Lifestyle evaluation using wearable technologies: opportunities for stroke patients

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Abstract— **Stroke is the leading cause of disabilities in the western world and may cause severe motor impairments. In the current clinical practice, progress during physical rehabilitation is assessed by a therapist for specific motor functions and through questionnaires that address patient's general well-being or lifestyle. However, this approach is not only prone to subjectivity due to both the patient and the rater during the assessment, but it is also non-continuous and coarse-grained, since it can only be administered every few months. In this paper, the concept of a complementary solution based on wearable technologies is proposed, and the remaining challenges to provide an objective, fine-grained and long-term evaluation of patient's lifestyle through physical activity monitoring are highlighted.**

I. Introduction

STROKE results from a shortage of blood supply in certain area of the brain due to a blockage or a hemorrhage. The consequences in terms of disabilities vary widely depending on the size of the affected brain regions, but the main problem is the limitation of motor functions and mobility [1]. To evaluate the recovery of patients after stroke, clinicians have developed assessment tools, referred to as Quality-of-Life (QoL) clinical scales (CS), assessing the general well-being, and Motor Function Tests (MFTs) for quantifying patient's motor functional impairment. A QoL test consists of a questionnaire and is therefore subject to the interviewer's perception, and the patient's interpretation and state-of-mind during the assessment, and may lead to discrepancies [2] between the self-reported and the interview-based assessment.

During a MFT, the patient performs a series of motor tasks and is graded by the rater with respect to his/her performance. The evolution of the score is used to assess the patient's recovery. Each test often targets one specific area of motor function: posture and balance, upper-limbs, or gait. As for the QoL CS, they suffer from the subjectivity of the rater (due to the grading system). Moreover, they are prone to floor and ceiling effects, i.e., they are unable to discriminate changes in motor capacity before or after a certain level of motor capacity. Furthermore, MFTs can only be performed in clinics and are not necessarily representative of the patient's activity in daily life.

To overcome these limitations of current assessment tools, the first attempt to provide objective outcome parameters was to use a motion capture system in laboratory conditions. However, such motion capture system still did not allow for obtaining the required parameters in ambulatory conditions.

Lifestyle evaluation, on the other hand, provides a multi-parametric overview of motor functions and physical activity in the patient's daily environment. Recent advances in electronics have enabled monitoring of physical activity in daily life using wearable/body-fixed inertial devices. The collection of long-term body movement data in subjects with different clinical conditions allowed to develop new methodological analyses and quantify various features of physical activity behavior [3].

The aim of this paper is to: (1) describe the opportunities offered by lifestyle evaluation using wearable technology in the context of objective clinical assessment and personalized feedback therapies for stroke patients; (2) discuss technical and clinical challenges to be addressed in REWIRE project.

II. Lifestyle evaluation: opportunities

A. *Day-to-day lifestyle assessment*

In the context of REWIRE project the lifestyle concept will be assessed from a set of metrics quantifying movement quantity and quality, daily routine, outdoor activity, etc. [3]. Unlike clinical assessments (such as MFTs) performed at specific time (e.g., once a month, or 1, 3, and 6 months after the stroke), ambulatory lifestyle assessment provides a continuous overview of patient's physical status in daily-life environment. It can therefore not only be used by the therapist to better assess and understand the transfer of current rehabilitation strategy into patient's daily-life environment and adjust the strategy accordingly, but also by hospital officials to compare different therapies on a large cohort of patients.

B. *Lifestyle feedback to therapy-planning engine*

The REWIRE project, funded by the European Union under the FP7, aims at providing a virtual-reality (VR)-based home rehabilitation tool for patients already discharged from the hospital. Although the REWIRE rehabilitation platform allows patients to remain connected to their initial center of care for remote therapy planning and performance assessment, such a home therapy introduces several challenges due to the limited supervision during training. For this purpose, a lifestyle evaluation module will be designed in order to deliver a feedback to the therapy planning engine. This will enable an automatic, fine-grained adaptation of the rehabilitation exercises, based upon the patient's physiological and physical functioning metrics.

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C. Exploring the threshold theory in stroke rehabilitation

In stroke rehabilitation, the emerging threshold theory described in [4] is based on the fact that patient's recovery (evolution) depends on whether or not he/she manages to cross a motor function threshold. It assumes that the patient would start using the paretic limb for daily activities, when the impaired limb reaches a certain degree/threshold of mobility. A more frequent activation of the impaired motor cortex area would therefore induce a faster recovery of the paretic limb and enable the patient to keep and even further increase his/her mobility even after the end of the therapy. However, if such a threshold is not achieved during the rehabilitation therapy, patients would be likely not to use the paretic limb during daily activities and a decrease of mobility of the impaired limb would be noticed. As lifestyle evaluation provides a continuous overview of patient's physical status, it can serve as an input to dedicated machine learning algorithms which might help in estimating this mobility threshold.

