AInCP: l'interdisciplinarietà per costruire un progetto di successo

G. Sgandurra
Dip. Medicina Clinica e Sperimentale

G. Prencipe
Dip. Informatica

Pisa, 8 Luglio 2022
Polo Didattico S. Rossore 1938
Via Risorgimento 23

- Child neurologist and psychiatrist
- PhD on New approaches in Biomedical Research
- Head of INNOVATE Lab

SPECIAL INTERESTS

- Cerebral palsy
- Upper limb
- Smart technologies
- Tele-medicine
- Tele-rehabilitation

- PhD in Computer Science

SPECIAL INTERESTS

- Data analysis, ML
  - Digital Health A^{3}Lab scientific coordinator (http://acube.di.unipi.it/)
  - Responsible of national projects for the CS Dept. on digital health
  - Participation in several EU projects on Big Data analysis
  - Sports analytics (spin-off CEO)
- Distributed agents and distributed algorithms

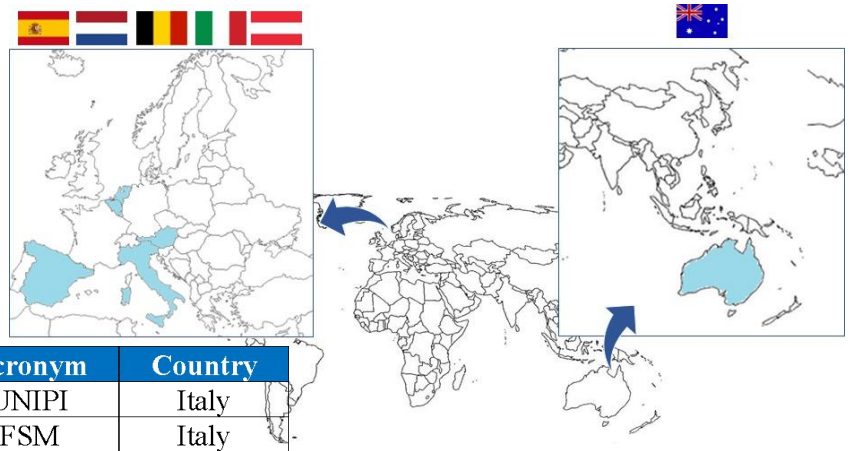
AINCP

clinical validation of **A**rtificial **IN**telligence for providing a personalized motor clinical profile assessment and rehabilitation of upper limb in children with unilateral **C**erebral **P**alsy

Call: HORIZON-HLTH-2021-DISEASE-04
Type of Action: RIA
Acronym: AINCP
Grant Agreement: 101057309
Project starting date: 01 June 2022
Project end date: 31 May 2027
Project duration: 60 months
EU Contribution: € 5,999.942,00

AInCP Consortium

11 partners:
5 EU Member Countries
1 from Australia



No.	Participant organisation name	Acronym	Country
1	Università di Pisa	UNIPI	Italy
2	Fondazione Stella Maris	FSM	Italy
3	Universidad de Castilla – La Mancha	UCLM	Spain
4	Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna	SSSA	Italy
5	Noldus Information Technology	NOLDUS	Netherlands
6	FightTheStroke Foundation	FTS	Italy
7	KHYMEIAmeia s.r.l.	KHYMEIA	Italy
8	Tyromotion GmbH	TYM	Austria
9	The University of Queensland	UQ	Australia
10	Università del Salento	UNILE	Italy
11	Katholieke Universiteit Leuven	KU Leuven	Belgium

Most common cause of childhood chronic physical disability in Europe

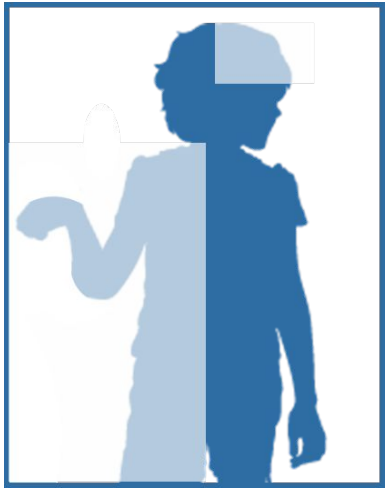
Children with Unilateral CP

The definition of cerebral palsy

Cerebral palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behaviour, and/or by a seizure disorder.

