The Quantified Outpatient
Challenges and Opportunities in 24hr Patient Monitoring

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Introduction

Patient monitoring systems capable of accurate recording in the real-world, during activities of everyday living, can provide rich objective accounts of patient well-being that have broad application in clinical decision support. **Combining physiological, environmental and actigraphy sensing together with a quantified subjective patient report and activity log**, provides **new opportunities and new challenges in big data analysis, data mining and visual analytics**.

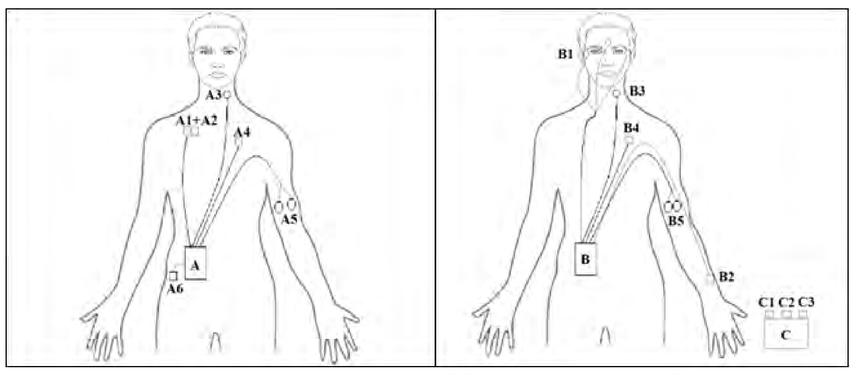
Method

An iterative prototyping approach together with clinical collaboration informed the design and development of a novel **24hr sensing system with broad application relevant to sleep assessment**. The system design, sensor selection and visual analytic strategies were informed by literature review and pilot studies with i) clinical staff and ii) healthy participants.

The sensing system comprised:

- **Daytime wearable sensing unit**: on-body accelerometry for Metabolic Equivalent Task, pulse, skin temperature and resistivity
- **Night-time sensing units**: on-body unit as per daytime but with wrist accelerometry, and bedside unit for ambient light, temperature and sound-level

Continuous recordings were used to generate averages, minima and maxima in 1-minute, 15-minute, 1-hour and 4-hour intervals. For data mining and visual analytics, these records were combined with quantified accounts of subjective user reports and activity logs. Ten subjects (including three clinicians) tested the system for up to three consecutive days and nights and provided assessments of use and comfortability. Five clinicians were interviewed regarding system applications, barriers to use, data use and visual analytics.



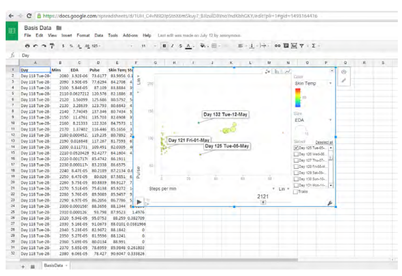
A. On-body waking hours unit
A1. Ambient temperature
A2. Ambient light
A3. Pulse
A4. Body temperature
A5. Galvanic skin response
A6. Accelerometer

B. On-body sleeping unit
B1. EOG
B2. Accelerometer
B3. Pulse
B4. Body temperature
B5. Galvanic skin response

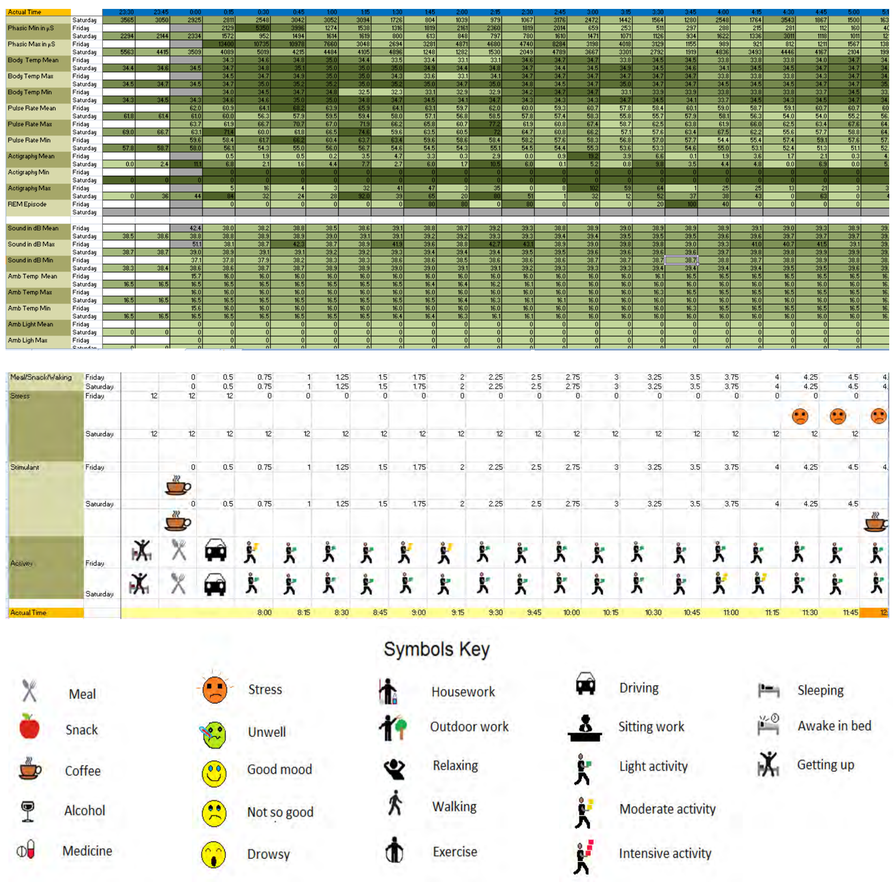
C. Ambient sleeping unit
C1. Ambient temperature
C2. Ambient light
C3. Ambient sound level

