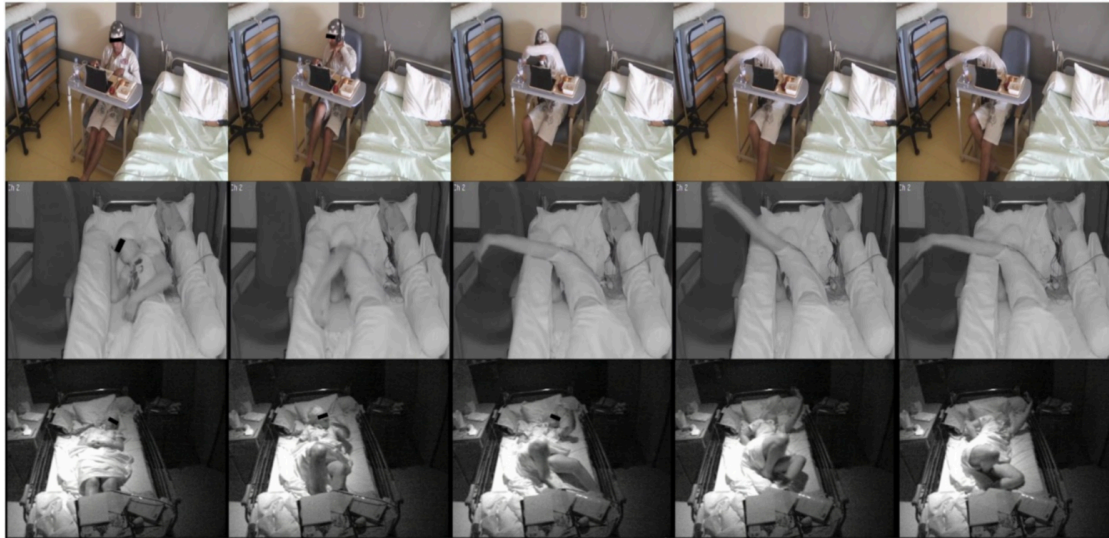
- Abnormal behavior associated with motor activity changes, including repeated or rhythmic movements.
- Caused by epileptic/excessive neuronal activity in the brain.



Depth electrode

# Examples of epileptic seizures

- Limb dystonia: **rigid/stiff arms**



# Non-epileptic seizures

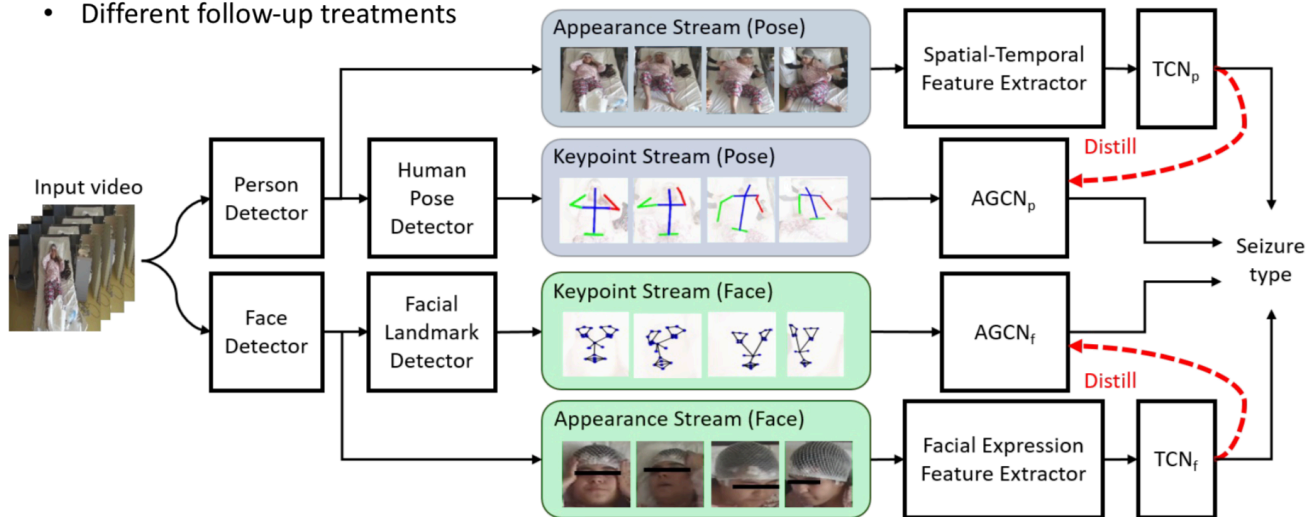
- Not all seizures are epileptic.
- Psychogenic non-epileptic seizures (PNES)
  - Caused by **psychological factors**