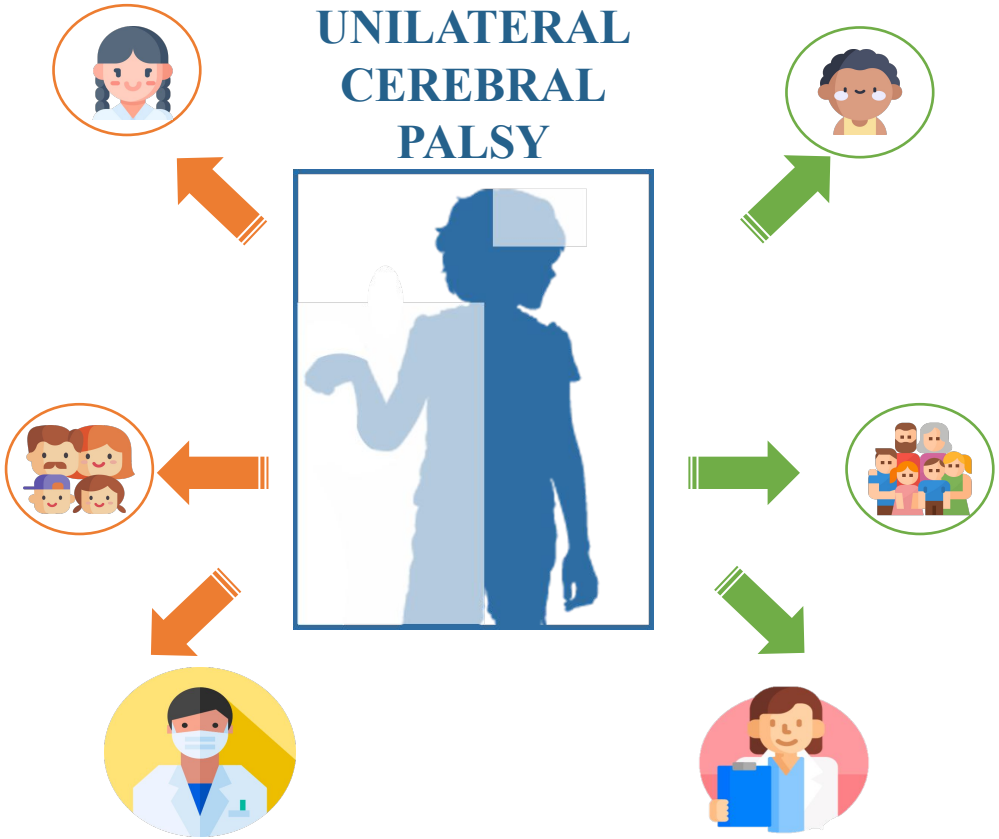
Developmental Medicine & Child Neurology 2005, 47: 571–576 571

Children with Unilateral CP



UCP:
- the most frequent motor type: 30-40% of children with CP
- up to one child in 1,000 live births.

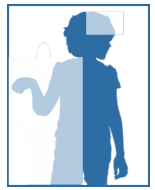
In Europe:
- every year 5,050 new cases
- about 55,000 subjects of developmental age (0-18 years) live



different perspectives

Anna (14 years old) has a **right UCP**. She is attending every year **many visits** at the clinical centre, performing the same standardized assessment tests every time. She is fed up of this, she wants to know more about her disease and her clinical outcome but she asks to reduce the travels, asking for the possibility to be remotely followed by her clinical staff.

Her parents are very worried about her disease and every time they asked to the clinicians detailed information about the UCP and its prognosis. Both parents work full time and they have another son, however they make the effort to accompany **2 times a week** Anna to the rehabilitation centre. They care about Anna's difficulties and they want to know which is the best of treatment for her.



child/families

Sgandurra-Prencipe

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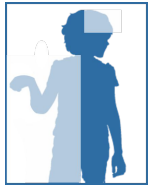

Peter (6 years old) has a **left UCP**. He has difficulties in bimanual activities as wearing his clothes on and cutting his meal with a knife, resulting in a limited independence and reduction of experiences (e.g. sleep at his friend's home and go to the summer camp).

