Integrated Digital Neuro-rehabilitation: From Clinic to Home

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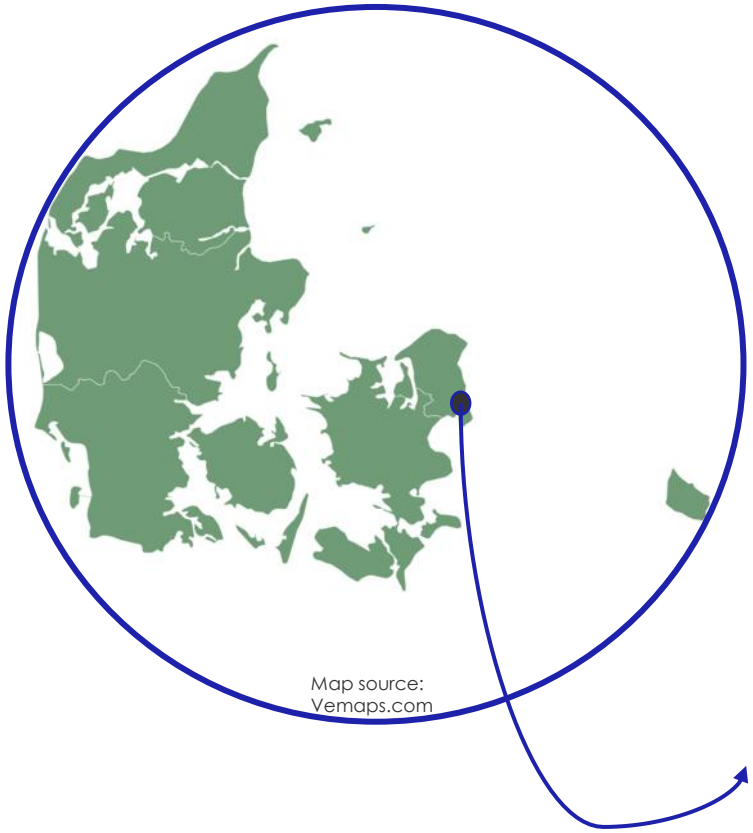
HIMSS 26

The scale of acquired brain injury in Denmark



- **In Denmark**, around 230,000 people live with the long-term consequences of acquired brain injury
- More than 20,000 new cases occur every year due to stroke and thousands sustain traumatic brain injury[1]
- => This creates a substantial and growing need for rehabilitation – much of which currently takes place at hospital and in a community setting, where many require long-term rehabilitation[2]
- **Population context**: Denmark: ~6.0 million inhabitants[3]

➡️ ~1 in 25 Danes lives with the consequences of brain injury

- **Case focus**: Copenhagen Municipality ~11% of the Danish population lives in Copenhagen with ~670,000 inhabitants

[1] Sundhedsdatastyrelsen, Dataopgørelser vedrørende voksne med erhvervet hjerneskade (2020).
[2] Fuglsang, C. H. et al. Occurrence, mortality, and economic burden of brain disorders in Denmark, 2015–2021: a population-based cohort study. The Lancet Regional Health - Europe 50, 101189 (2025).
[3] https://www.dst.dk/da/Statistik/emner/borgere/befolkning/befolkningstal

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Neurorehabilitation in Denmark: Phases

Example: neurorehabilitation pathway in Denmark – from hospital to home

Injury to the brain

1 Acute hospital care

Early, specialized hospital-based treatment

2 Subacute / specialized rehab.

Intensive, interdisciplinary rehabilitation at hospital

3 Community-based rehab.

4 Long-term follow-up and independence

Sustained support, self-management, and quality of life

https://www.kk.dk/borger/sundhed-og-forebyggelse/sygdom/hjerneskade/genoptraening-og-rehabilitering
https://hjerneskadet.dk/raadgivning/behandling-og-rehabilitering/
https://www.social.dk/voksne/erhvervet-hjerneskade/viden-og-temaer/rehabilitering

Neurorehabilitation – Copenhagen (NCPH)

Inpatient, 2024
- Cases, in total: 294
  - 229 advanced level
  - 65 specialized level
- Mean length of stay: 42 days*

Inpatient, 2025
- Cases, in total: 346
  - 281 advanced level
  - 65 specialized level
- Mean length of stay: 40 days*

