IoT-Supported Behavioural Descriptions for Return to Work Rehabilitation

Martin Holmberg*, Maria Bergström^
* Department of Science and Technology
^ Department of Health, Medicine and Caring Sciences
Linköping University
Sweden
e-mail: martin.holmberg@liu.se, maria.bergstrom@liu.se

Tomas Westlund
Department of Industrial Systems
RISE, Research Institutes of Sweden
Linköping, Sweden
e-mail: tomas.westlund@ri.se

Abstract— **Healthcare professionals need rich, contextual information about patients' everyday activities, but current assessments provide only sparse snapshots of real-world behaviour. The RELATE project explores how Internet of Things (IoT) technologies and Artificial Intelligence (AI) can unobtrusively capture clinically relevant movements and behaviours in home and workplace environments and present them in therapist-friendly summaries to support rehabilitation planning and follow-up in a Return To Work (RTW) process. We outline a co-design-based methodology with rehabilitation professionals to identify key behavioural targets, map them to sensor and analytics requirements, and guide the development and future real-world evaluation of an IoT-supported rehabilitation system. This early-stage vision and ideas contribution focuses on the clinical-to-technical mapping rather than presenting empirical validation, and it specifies a roadmap towards evaluating technical performance, system robustness, and clinical utility in future pilot studies.**

Keywords-component; IoT; RTW; Rehabilitation Analytics

I. Introduction

Rehabilitation professionals, such as occupational therapists and physiotherapists, rely heavily on rich, contextual observations of patients' everyday activities and participation to plan, adapt, and evaluate rehabilitation interventions. However, systematic observation in real-life environments (home, community, workplace) is time-consuming, intrusive, and often limited to short visits or self-reports, creating an information gap between what happens during clinical encounters and how patients actually function in daily life, including work.

Recent advances in Internet of Things (IoT) technologies and smart home sensing have enabled unobtrusive monitoring of activities of daily living (ADL) and behavioural routines in the home, particularly for older adults and people with chronic conditions [1]–[3]. For example, smart home platforms using distributed motion, contact, and environmental sensors have been used to identify daily routines and deviations in seniors living at home [1][2], and to infer ADL patterns that can support remote care and early detection of problems [3]. In parallel, IoT-based wearable and rehabilitation systems have been proposed to capture fine-grained movement data and vital signs during therapy or home-based exercises, enabling more personalized and continuous rehabilitation support [4][5]. Furthermore, similar wearables have been used to track symptoms, such as fatigue in the workplace [6]. Together, these developments demonstrate the potential of IoT to provide continuous, context-rich behavioural data that could inform clinical decision-making—yet most existing systems are not explicitly tailored to the information needs and workflows of rehabilitation professionals.

The RELATE project at Linköping University aims to bridge this gap by exploring how IoT technologies can unobtrusively capture meaningful aspects of patients' movements, behaviours, and activity patterns in naturalistic environments, such as their homes and workplaces, and present this information in clinically useful ways to rehabilitations staff. Rather than starting from available sensors or algorithms, RELATE begins from clinical questions: Which activities, behaviours, and environmental factors are most relevant for rehabilitation decisions? What types of changes do professionals want to detect over time? How should data be summarized and visualized to be actionable in practice? By grounding system design in RTW rehabilitation needs and then mapping these needs to IoT and AI capabilities, the project seeks to contribute to IoT–AI solutions for medicine and health care that move beyond generic activity tracking towards clinically grounded, domain-specific behavioural descriptions that support RTW rehabilitation assessment, planning, and follow-up.

.

II. Objectives

The goal of this early-stage work is to define a clinically meaningful, technically feasible specification for an IoT system that can characterize patients' everyday behaviour in ways that directly support assessment and rehabilitation planning. Specific objectives are:

- Identify and structure the movements, activities, behavioural patterns, and mobility impairments, that professionals consider crucial for RTW rehabilitation in selected patient groups.[7][8]
- Translate these clinical concepts into measurable IoT/AI descriptors, including candidate sensor modalities, contextual data, and analytic features.
- Develop a design of interfaces and visualizations that integrate behavioural data into existing assessment and follow-up routines for RTW.

- Map out a research agenda for iterative real-world testing and evaluation of such systems.