His parents are very worried about Peter's difficulties and they know that he **shows better abilities during the clinical assessments than in daily life**. They work full time and they have 3 other sons, anyway they accompany **3 times a week** Peter to the rehabilitation centre. During the covid lockdown they totally interrupted the rehabilitation activities, with a significant clinical worsening of Peter. They would like to do their best for him.

child/families

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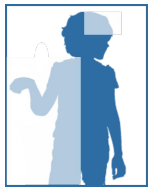

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Jakob is the **child neurologist** and **Kate** the **physical therapist** of Anna and Peter, with high experience in carry out the assessment and the rehabilitation of children with UCP. **They assess the clinical profile** of Anna and Peter by clinical measurements, standardized tests and questionnaires and although they are using **wearable sensors and brain imaging**, there is ***not yet an evidence-based clinical DST to combine them for personalizing the treatment and predict the outcome***. From the lockdown experience, Jakob and Kate yearn to provide intensive and playful home-based assessment, monitoring and treatment.

clinicians

Sgandurra-Prencipe

CENTRO INTERDIPARTIMENTALE PROSIT
PROMOZIONE DELLA SALUTE E INFORMATION TECHNOLOGY

Rehabilitation of Upper Limb
Action Observation therapy

PEDIATRIC NEUROLOGY (WE KAUFMANN, SECTION EDITOR)

Check for updates

State of the Evidence Traffic Lights 2019: Systematic Review of Interventions for Preventing and Treating Children with Cerebral Palsy

Iona Novak[1] · Catherine Morgan[1] · Michael Fahey[2,3] · Megan Finch-Edmondson[1] · Claire Galea[1,4] · Ashleigh Hines[1] · Katherine Langdon[5] · Maria Mc Namara[1] · Madison CB Paton[1] · Himanshu Popat[1,4] · Benjamin Shore[6] · Amanda Khamis[1] · Emma Stanton[1] · Olivia P Finemore[1] · Alice Tricks[1] · Anna te Velde[1] · Leigha Dark[7] · Natalie Morton[8,9] · Nadia Badawi[1,4]

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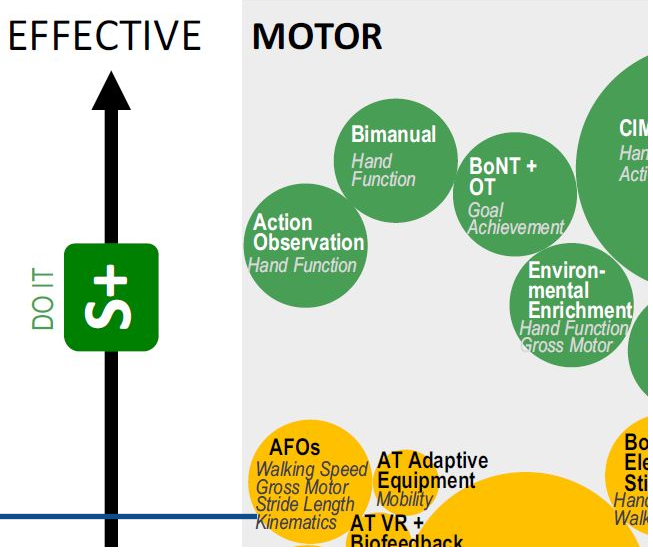
Buchignani *et al. BMC Neurology* (2019) 19:344
https://doi.org/10.1186/s12883-019-1533-x

BMC Neurology

RESEARCH ARTICLE Open Access

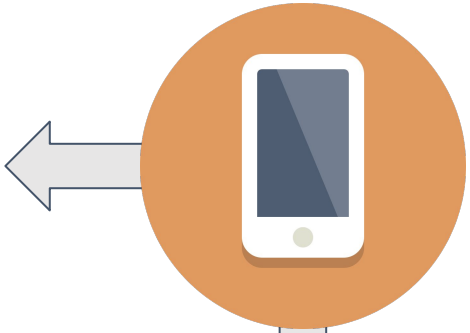
Action observation training for rehabilitation in brain injuries: a systematic review and meta-analysis