*Mean for advanced and specialized levels combined

Cost-effective with a focus on coherent pathways and seamless transitions
E.g., short inpatient stays followed by transition to outpatient rehabilitation and return to home

Outpatient, 2024
- Cases, in total: 741
  - 714 advanced level
  - 27 specialized level
- Mean length of stay: 84 days*

Outpatient, 2025
- Cases, in total: 758
  - 740 advanced level
  - 18 specialized level
- Mean length of stay: 83 days*

*Mean for advanced and specialized levels combined

Interdisciplinary structure

200 (+/-) Professionals

8 Professions

Digital solutions

Bridging: Clinic to home

45 Inpatient beds

Training apartment

Focus on family members

Outpatient service

Mobile neurological team

Home-based rehabilitation

Case – stroke survivor at NCPH outpatient unit

Time of Injury → Hospital → Discharge → Community-based Neurorehabilitation at NCPH / Home

Case
• Thomas, 21-year-old male, subarachnoid hemorrhage
• Hemiparesis, dysphagia, dysarthria, cognitive impairment & fatigue
Transitions
• Seamlessly from hospital to specialized outpatient care through a coordinated, interdisciplinary pathway
Key Challenge
➡️ Need for intensive, coordinated rehabilitation across sectors
➡️ Risk of fragmentation post-discharge

Care Coordination
• Brain injury coordinator ensures seamless transition continuity across sectors, Hospital -> Community
Assessment Interdisciplinary
• PT, OT, Neuropsychology, Speech therapy
Hybrid Interventions (overall)
🏥 On-site therapy
💻 Digital rehab (online cognitive training, virtual sessions)
🏠 Home-based training
Continuous Follow-up
• Shared care plan & status reviews

Hybrid Model of Care
🏥 **Initial intake takes place in-person at NCPH** and includes a comprehensive, multidisciplinary baseline assessment
On-site interventions:
•Goal-oriented physiotherapy
•Neuropsychological therapy and cognitive group sessions (including relatives)
•Occupational therapy, including energy management and ADL
• Speech and language therapy

Hybrid Model of Care
💻🏠 **Digital and home-based components:**
• Online cognitive rehab and self-management modules (HappyNeuron – Professional Cognitive Rehabilitation)
• Virtual therapy sessions
• Structured home rehab programs supported by clinicians (Exorlive Go, ICURA, My Day - My Energy, FamilyWall, Travel Planner)
• Remote follow-up & asynchronous patient engagement

For Thomas, **digitally supported, hybrid neurorehabilitation can:**
•Improve continuity of care across sectors and enable scalable rehab delivery
•Reduce reliance on in-person services without compromising quality
•Enhance engagement and self-management through targeted, adaptive interventions
➡️ **Extends care beyond clinical settings**
➡️ **Increases accessibility & flexibility**

What this case shows us - From hands-on to hybrid care:
In community-based neurorehabilitation at NCPH, treatment already can take place in the survivors' home – and digital solutions are part of practice. But adaptation is still limited. What we see in practice is not digital-first treatment currently, but a gradual transition into hybrid rehabilitation.

Barriers, adaptation and data gaps

- Digital solutions depend on: Timing, readiness, and cognitive capacity, and digital exclusion is often clinical, not just technical
- **75%** Of persons receiving outpatient rehabilitation at NCPH are not initially assessed as suitable due to:

1) Cognitive impairments (memory, attention, problem-solving)
2) Limited access to or familiarity with technology
3) Visual disturbances
4) Fatigue (brain fatigue) or dizziness

- Consequently, **this case is not overall representative as only 25 – 30%** of persons with injury receiving outpatient rehabilitation at NCPH use digital solutions in some form => **However,** current monitoring only includes Exorlive Go and ICURA, thus, hidden usage ("dark data") across other digital tools
- **…But;** might we as professionals have biases too?...

- Digital rehabilitation is not a replacement – it is a progressive enabler
- We are already digital – but we are not fully measuring it, and other solutions are needed to expand the digital possibilities for this group of brain injury survivors

What the future calls for?

Why digital rehabilitation matters

- Growing number of survivors => rising rehabilitation demand:
  - Projected increase in brain injury survivors in Denmark *(estimate)*

➢2020: 230,000

2030: 250,000

2040: 270,000

2050: 300,000

- Geographic and social disparities:

⇒Home-based digital tools improve proximity, quality, and equity

⇒Allows consistent, sufficient training regardless of location

The question is:

- How to design solutions that include more survivors, earlier in their recovery and support them in their everyday lives?
- …And how do we ensure relevance and daily support for clinicians?