III. METHOD AND PLANNED APPROACH

The first concrete step is a structured workshop series with case-based discussions with practising rehabilitation professionals. The workshops will be designed to elicit:

- Clinical priorities: Participants will describe representative patient journeys and identify critical decision points where additional behavioural information would be valuable.
- Target behaviours and movements: Through scenario-based discussions, professionals will specify the types of movements, tasks, and behaviours they wish to monitor.
- Contextual factors: The workshop will explicitly address environmental, temporal, and social contexts that influence performance and are important for interpretation.
- Information needs and representations: Participants will sketch and comment on possible summaries and interaction modes that fit their workflow.

In the second step, the clinical requirements will be translated into technical design elements:

- Sensor mapping: For each behaviour and context dimension, candidate IoT components will be proposed.
- Data and feature specification: Possible derived features (e.g., step symmetry, sit-to-stand duration, variability in movement paths, frequency of near-falls, distribution of activities across the day) will be defined, with an emphasis on interpretability.
- Architecture sketch: A high-level system architecture will be outlined, covering local data acquisition, secure transmission, edge/cloud processing, and interfaces for therapists, while highlighting privacy and security mechanisms.
- AI components: Potential AI methods (e.g., supervised and semi-supervised activity recognition, pattern mining, anomaly detection, explainable models) will be identified, with explicit attention to transparency and the ability to incorporate therapist feedback.

Based on the outcomes of Steps 1 and 2, a prototype IoT system will be implemented and iteratively tested. The evaluation criteria will be based on the perceived benefit for the health care professional in their work.

IV. FUTURE PLANS

In the next stages of the RELATE project, we plan to:

- Refine and prioritize requirements across different patient groups and care settings, involving additional stakeholders, such as patients, informal caregivers, and other health professionals.
- Implement a first functional prototype focusing on a limited but clinically high-value set of behaviours, using off-the-shelf IoT components combined with tailored analytics.
- Conduct real-world pilot studies in collaboration with local healthcare providers, evaluating:
    - Technical performance (robustness, data completeness, reliability).
    - Clinical utility (impact on assessment quality, intervention tailoring, and follow-up decisions).
    - Human factors (acceptability, perceived intrusiveness, workload, trust, and interpretability).
- Explore adaptive and personalized models, where AI components can be adjusted based on staff feedback and patient-specific patterns, while maintaining transparency and control.
- Deepen evaluation of ethical and legal considerations.

We will work actively and continuously with ethical considerations, with particular focus on how our choice and combination of sensors may introduce new ethical dilemmas. Each proposed technical solution will therefore be evaluated not only in terms of performance, but also with regard to privacy, autonomy, data justice, and potential misuse or unintended consequences for different user groups.

ACKNOWLEDGMENT

This work was/is conducted within the RELATE Research Centre at Linköping University, focusing on sustainable working life and return to work, funded by the Swedish Research Council for Health, Working Life and Welfare (FORTE), grant no. 2025-02059

REFERENCES

[1] V. R. Chifu, et al., ”Identifying and Monitoring the Daily Routine of Seniors Living at Home”, Sensors, vol. 22, no. 3, pp 992-1012, 2022.

[2] Q. Zhang and M. Karunanithi, ”Assessment of Activities of Daily Living via a Smart Home Environment”, in *Quantifying Quality of Life*, ISBN 978-3-030-94211-3, Springer, 2022, pp. 483–500.

[3] K. Maswadi, N. B. A. Ghani, and S. B. Hamid, ”Systematic Literature Review of Smart Home Monitoring Technologies Based on IoT for the Elderly”, *IEEE Access*, 2020.

[4] H. Dhiman and R. Kumar, ”An Internet of Things-Enabled Smart Glove for Brain Stroke Rehabilitation”, *Measurement: Digitalization, Vol 1*, 2025.

[5] Y. Moghbelan, et al., ”A Smart Motor Rehabilitation System Based on the Internet of Things and Humanoid Robotics”, *Applied Sciences*, vol. 14, no. 24, 11489, 2024.

[6] M. Moshawrab, et al., ”SmartWearables for the Detection of Occupational Physical Fatigue: A Literature Review”, Sensors 2022, 22, 7472. https://doi.org/10.3390/s22197472

[7] F. Rast and R. Labruyère, J NeuroEngineering Rehabil (2020) 17:148, https://doi.org/10.1186/s12984-020-00779-y

[8] B.H. Dobkin, Neurorehabilitation and Neural Repair 2017, Vol. 31(3) 217– 227, DOI: 10.1177/1545968316680490