Development and validation of a system to quantify dexterity in patients with neurological disorders

Pim Bouwmeester

Supervisor(s): Prof. Dr. Tobias Nef, Prof. Dr. phil. Tim Vanbellingen, MSc Kevin Möri, MSc Nic Krummernacher
Institution(s): University of Bern, ARTORG Center for Biomedical Engineering Research
Examiners: Prof. Dr. Tobias Nef, Prof. Dr. phil. Tim Vanbellingen

Introduction

Neurological disorders such as multiple sclerosis, Parkinson's disease and stroke, are increasingly prevalent in the aging population and may cause impairments to finger and hand dexterity [1]. This can impact the activities of daily living (ADL) such as cooking, buttoning a shirt or handwriting. The current practice in neurorehabilitation for finger and hand dexterity covers a wide variety of approaches and despite being innovative, they often lack precision and the accessibility needed for effective home-based telerehabilitation.

The Smart Sensor Egg (SSE) system, developed by the ARTORG Center Gerontechnology and Rehabilitation Group in Bern, Switzerland, addresses this gap by providing a system designed to train finger and hand dexterity. This thesis aims to advance the SSE system by developing and evaluating targeted dexterity assessments that are integrated into the system. The goal is to enable precise and remote monitoring of patient progress, improving both the effectiveness and accessibility of rehabilitation interventions.

Materials and Methods

The project involved three key phases: The development and integration of an SSE software extension to monitor movement assessments, the establishment of a motion tracking pipeline, and the conducting of a validation study. The SSE system was enhanced with new assessment modules developed in Unity, focusing on finger dexterity, pressure control and wrist movements. Motion tracking using a marker-based system was implemented to provide a ground truth for the SSE measurements. To evaluate user performance over time, data from the assessments was collected and analysed using Python scripts.

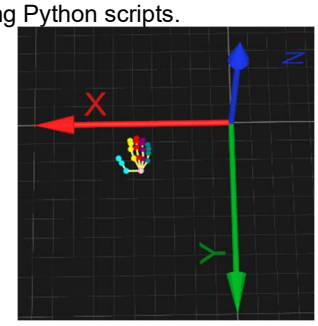

Fig. 1 Labeled Hand Model after recording exercises with marker-based motion tracking to provide the ground truth for the SSE assessments.

Results

Several assessments for the SSE system were developed and integrated. The study demonstrated improvements in participants dexterity, responsiveness and speed over the assessment period, alongside overall positive trends in motor performance metrics. The analysis also highlighted a correlation between assessment metrics data and actual performance outcomes, showing the effectiveness of the system for monitoring the performance of users.

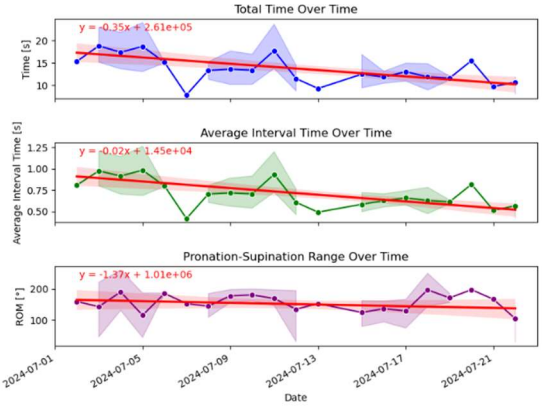

Fig. 2 SSE Assessment part 3 results with trendline

Discussion

The findings validate the ability of the SSE system to accurately capture performance of fine motor skills, thereby supporting its potential as a valuable tool for remote rehabilitation. Despite limitations, including the prototype status of the SSE and the use of a healthy participant group, the positive results reinforce the suitability of the SSE system for to enhance telerehabilitation practices.

References

[1] *Lima, A. A., Mridha, M. F., Das, S. C., Kabir, M. M., Islam, M. R., Watanobe, Y. A Comprehensive Survey on the Detection, Classification, and Challenges of Neurological Disorders, Biology 11(3): 469, 2022.*

Acknowledgements

Many thanks to my supervisors Prof. Dr. Tobias Nef, Prof. Dr. phil. Tim Vanbellingen, Kevin Möri, and Nic Krummenacher for their guidance and dedicated support. Further thanks to all members of the Gerontechnology and Rehabilitation research group for their contributions and valuable support