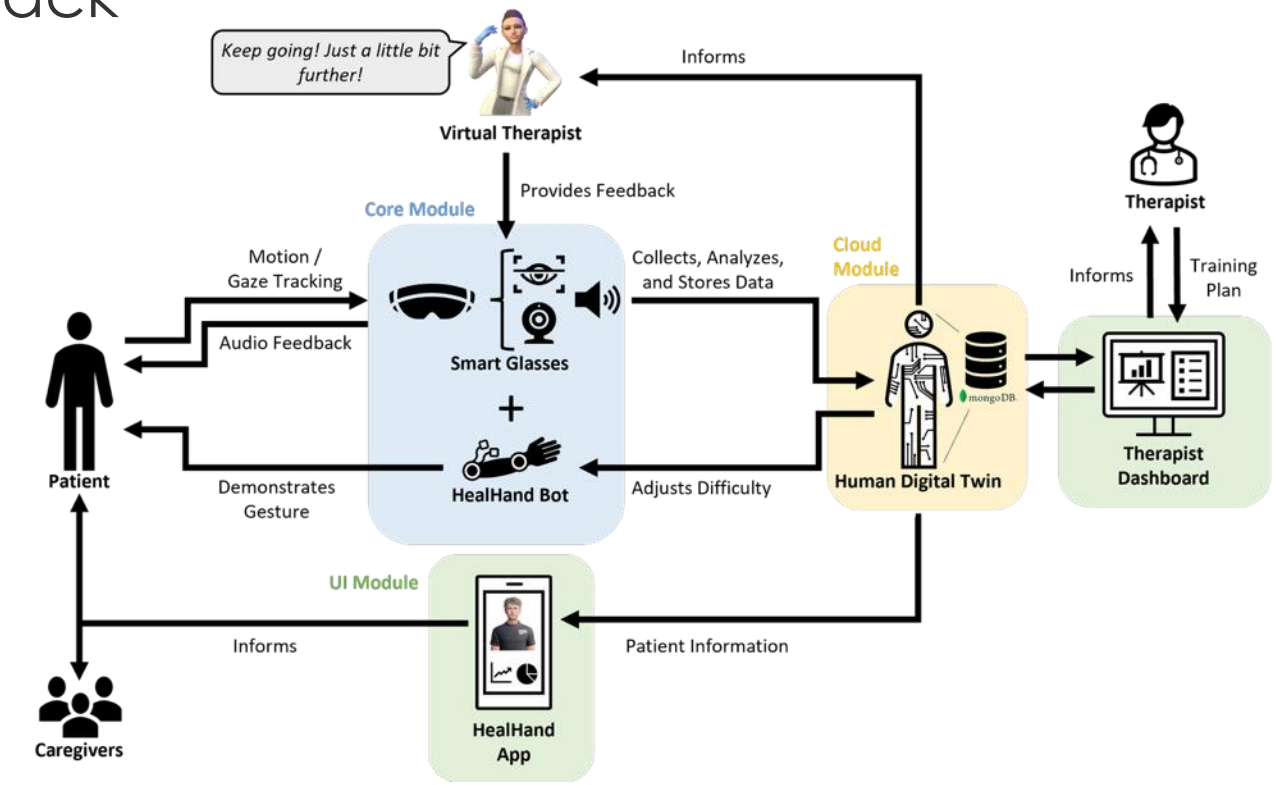
Maribo T, Ibsen C, Thuesen J, Nielsen CV, Johansen JS, Vind AB (Red.). Hvidbog om rehabilitering,1. udgave. Rehabiliteringsforum Danmark, Aarhus. 2022.
Sundhedsdatastyrelsen, Dataopgørelser vedrørende voksne med erhvervet hjerneskade, 2020.
Feigin VL, Brainin M, Norrving B, Martins SO, Pandian J, Lindsay P, F Grupper M, Rautalin I. World Stroke Organization: Global Stroke Fact Sheet 2025. Int J Stroke. 2025 Feb;20(2):132-144.