# A Multi-Stream Approach for Seizure Classification with Knowledge Distillation: Overview of the model

J-C Hou, A Mcgonigal, F Bartolomei, M Thonnat. A Multi-Stream Approach for Seizure Classification with Knowledge Distillation. AVSS 2021

- Goal: A binary classification task for ES vs. PNES
  - Caused by different reasons
  - Different follow-up treatments



\*TCN: Temporal Convolutional Network \*AGCN: Adaptive Graph Convolutional Network [Shi, CVPR 2019]

## Challenges: limited labeled data

- Costly to collect labeled data in medical domains
  - Video dataset for seizure type classification:

Study	# of seizure videos	# of patients
Achilles (2016)	52	10
Aristizabal (2018)	52 (MTLE:40, ETLE:12)	18 (MTLE:12, ETLE:6)
Karácsony (2020)	126 (FLE:85, TLE:41)	35 (FLE:20, TLE:15)
Maia (2019)	143 (ETLE:107, TLE:36)	31
Aristizabal (2019)	161 (MTLE:90, ETLE:71)	34 (MTLE:17, ETLE:17)
Ours	<b>283</b> (ES:235, PNES:48)	<b>81</b> (ES:52, PNES:29)

\*MTLE: mesial temporal lobe epilepsy, FLE: frontal lobe epilepsy, ETLE, extra-temporal lobe epilepsy

- Action recognition dataset (#Videos): Kinetics (500k), VLOG (114k), HACS (520k)
- Utilize **large amount of unlabeled data**.
  - Without the need for data annotation from clinicians
  - Easier to access and collect.

## Focus n°3

ADAPT: Wheelchair navigation assistance

**Rainbow**

*Inria*

# ADAPT : Wheelchair navigation assistance

## Intuitive trajectory correction

- An embedded plug & play kit providing reactive collision avoidance.
- Shared Control with the user.



## How far have we come?

- **Clinical investigations:** Scenarios of progressive difficulty co-designed with clinicians (+ ethical requirements, compliance with medical device regulation...)
- Experiments **“in real-life”**: testing in the museums of Rennes.

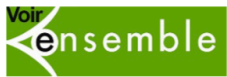


Around **350 users** or people who had failed to drive a wheelchair tested the system, with **100+ participants** included in the clinical investigations.



## Focus n°4

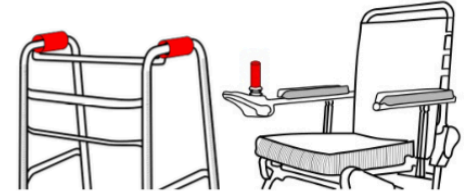
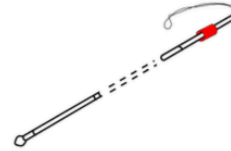
DORNELL: A multimodal, shapeable haptic handle for mobility assistance of people with visual impairments



# DORNELL: Increase mobility

## An innovative haptic handle for efficient and safe navigation

- A **multimodal haptic and tactile feedback**
  - > about the surrounding environment.
  - > about the interaction between the user and the handle.
- A **plug-and-play handle adaptable** with any technical aid.