Bianca Buchignani[1], Elena Beani[1], Valerie Pomeroy[2], Oriana Iacono[1], Elisa Sicola[1], Silvia Perazza[1], Eleonora Bieber[1], Hilde Feys[3], Katrijn Klingels[3,4], Giovanni Cioni[1,5] and Giuseppina Sgandurra[1,5*]



ICT *for telecare systems*

health care providers



sme

KHYMEIA
TYM
FTS

UNIPI
FSM
SSSA
UQ
Tele-UPCAT

academia

care givers

chronic illness

CENTRO INTERDIPARTIMENTALE PROSIT
PROMOZIONE DELLA SALUTE E INFORMATION TECHNOLOGY

ICT *for telecare systems*

Neurorehabilitation and Neural Repair
http://nnr.sagepub.com/

Randomized Trial of Observation and Execution of Upper Extremity Actions Versus Action Alone in Children With Unilateral Cerebral Palsy
Giuseppina Sgandurra, Adriano Ferrari, Giuseppe Cossu, Andrea Guzzetta, Leonardo Fogassi and Giovanni Cioni
Neurorehabil Neural Repair published online 25 July 2013
DOI: 10.1177/1545968313497101

Open Access Protocol

BMJ Open **Tele-UPCAT: study protocol of a randomised controlled trial of a home-based Tele-monitored UPper limb Children Action observation Training for participants with unilateral cerebral palsy**

Giuseppina Sgandurra,[1,2] Francesca Cecchi,[3] Elena Beani,[1] Irene Mannari,[3] Martina Maselli,[3] Francesco Paolo Falotico,[3] Emanuela Inguaggiato,[1] Silvia Perazza,[1] Elisa Sicola,[1] Hilde Feys,[4] Katrijn Klingels,[4,5] Adriano Ferrari,[6,7] Paolo Dario,[3] Roslyn N Boyd,[8] Giovanni Cioni[1,2]

Sgandurra et al. BMC Neurology 2011, 11:80
http://www.biomedcentral.com/1471-2377/11/80

BMC Neurology

STUDY PROTOCOL Open Access

Upper limb children action-observation training (UP-CAT): a randomised controlled trial in Hemiplegic Cerebral Palsy

Giuseppina Sgandurra[1,2], Adriano Ferrari[3,4], Giuseppe Cossu[5], Andrea Guzzetta[2], Laura Biagi[2], Michela Tosetti[2], Leonardo Fogassi[5] and Giovanni Cioni[2,6*]

UP-CAT

frontiers in Neurology

ORIGINAL RESEARCH
published: 28 February 2020
doi: 10.3389/fneur.2020.00016

Feasibility of a Home-Based Action Observation Training for Children With Unilateral Cerebral Palsy: An Explorative Study

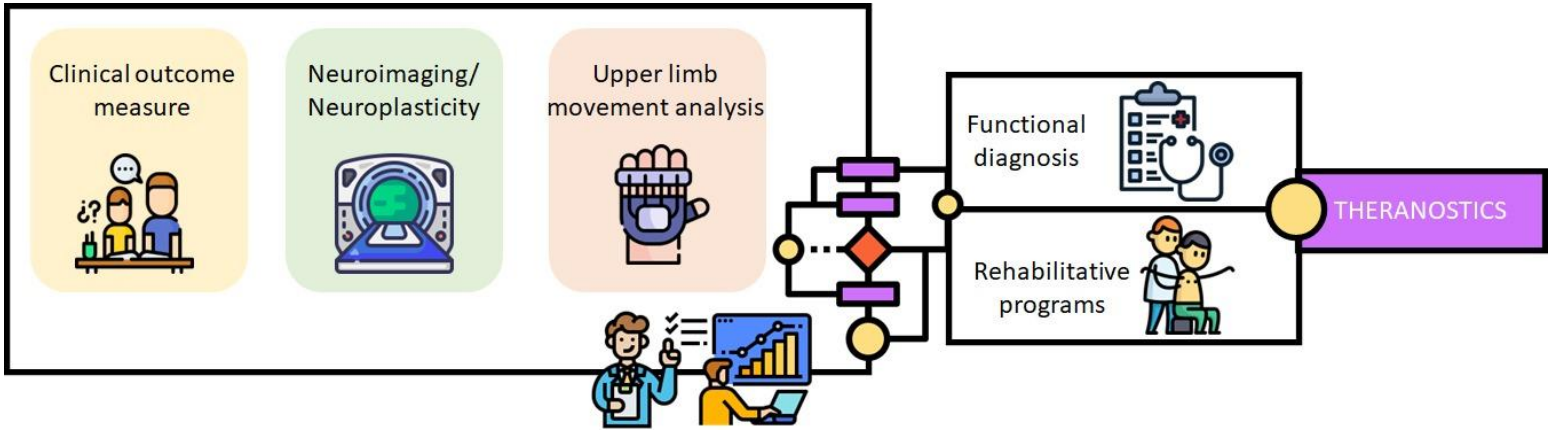
Elena Beani[1], Valentina Menici[1], Adriano Ferrari[2,3], Giovanni Cioni[1,4] and Giuseppina Sgandurra[1,4]*