Aims & challenges for future solutions

- More accessible and intuitive technologies, designed for fatigue, attention and memory impairments
- Therapy is limited, hard to personalize, and difficult to scale
- Home-based therapy holds promises but needs monitoring - without increasing clinician workload
- Better data capture and integration

Human Digital Twins in Rehabilitation

- AI-powered, real-time digital replicas of rehabilitation-relevant data
- Continuously updated with multimodal sensor inputs
- Modify exercises based on simulation, predictions, and real-time feedback



Designing Human Digital Twins for Behaviour-Changing Therapy and Rehabilitation: A Systematic Review. *Proceedings of the Design Society*. doi:10.1017/pds.2022.132

Human Digital Twins in Rehabilitation: A Case Study on Exoskeleton and Serious-Game-Based Stroke Rehabilitation Using the ETHICA Methodology

IEEE Access

DOI: 10.1109/ACCESS.2024.3508029

Two examples

Healhand

- Hand rehabilitation using smart glasses, phones,tablets, or PC
- Adaptive training guided by AI therapists

Gazetalk

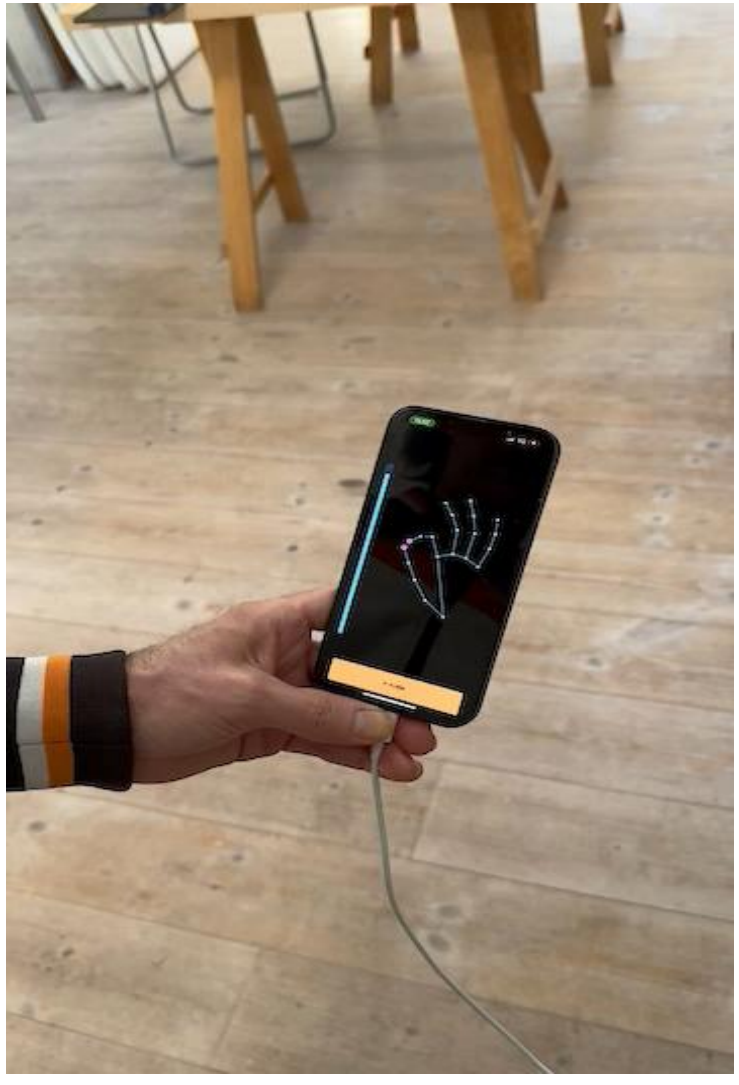
- AI-assisted, web-based communication for people with aphasia
- Supports gaze, speech, and hand interaction