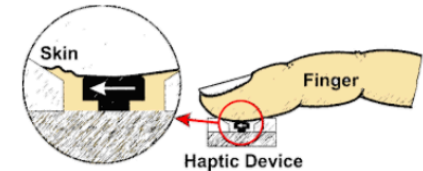
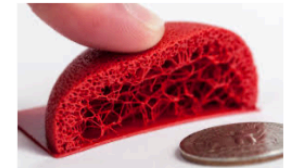


## Scientific challenges

Sensory substitution: tactile and haptic feedback (vibrations, pressure, temperature, etc.)

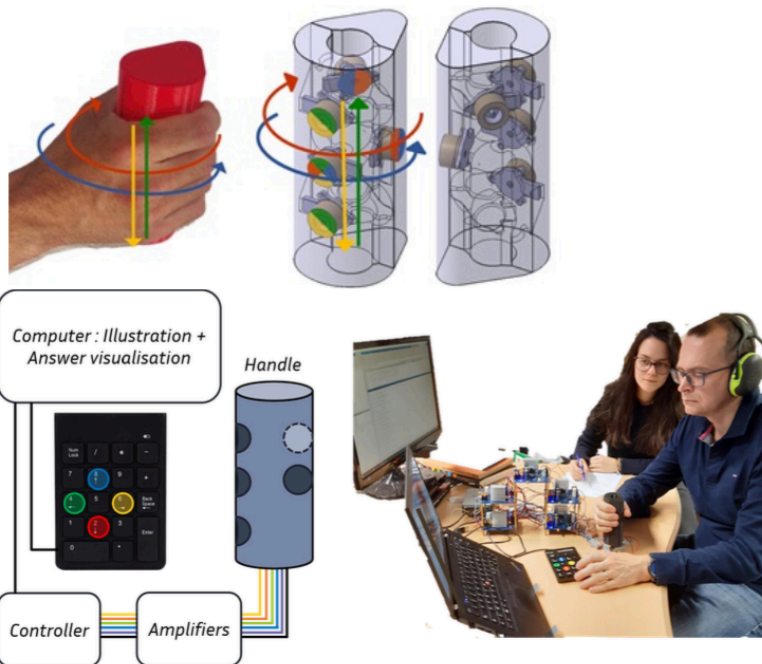
Intelligent and connected device for cane, chair, walker

Adaptable to other disorders



# First prototypes

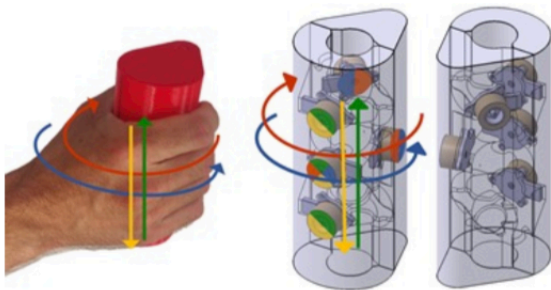
What are we perceiving? Do we succeed navigating thanks to haptic feedback?



# First experiments – perception

## Experiments at INSA Rennes – July 2023

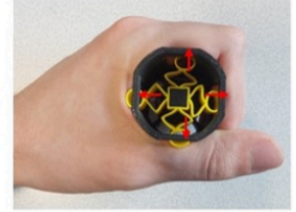
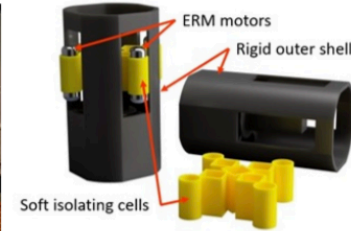
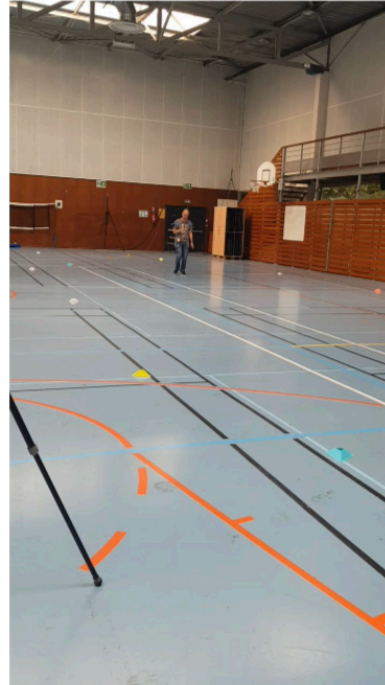
- Perceive haptic feedback direction with handles equipped on a rollator.
- Directional feedback by providing Apparent Haptic Motion Illusion.
- Participation of occupational therapists, physiotherapists, etc.