TELE UP-CAT

AInCP Goals

1. Develop a decision support system for diagnostic purposes (dDST)
2. Develop a decision support system for rehabilitation purposes (rDST)

⇒ to combine into a theranostic DST (tDST)



Data is king

MRI

Neuroimaging/
Neuroplasticity

wearable

Upper limb
movement analysis

clinicians

Clinical outcome
measure

diagnostic

dDST

Data is king

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Neuroimaging/
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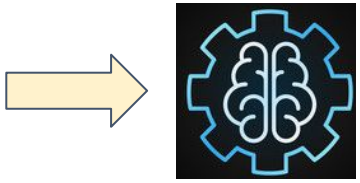
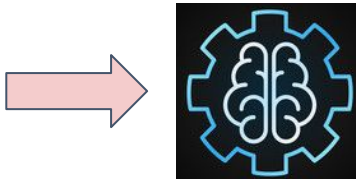


diagnostic

dDST

theranostic

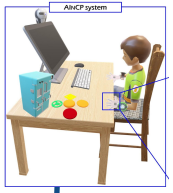
tDST



rehabilitation

rDST

- **At home**
  - Exercises
  - Wearable sensors
  - Eye tracker
- MRI
- Clinical assessment



ML and big-data analytics
to transform data into
meaningful information

Data-driven, ML approach

Diagnostic as a classification problem. Challenges:

- heterogeneity of data
- structured/unstructured
- much data, but not “big” in scope (few patients)

Opportunities

- integration of different data sources (correlations? patterns?)
- useful stratification of patients might emerge
- diagnostic model useful for feature evaluation also

Diagnosis

Main sources for **diagnosis**:

- Patient demographic
- MRI
- Classification of motor and sensory functions
- Actigraphs

Along with sample target diagnoses

Without data, there's no building of a model: Availability, usability, reliability.

Rehabilitation

Choosing the best rehabilitation path for the patient

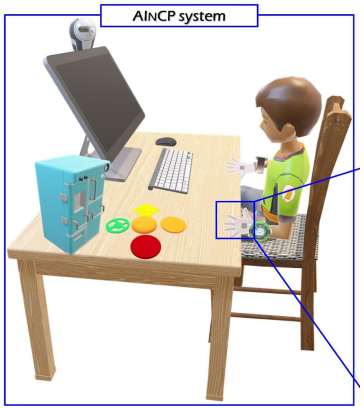
Which of these 1000 rehabilitation exercises work best for the specific patient?

"**recommendation**": ranking exercises by "likelihood of being beneficial" given:

- characteristics of the patient
- history of past interactions
- a model based on as many patients as possible
- a baseline

Data:

- movement analysis ("smart" toys, actigraphs)
- gaze detection (to identify distress, effort, focus)
- evaluation of the exercise execution



Rehabilitation

Challenges:

- the system must learn, but it **can't do so by way of mistakes** => must rely on a baseline
- the system must be tightly fitted into the rehab protocol
- data must be available promptly

AInCP!

CENTRO INTERDIPARTIMENTALE PROSIT
PROMOZIONE DELLA SALUTE E INFORMATION TECHNOLOGY

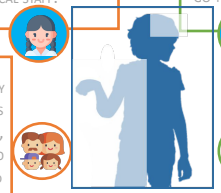
IN SUPREMÆ DIGNITATIS

ANNA IS HAPPY BECAUSE AFTER A COMPLETE CLINICAL ASSESSMENT, SHE CAN STAY AT HOME WEARING THE **GLITTERED SENSORS** SHE CHOSE, AND **SELF-MONITORING** HER UPL ACTIVITY BY THE **AINCP PLATFORM**!