Healhand

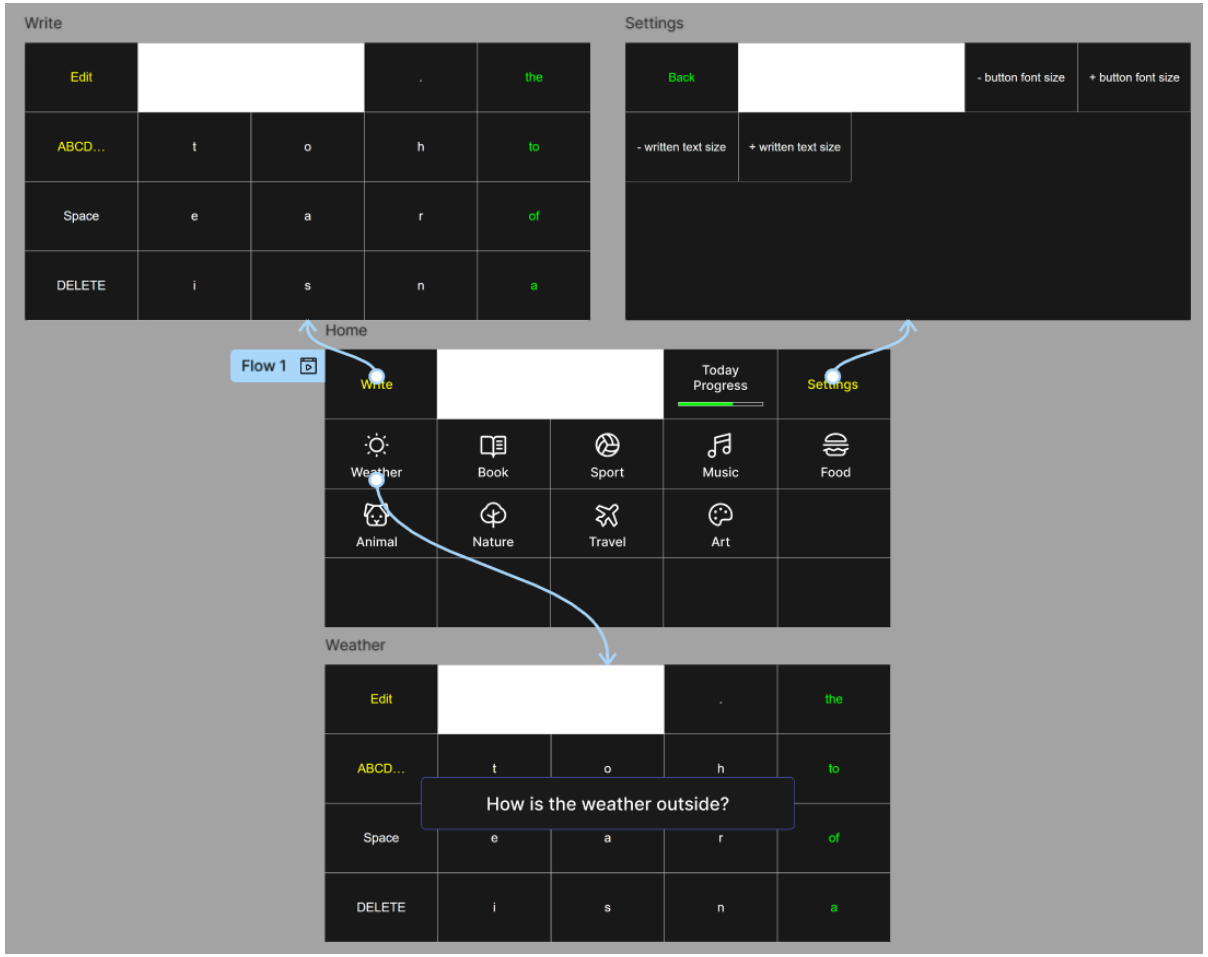
AR-based

Ext. camera

Mobile



Gazetalk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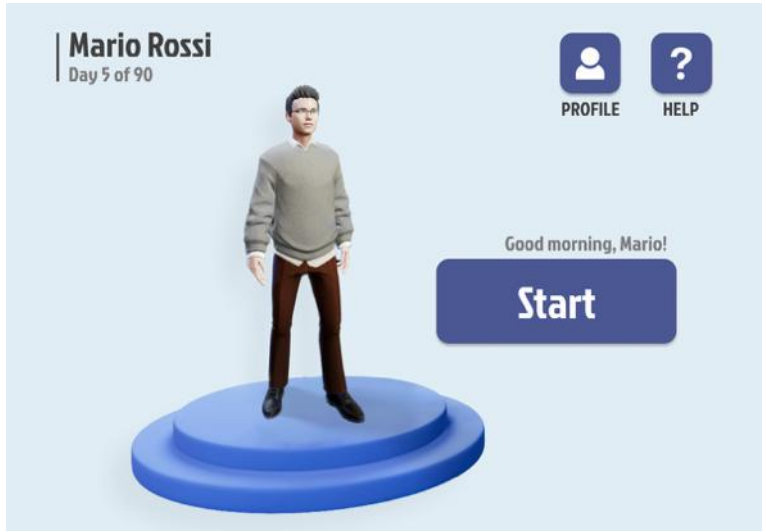
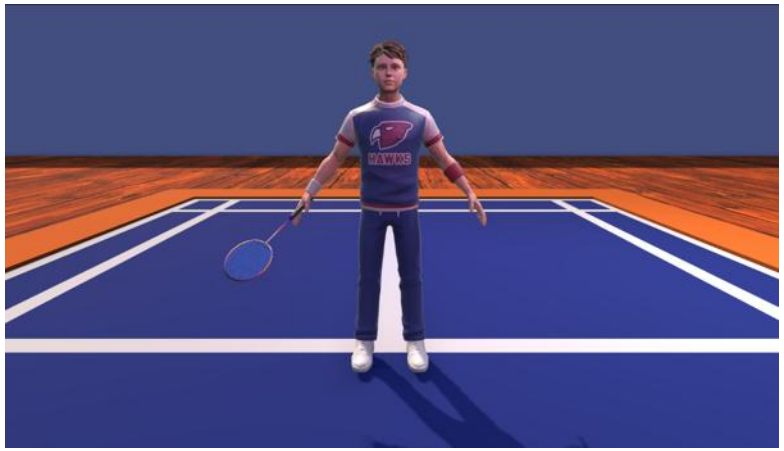
I wish to talk to myself before I got aphasia....

