Continuous mobility monitoring: what is currently missing for a widespread deployment in clinical and research settings?

T. Bonci[a1], A. Keogh[b], S. Del Din[c], K. Scott[a], and C. Mazzà[a]

[a] *Department of Mechanical Engineering & INSIGNEO Institute for in silico Medicine, The University of Sheffield, Sheffield, UK;* [b] *School of Public Health, Physiotherapy and Sports Science, University College Dublin;* [c] *Translational and Clinical Research Institute, Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, UK*

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1. Introduction

Mobility has been recognised as "the sixth vital sign" and its study and quantification usually occur in laboratory or clinical settings. However, it has been shown that free-living gait characteristics have better discriminative validity, especially in diseases characterised by specific mobility dysfunctions as in Parkinson's Disease [1]. Continuous mobility monitoring could indeed detect, measure, and eventually predict mobility loss for providing essential information for personalized treatment. Therefore, a low-cost, easy-to-use and accurate approach that uses a technology that can operate in "real-world" scenario is mandatory for this aim; wearable inertial sensors are certainly ideal candidates.
However, their widespread deployment in clinical and research settings can be influenced by a number of factors that might be grouped in four different categories, hereafter called "domains":

- Concurrent validity – factors related to the validity of the measurements;
- Human factors – factors related to the context of data capture, perception of the user towards the technology, data security and privacy, effect of monitoring outside clinical settings;
- Wearability & usability for the user – e.g., size, location, fixation modality, charging frequency;
- Data capture process – e.g., whether a calibration procedure, device programming, or anthropometric information are required for an appropriate data capture.

Although different solutions have been proposed in the literature, when these have been tested and/or compared, such domains were either considered in isolation [2]-[3] or only in a subset [4]-[5]. This poses serious limitations when a specific wearable solution has to selected for a prolonged time and all these domains should be considered, accounting for their relative importance, which has to be yet established. The aim of this study is to define an objective methodology for combining these domains, allowing optimal sensor choice for continuous mobility monitoring. A decision matrix is proposed to establish the relevant importance of different domains and subsequently rank different sensor solutions. A purposely developed questionnaire is used to define such matrix using responses gathered by selected participants with a variety of backgrounds.

2. Methods

A decision matrix is made of three components, as proposed in established design processes [6]: the elements to evaluate (i.e., domains/criteria), their relevance and the relevant scoring system.
Firstly, the four domains and relevant criteria were identified through literature research. Secondly, their relevance was established collecting the perceived level of importance using a 1-5 Likert scale (1 = unimportant; 5 = very important). Respondents' background and experience on the use of inertial sensors in clinical practice was alongside captured. For each domain (j_d) and criterion ($j_{d,c}$), the overall weights were obtained considering the modal value of the responses, accounting for the relevant Respondent' level of expertise. Weights were then normalised as [6]:

$$\sum_{j=1}^{N} w_j = 1 \qquad (1)$$

where j was either j_d or $j_{d,c}$.
Thirdly, a scoring system was specified. Since the overall score E_i for each solution i was obtained as

$$E_i = \sum_{d=1}^{4} e_{ij_d} * w_{j_d} \qquad (2),$$

the scores were differently normalised for benefit and cost criteria as described in [3].

3. Results and discussion

Preliminary results from 50 Respondents are shown in Table 1. Overall, 72% of them had experience on the use of inertial sensors (*i*) in clinical settings, (*ii*) on patients, (*iii*) for identifying/ extracting gait features, and (*iv*) for characterising patients' mobility, and therefore classified with an excellent level of expertise (Figure 1).

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[1] Corresponding author. Email: t.bonci@sheffield.ac.uk

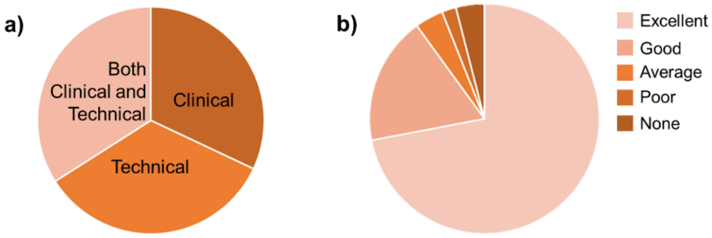

Figure 1 – a) Background of the respondents (n = 50); **b)** Respondents' level of experise on the use of inertial sensors in clinical settings as assessed through the purposely developed questionnaire.

	Domains	**Concurrent Validity**	**Human Factors**	**Wearability & Usability**	**Data Capture Process**
Level of importance	**very important**	**70% [69.3%]**	40% [38.6%]	**52% [52.2%]**	34% [32.4%]
	important	22% [22.7%]	**42% [42.1%]**	40% [39.2%]	**36% [36.9%]**
	somewhat important	6% [6.2%]	14% [15.3%]	8% [8.5%]	20% [20.4%]
	of little importance	–	4% [3.9%]	–	10% [10.2%]
	unimportant	–	–	–	–
Normalised Level of importance		**38.3%**	**17.4%**	**29.0%**	**15.3%**

Table 1 – Distribution of the responses (n = 50) of the different levels of importance for the four domains. Responses adjusted by the *Respondents*' level of expertise are provided within squared brackets. The normalised levels of importance of the different domains are also shown.

Both concurrent validity and wearability & usability domains are perceived as "very important" for a seven-day mobility monitoring solution. The other two domains, instead, have been classified as "important". Although the concurrent validity domain is usually the one considered as being the most important (37.5%), and the one usually considered in studies reported in the literature [2]-[5], the other domains, especially wearability & usability (28.3%), also seem to play an important role for the identification of the best wearable solution for a 7-day mobility monitoring assessment. It is therefore evident that all the above-mentioned domains, and their relevant criteria, should be considered when such comparison exercises are performed while aiming to a widespread deployment of this wearable technology.

4. Conclusions

A methodology, which does not simply rely on the knowledge and expertise of a single decision-maker [3], for an objective ranking of different wearable solutions aimed at continuous mobility monitoring has been proposed. This approach appears therefore to be easy to use in selecting the best wearable technology. Data collection is still ongoing and further analysis have to be conducted before stronger conclusions could be made.

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6. References

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