Wearable Patient and Health Worker Monitoring: Opportunities for Improved Outcomes and Open Source Sensing

T. COLLINS [a], S. WOOLLEY [b], D. INFANTE SANCHEZ [c], P. PEMBERTON [d], T. VEENITH [d], D. HUME [d], K. LAVER [d], C. SMALL [d], L. LAPÃO [e]
[a] *Manchester Metropolitan University, UK;* [b] *University of Keele, UK*
[c] *University of Birmingham, UK;* [d] *University Hospitals Birmingham, UK,*
[e] *Universidade Nova de Lisboa, Portugal*

1. Introduction

Wearable multi-modal monitoring systems, capable of robust real-world recording during the activities of daily life, have the potential to provide rich objective experiential and well-being accounts. Sensing systems have wide clinical application in rehabilitation, pre- and post-surgical assessment, monitoring of the acute medical patient [1] and management of chronic conditions [2] [3], among others. They also provide new opportunities for insights into the workplace activities, processes and stressors of clinical staff and health workers [4] [5]. In prior work [6] of The Quantified Outpatient Project (http://quantifiedoutpatient.com), a prototype 24-hour wearable and ambient monitoring system was developed, and opportunities and challenges identified. A new and evolved "Sense247" design is now presented that addresses data and usability challenges identified in interview feedback and participant assessments. The underpinning vision is for a generic and expandable "core" sensing system to provide objective sensed recordings that supplement, not supplant, subjective reports. To this end, continuously-sensed physiological, environmental and actigraphy recordings are combined with quantified subjective reports.

2. Method

A clinical prototyping methodology, with clinician and healthy user participation, was employed to evolve the new Sense247 design. It employs digital sensors for on-body day/night measurement of pulse rate, actigraphy, body temperature, and night-time ambient light and temperature; and analogue sensors for day/night electro-dermal activity and night-time ambient sound level. Importantly, unlike many commercial monitors, the system provides continuous, high-precision Metabolic Equivalent Task (MET) monitoring down to sedentary levels. For ease of deployment [7], the original prototype was designed for continuous 72-hr operation. Sense247 is enhanced with USB rechargeable Lithium-Polymer batteries and Feather Cortex-M0 Adalogger data loggers with built-in charging circuitry and micro-SD data storage. Additional circuitry detects critical battery levels and automatically closes files to prevent SD card corruptions. The

design maintains the original use of continuous recordings to generate averages, minima and maxima at 1-min, 15-min, 1-hr and 4-hr intervals for physiological, environmental and actigraphy recordings. These are combined with quantified subjective user reports for data mining and visual analytics.

3. Results

Assessments of system features and wearability, together with feedback from users and clinicians, informed improvements to the Sense247 design, including the repositioning of pulse and actigraphy sensors. The new data loggers have enhanced data integrity and are half the size of the original units, making them smaller and lighter than a typical smartphone. The improvements benefit wearability, usability and system performance outcomes.

4. Discussion

In addition to further use and testing, future research will focus on robust and compliant information security and clinical hygiene, and open source delivery.

5. Conclusion

Whilst there are challenges in achieving robust, secure, ambulatory, multi-modal recordings from user-applied, hygienically-compliant systems, these challenges are not insurmountable, and the potential benefits are considerable, both in terms of improved insights and improved outcomes.

References

[1] R.S Weller, K.L. Foard and T.N. Harwood, Evaluation of a Wireless, Portable, Wearable Multi-Parameter Vital Signs Monitor in Hospitalized Neurological and Neurosurgical Patients, *Journal of Clinical Monitoring and Computing*, (2017), 1-7.

[2] L. Hernandez-Munoz. and S.I. Woolley, A User-centered Mobile Health Device to Manage Life-Threatening Anaphylactic Allergies and Provide Support in Allergic Reactions, *IEEE Information Technology and Applications in Biomedicine*, (2009), 1-4.

[3] L. Hernandez-Munoz, S.Woolley, D. Luyt, G. Stiefel, K. Kirk, N. Makwana, C.Melchoir, T. Collins, T. Dawson, G. Wong. and L. Diwakar, Evaluation of AllergiSense Smartphone Tools for Adrenaline Injection Training, *IEEE Journal of Biomedical and Health Informatics*, **21(1)** (2017), 272-282.

[4] L.V Lapão and G. Dussault, The Contribution of eHealth and mHealth to Improving the Performance of the Health Workforce: A Review, *WHO Public Health Panorama*, (2017), 463-471.

[5] R. Marques, J. Gregório, F. Pinheiro, P. Póvoa,, M. Mira da Silva. and L. V. Lapão, How Can Information Systems Provide Support to Nurses' Hand Hygiene Performance? Using Gamification and Indoor Location to Improve Hand Hygiene Awareness and Reduce Hospital Infections, *BMC Medical Informatics and Decision Making*, **17**:15 (2017).

[6] D. Infante Sanchez, S. Woolley, T. Collins, P. Pemberton, T Veenith, D. Hume, K. Laver and C. Small The Quantified Outpatient - Challenges and Opportunities in 24hr Patient Monitoring, *Informatics for Health*, **24(1)** (2017), 163-4.

[7] T. Collins, S. Aldred, S. I. Woolley and S. Rai, Addressing the Deployment Challenges of Health Monitoring Devices for a Dementia Study, *Wireless Mobile Comm. and Healthcare*, (2015), 202-205.