# First navigation experiments

## Experiments at INSA Rennes – July 2023

- Navigate on a pre-define virtual trajectory.
- Directional feedback to assist navigating on the virtual trajectory.
- Participation of occupational therapists, physiotherapists, etc.





# An available solution: “Swalkit”

## Co-design of a rollator with haptic feedback

- Emerged from the need of Esteban, a user of a rollator with blindness and difficulties to navigate safely.
- Vibrotactile sensations to indicate proximity to obstacles.
- “DIY” assistance kit:
  - > Low cost and open-source.
  - > Can be installed with the help of a fablab.



## Providing daily assistance for 18 monts...

- Before the kit: no autonomy of movement.
- With the use of the kit: autonomy, motivation, renewed confidence and more social interactions.
- Tests with 2 other end-users with the Institut des Jeunes Aveugles in Moulins: study in progress.



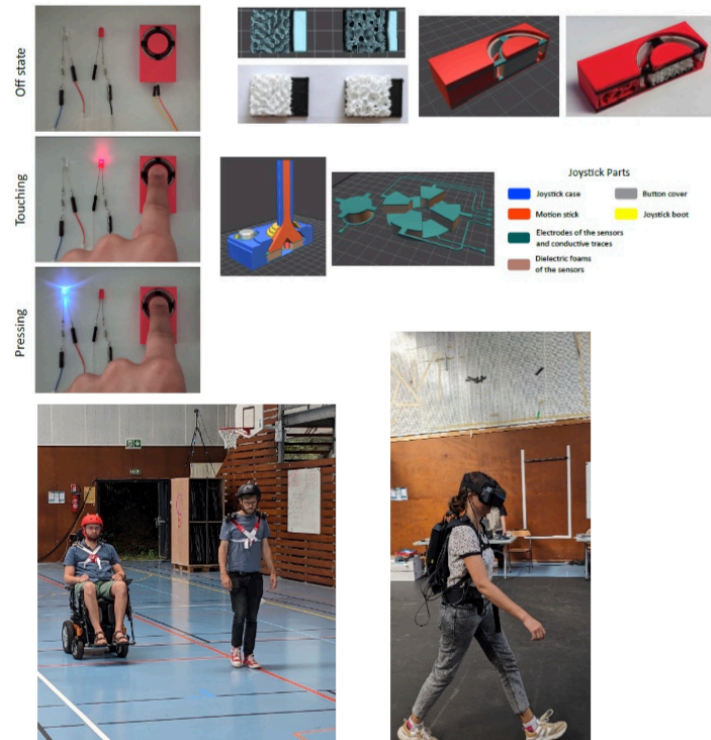
# Dornell is at its halfway stage! What are the next steps?

## Improve feedback and embedded sensing...

- Iterative co-design.
  - > Use the results and participant feedback of the first experiments to improve designs.
  - > Adapt and personalize the handle feedback as well as ergonomics.
- Innovative one-shot 3D printed sensors to incorporate into the handle.
  - > User state and intention detection.
  - > Bidirectional communication.

## Anticipate social navigation challenges

- Evaluate cognitive challenges between the proposed frameworks of haptic feedback and walking/navigation tasks.
- Link with other works on social navigation pedestrian/wheelchair.



# Thanks!

Visit [www.inria.fr](http://www.inria.fr)