AINCP

ANNA (14 YEARS OLD) HAS A RIGHT UCP. SHE IS ATTENDING EVERY YEAR MANY VISITS AT THE CLINICAL CENTRE, PERFORMING THE SAME STANDARDIZED ASSESSMENT TESTS EVERY TIME. SHE IS FED UP OF THIS, SHE WANTS TO KNOW MORE ABOUT HER DISEASE AND HER CLINICAL OUTCOME BUT SHE ASKS TO REDUCE THE TRAVELS, ASKING FOR THE POSSIBILITY TO BE REMOTELY FOLLOWED BY HER CLINICAL STAFF.

HER PARENTS ARE VERY WORRIED ABOUT HER DISEASE AND EVERY TIME THEY ASKED TO THE CLINICIANS DETAILED INFORMATION ABOUT THE UCP AND ITS PROGNOSIS. BOTH PARENTS WORK FULL TIME AND THEY HAVE ANOTHER SON, HOWEVER THEY MAKE THE EFFORT TO ACCOMPANY 2 TIMES A WEEK ANNA TO THE REHABILITATION CENTRE. THEY CARE ABOUT ANNA'S DIFFICULTIES AND THEY WANT TO KNOW WHICH IS THE BEST OF TREATMENT FOR HER.



PETER (6 YEARS OLD) HAS A LEFT UCP. HE HAS DIFFICULTIES IN BIMANUAL ACTIVITIES AS WEARING HIS CLOTHES ON AND CUTTING HIS MEAL WITH A KNIFE, RESULTING IN A LIMITED INDEPENDENCE AND REDUCTION OF EXPERIENCES (E.G. SLEEP AT HIS FRIEND'S HOME, GO TO THE SUMMER CAMP).

AINCP

HIS PARENTS ARE VERY WORRIED ABOUT PETER'S DIFFICULTIES AND THEY KNOW THAT HE SHOWS BETTER ABILITIES DURING THE CLINICAL ASSESSMENTS THAN IN DAILY LIFE. THEY WORK FULL TIME AND THEY HAVE 3 OTHER SONS, ANYWAY THEY ACCOMPANY 3 TIMES A WEEK PETER TO THE REHABILITATION CENTRE. DURING THE COVID LOCKDOWN THEY TOTALLY INTERRUPTED THE REHABILITATION ACTIVITIES, WITH A SIGNIFICANT CLINICAL WORSENING OF PETER. THEY WOULD LIKE TO DO THEIR BEST FOR HIM.

PETER IS VERY ENTHUSIASTIC OF CHOOSING THE TYPE OF **TOYS AND ACTIVITIES** AND TO UNDERSTAND BY THE **AOT VIDEOS**, PROVIDED BY **AINCP SYSTEM**, HOW TO USE THEM AND SHARE HIS IMPROVEMENTS WITH HIS FRIENDS!

JAKOB IS THE CHILD NEUROLOGIST AND KATE THE PHYSICAL THERAPIST OF ANNA AND PETER, WITH HIGH EXPERIENCE IN CARRY OUT THE ASSESSMENT AND THE REHABILITATION OF CHILDREN WITH UCP. THEY ASSESS THE CLINICAL PROFILE OF ANNA AND PETER BY CLINICAL MEASUREMENTS, STANDARDIZED TESTS AND QUESTIONNAIRES AND ALTHOUGH THEY ARE USING NEW TECHNOLOGIES (SUCH AS WEARABLE SENSORS AND BRAIN IMAGING), THERE IS NOT YET AN EVIDENCE-BASED CLINICAL DST TO COMBINE THEM FOR PERSONALIZING THE TREATMENT AND PREDICT THE OUTCOME. FROM THE LOCKDOWN EXPERIENCE, JAKOB AND KATE YEARN TO PROVIDE INTENSIVE AND PLAYFUL HOME-BASED ASSESSMENT, MONITORING AND TREATMENT.

PATIENT

IN SUPREMÆ DIGNITATIS 1343

Sgandurra-Prencipe

AInCP!