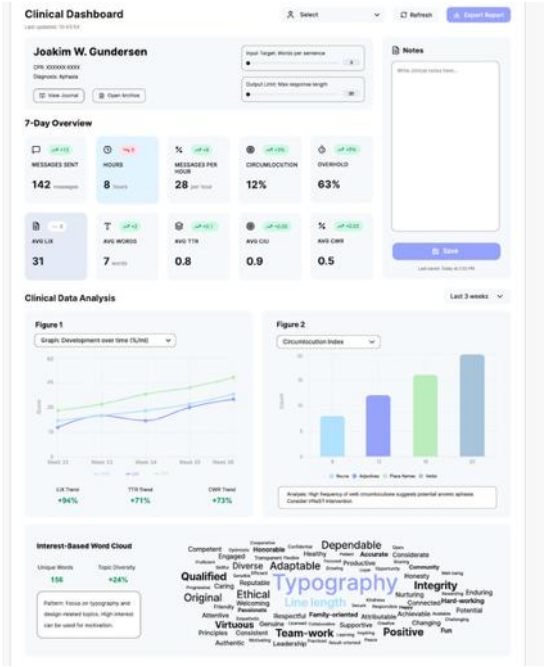
Both systems: Information dashboards

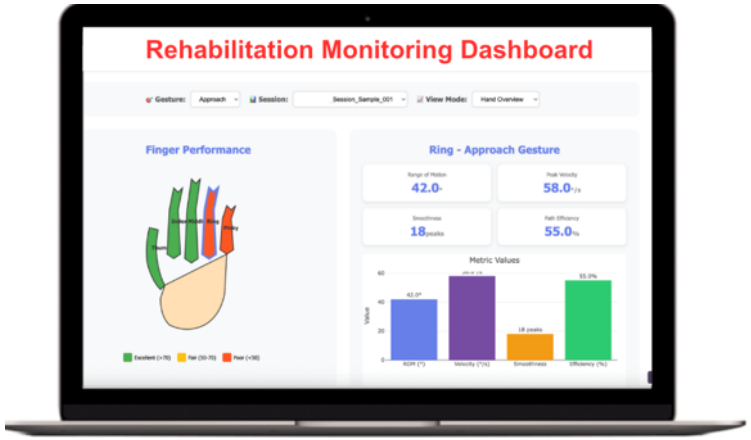
Patients



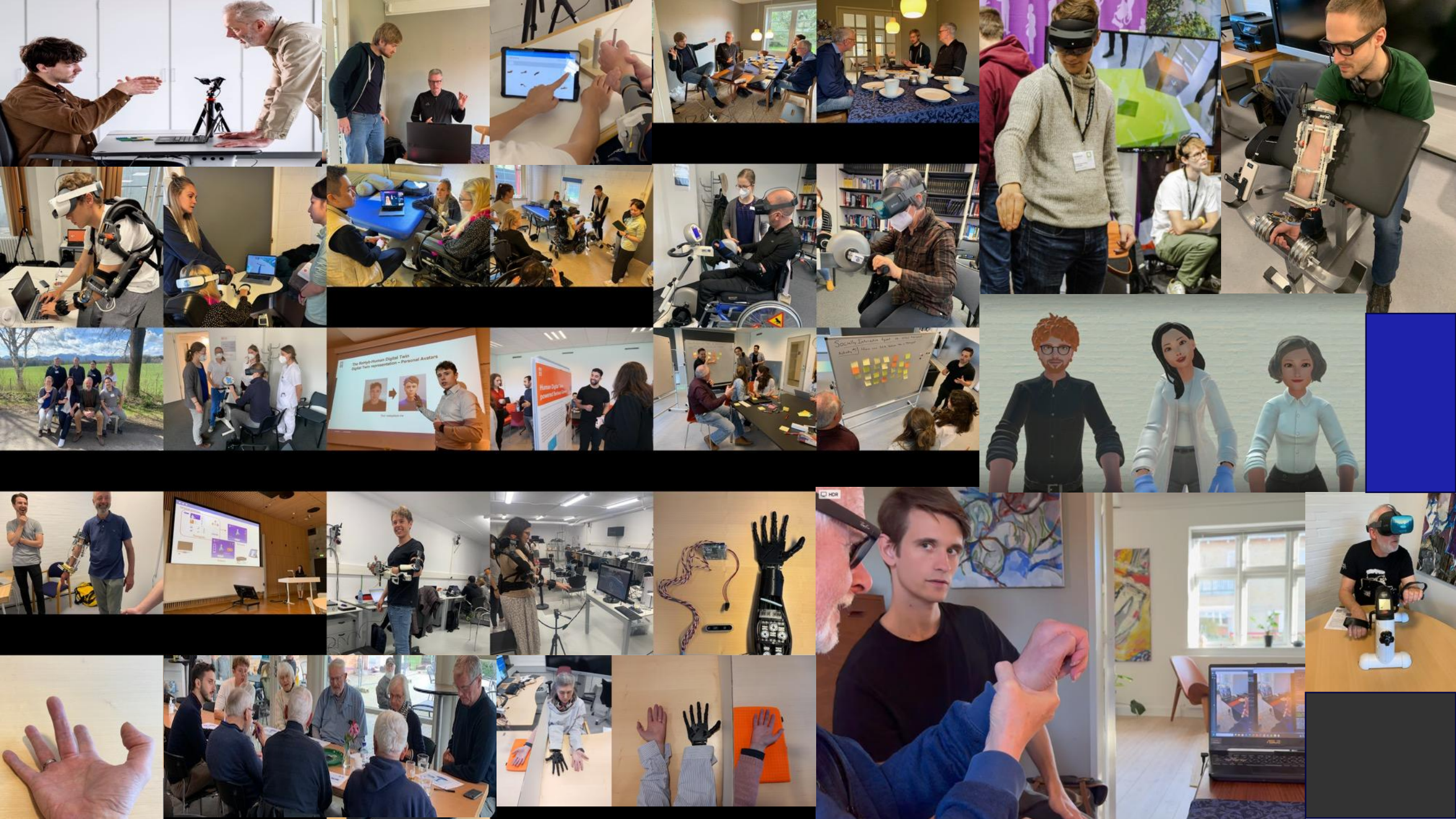


Therapists





Caregivers


The Robyd-Human Digital Twin
Digital Twin representation – Personal Avatars

Take-home Messages

1

High prevalence and growing need

Thousands of adults in Denmark acquire brain injuries each year; total survivors expected to rise by 2030

2

Community-based rehab is critical

Rehabilitation in long-term is importing, including rehabilitation in the survivors' home or local communities (phase 3-4)

3

Digital tools enhance care

Digital solutions support continuity, independent training, and equitable access

4

Tailored approach required

Not all survivors can immediately use digital solutions; thus, assessment and personalization are essential, but clinical considerations must also be addressed => "clinicians-in-the-loop"

5

Future-proofing rehab

Increasing numbers of survivors and geographic challenges call for scalable, home-based digital rehabilitation to ensure **quality, proximity, and equity** across rehabilitation phases

Thank you

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