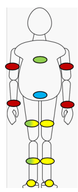

Fig. 1. A typical sensor setup for measuring lifestyle parameters in ambulatory conditions: upper limb [5] (red), posture [3] (green and yel/green), balance[6] (blue), and gait [7] (yellow and yel/green)

III. Lifestyle evaluation: remaining challenges

A. System-level comfort

The comfort of the wearable system perceived by the patient is critical when evaluating lifestyle as comfort-related issues can not only reduce the compliance of the patient with respect to the system, but also hinder the patient during daily activities. Wearable systems impose an important compromise between complexity of the sensor configuration and accuracy of the measurements. In this case, the complexity is related to the number of wearable devices carried by the patient and has therefore an impact on the comfort of the system. For instance, algorithms required for assessing physical activity using wearable sensor networks often require multiple sensor devices located on different body limbs [3], at positions that could be uncomfortable when the sensor is fixed with band straps. Single sensor solutions for monitoring physical activity do exist [8], but suffer from a lack of high accuracy.

Due to the complexity of the sensor setup, as described in Figure 1, current monitoring systems have only addressed one specific area of the motor function. Reducing the size of current wearable devices, refining the important lifestyle parameters for an adequate sensor configuration, and working at the algorithm level to extract robust parameters with a minimal sensor configuration are key issues to improve the system-level comfort.

B. Selection of lifestyle features

A strong hypothesis is that patient's recovery after stroke is mirrored in his motor function abilities and physical activity. However, cognitive problems or depression might also affect the physical-related outcome parameters [9]. A careful selection of those parameters will be required to propose relevant parameters to clinicians. Moreover, environmental parameters (e.g., weather forecast, temperature) shall be accounted for during the analysis as they may influence the patient's daily-life activity.

IV. Conclusion

In this paper, an overview of the concept of ambulatory lifestyle evaluation is presented and its relevance as an objective rehabilitation assessment tool for clinical practice is shown. It can serve as a feedback to either a therapist for regularly assessing the rehabilitation strategy, or a therapy-planning engine in the context of the REWIRE project for adjusting the therapy plan according to the patient's physical state prior starting a therapy session; it might also be a valuable asset for validating the threshold theory in stroke rehabilitation.

Moreover, current challenges for achieving lifestyle evaluation are highlighted and discussed. As any discomfort related to the wearable system might hinder patient's daily life, the system wearability plays an important role in assessing lifestyle accurately. As for any long-term monitoring system, algorithms for extracting robust features against sensor placement shall be primarily investigated.

By enabling a fine-grained understanding about how physical therapy strategies are effectively transferred to patient's home environment, lifestyle evaluation opens new perspectives in physical rehabilitation medicine.

References

[1] L. S. Williams, *et al.*, "Development of a Stroke-Specific Quality of Life Scale," *Stroke,* vol. 30, no. 7, pp. 1362-1369, July 1, 1999.

[2] A. Bengtsson-Tops, L. Hansson, *et al.*, "Subjective versus Interviewer Assessment of Global Quality of Life among Persons with Schizophrenia Living in the Community: A Nordic Multicentre Study," *Quality of Life Research,* vol. 14, no. 1, 2005.

[3] A. Paraschiv-Ionescu, *et al.*, "Barcoding Human Physical Activity to Assess Chronic Pain Conditions," *PLoS ONE,* vol. 7, no. 2 , 2012.

[4] N. Schweighofer, C. E. Han, *et al.*, "A Functional Threshold for Long-Term Use of Hand and Arm Function Can Be Determined: Predictions From a Computational Model and Supporting Data From the Extremity Constraint-Induced Therapy Evaluation (EXCITE) Trial," *Physical Therapy,* vol. 89, no. 12, Dec 1, 2009.

[5] M. de Niet, J. B. Bussmann, *et al.*, "The stroke upper-limb activity monitor: its sensitivity to measure hemiplegic upper-limb activity during daily life," *Arch Phys Med Rehabil,* vol. 88, no. 9, Sep, 2007.

[6] L. Palmerini, L. Rocchi, *et al.*, "Feature Selection for Accelerometer-Based Posture Analysis in Parkinson's Disease," *IEEE Trans. on IT in Biomedicine,* vol. 15, no. 3, May, 2011.

[7] B. Mariani, *et al.*, "3D gait assessment in young and elderly subjects using foot-worn inertial sensors," *J Biomech,* vol. 43, no. 15, 2010.

[8] R. Ganea, A. Paraschiv-Ionescu, and K. Aminian, "Detection and classification of postural transitions in real-world conditions," *IEEE Trans Neural Syst Rehabil Eng,* Jun, 2012.

[9] P. L. Morris, B. Raphael, *et al*, "Clinical depression is associated with impaired recovery from stroke," *The Medical journal of Australia,* vol. 157, no. 4, pp. 239-242, 1992.