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Peter is very enthusiastic of choosing the type of **toys and activities** and to understand the **AOT videos**, provided by AInCP system, how to use them and share his improvements with his friends!

AInCP

AInCP

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AInCP

Anna and her parents are happy to surf through the AInCP **web interactive platform,** finding **personal stories** of other children with UCP, **flyer and videos** on clinical features and **rehabilitative approaches** for the UCP.

Jakob is the **child neurologist** and **Kate** the **physical therapist** of Anna and Peter, with high experience in carry out the assessment and the rehabilitation of children with UCP. They assess the clinical profile of Anna and Peter by clinical measurements, standardized tests and questionnaires and although they are using new technologies (such as wearable sensors and brain imaging), there is not yet an evidence-based clinical DST to combine them for

FAMILY

His parents are happy to have the opportunity of provide an useful, playful and intensive **treatment directly at home.** They have much time to play with Peter using the AInCP **system** because they do not have to reach the clinical centre.

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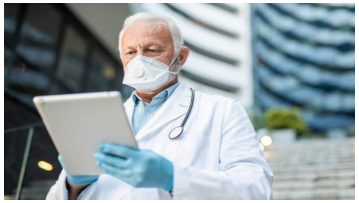

Jakob and **Kate** **positively changed their work**. They have clinically implemented the use of the **AInCP tDST**. Thanks to special **AI algorithms** they are able to **remotely assess children's daily life activities**, plan the treatment uploading personalized exercises and predict the outcome, without being stopped in a **lockdown period**.

CLINICAL STAFF

CENTRO INTERDIPARTIMENTALE PROSIT
PROMOZIONE DELLA SALUTE E INFORMATION TECHNOLO

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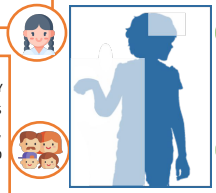
AInCP

Anna and her parents are happy to surf through the AInCP **web interactive platform**, finding **personal stories** of other children with UCP, **flyer and videos** on clinical features and **rehabilitative approaches** for the UCP.



Peter (6 years old) has a **left UCP**. He has difficulties in bimanual activities as wearing his clothes on and cutting his meal with a knife, resulting in a limited independence and reduction of experiences (e.g. sleep at his friend's home and go to the summer camp).

AInCP

Peter is very enthusiastic of choosing the type of **toys and activities** and to understand by the **AOT videos**, provided by AInCP system, how to use them and share his improvements with his friends!

His parents are very worried about Peter's difficulties and they know that he shows better abilities during the clinical assessments than in daily life. They work full time and they have 3 other sons, anyway they accompany 3 times a week Peter to the rehabilitation centre. During the covid lockdown they totally interrupted the rehabilitation activities, with a significant clinical worsening of Peter. They would like to do their best for him.

AInCP

His parents are happy to have the opportunity of provide an useful, playful and intensive **treatment directly at home**. They have much time to play with Peter using the AInCP **system** because they do not have to reach the clinical centre.

Jakob is the **child neurologist** and **Kate** the **physical therapist** of Anna and Peter, with high experience in carry out the assessment and the rehabilitation of children with UCP. They assess the clinical profile of Anna and Peter by clinical measurements, standardized tests and questionnaires and although they are using new technologies (such as wearable sensors and brain imaging), there is not yet an evidence-based clinical DST to combine them for personalizing the treatment and predict the outcome. From the lockdown experience, Jakob and Kate yearn to provide intensive and playful home-based assessment, monitoring and treatment.

AInCP

Jakob and Kate positively changed their work. They have clinically implemented the use of the AInCP **tDST**. Thanks to special **AI algorithms** they are able to **remotely assess children's daily life activities**, plan the treatment uploading personalized exercises and predict the outcome, without being stopped in a lockdown period.

Sgandurra-Prencipe

Thanks for your attention!