CircadianSense Prototype

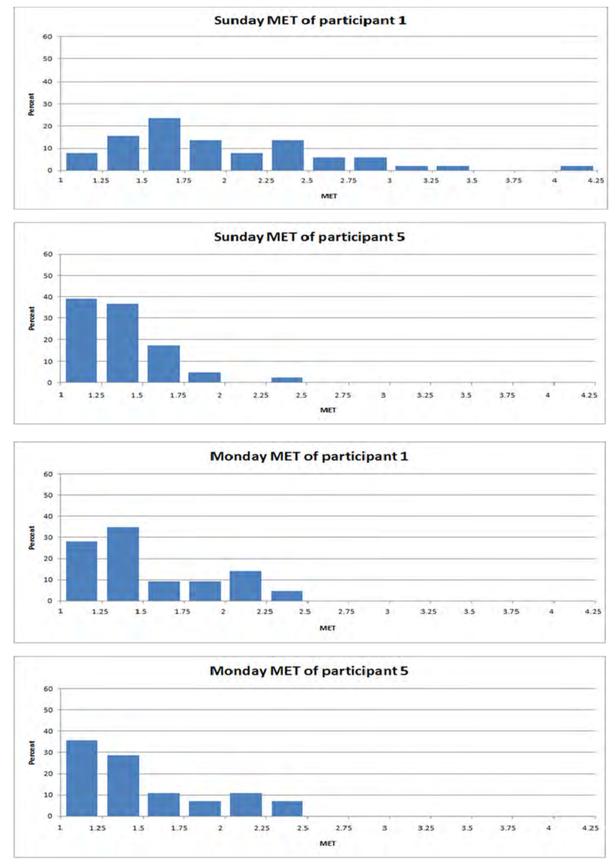
CircadianSense Prototype: Pilot Testing



CircadianSense Motion Chart Example



CircadianSense Heat Map and Activity Visualizations



CircadianSense Examples of Daily Metabolic Equivalent Task Summaries

Results

Data acquisition was successful across a wide range of MET levels. System comfortability was good but with some discomfort and skin irritation arising from prolonged use of a carotid pulse sensor (selected for its robust performance compared with wristband alternatives). Electrooculography sensing for REM sleep detection was attempted but was uncomfortable and performance was unsatisfactory. Usability of the system benefitted from prolonged battery operation. Few data losses resulted from user-administration of sensors, but more resulted from a lack of prototype ruggedisation. Attempts at intuitive multivariate data visualizations, including heat maps, motion charts and clustered views, had limited success. However, the system and approach was assessed as very good for real-life application and decision support.

Discussion

24hr outpatient sensing has wide clinical application in rehabilitation, in the management of chronic conditions and, in pre- and post-surgical assessment. However, better detection of both low level activity and sleep is required than currently available in commercial activity monitoring devices.

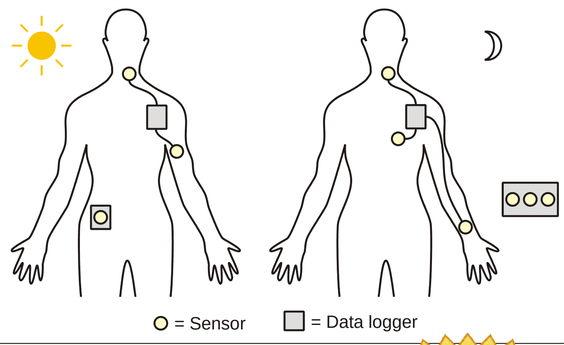
Conclusions

Multi-modal outpatient monitoring can perform robustly and with acceptable comfortability across a spectrum of activity types and levels, however, system robustness and ease-of-use are paramount to reliability, and users' self-application of sensors requires careful attention.

The new big un-delineated, multi-modal, multi-dimensional, data spaces created are unfamiliar, uncharted territories that require new understandings, guidance and training. Data mining and visual analytics provide new research insights but there are many challenges regarding their translation into clinical practice.

Further Work

PatientSense is a new 24hr patient monitoring prototype design evolving from the CircadianSense prototype and from participatory design inputs from community physicians.



Related Publications

Hernandez-Munoz, L.U., Woolley, S.I., Luyt, D., Stiefel, G., Kirk, K., Makwana, N., Melchior, C., Dawson, T.C., Wong, G., Collins, T. and Diwakar, L., 2017. Evaluation of AllergiSense Smartphone tools for Adrenaline Injection Training. IEEE Journal of Biomedical and Health Informatics, 21(1), pp.272-282.

Collins, T., Aldred, S., Woolley, S. and Rai, S., 2015. Addressing the Deployment Challenges of Health Monitoring Devices for a Dementia Study. In Proceedings of the 5th EAI International Conference on Wireless Mobile Communication and Healthcare, pp. 202-205.

Hernandez-Munoz, L., Woolley, S. and Diwakar, L., 2015. Pilot evaluation of smartphone technology for adrenaline injection training. Clinical and Experimental Allergy, 45(2), pp.507-507.

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