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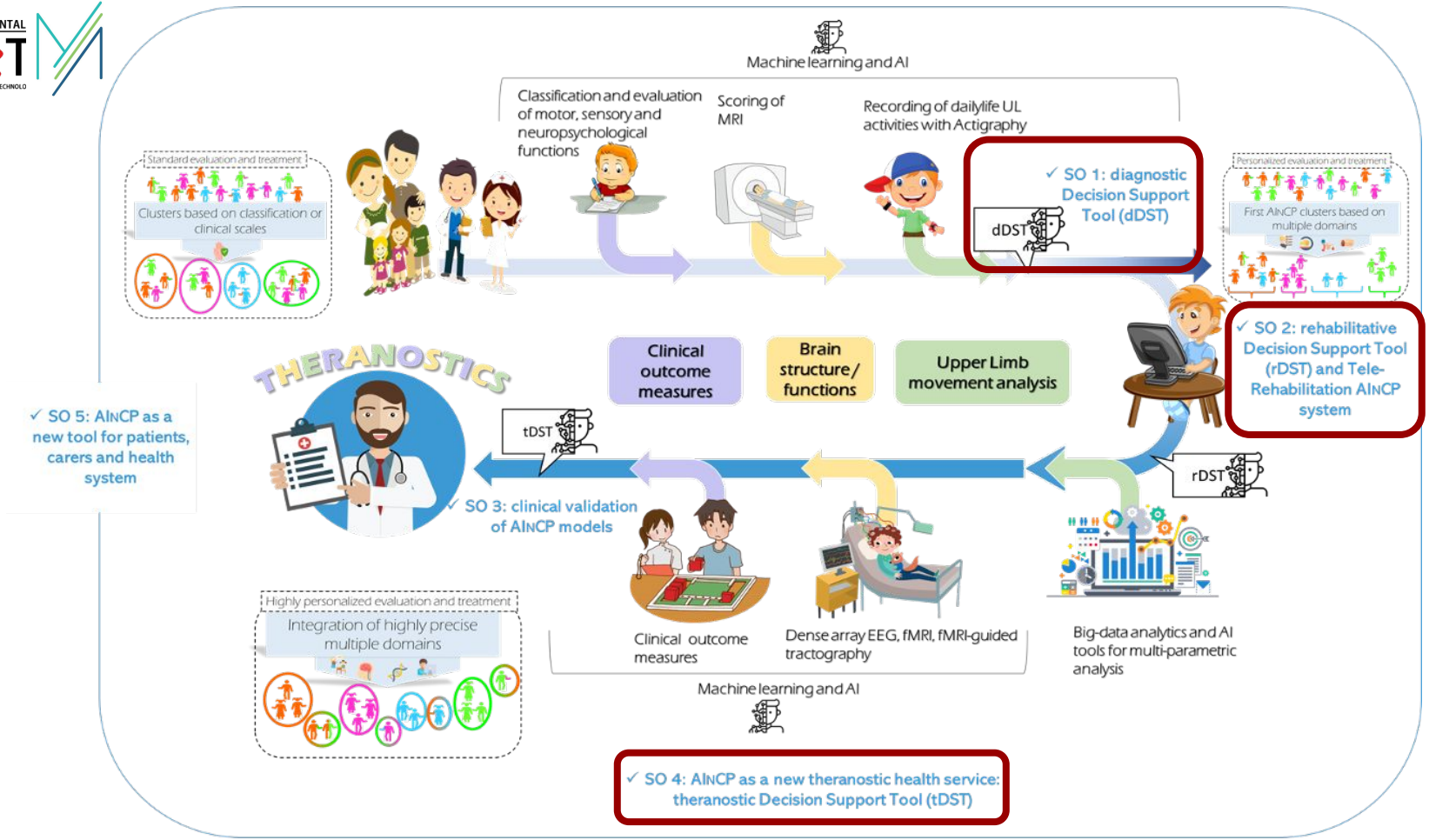
Validation

- dDST can be validated as a classifier, against a set of “golden” diagnosis it hasn’t been made aware of during training.

- rDST is harder to validate. We might keep track of: times when the rDST suggested an exercise, but a different one was chosen in a “control group” of patients not using the rDST. Finally, simulation, while not providing validation by itself, can however show convergence times in the learning process.



The AINCP approach

“Recommend”...how?

- If a baseline is available, reinforcement learning is a good starting point. It enables us to adjust exploration vs. exploitation in search of the best compromise.
- In matrix-based recommendation systems, items are represented by “latent” features based on who chose those items (think Netflix, Amazon…). We don’t have the numbers (nor can we afford the mistakes) to do the same, but we might leverage stratification.