Examining usage to ensure utility: Co-design of a tool for fall prevention

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Ambient Assisted Living (AAL) technologies can play an important role in helping elderly people achieve healthy ageing and maintain their autonomy. The balance quality tester (BQT) is a device for remote assessment of balance quality for older people at risk of falling. It has been validated both from a technical and a clinical perspective. However, for the BQT to be considered as a useful tool for long-term home monitoring of people with balance impairments, two issues are at stake: ease-of-use on a regular basis and trust in the validity of the data acquisition. To ensure this utility, a usage study has been made to understand the needs and values of different stakeholders: elders at risk of falling and their entourage, as well as health professionals. One main insight was the need to redesign the BQT, so as to fit the needs concerning ease-of-use and trust in validity of data acquisition. Using a Human-centred and Participatory Design approach, the redesigning work relates to hardware design, interaction design, interface design, and most of all to standardizing the protocol of stepping-on the BQT. This paper describes the results, i.e. the design recommendations, and discusses the collaborative and iterative design process, which allowed the successful redesign of the BQT.

Keywords: Balance quality tester, Fall prevention, Interdisciplinarity, Co-design, Needs analysis, Utility, Domestication

I. Introduction

According to the UN estimation, by 2050, one out of every five people will be over 60 years old. The ageing population therefore represents a demographic challenge, questioning new and innovative models to help elderly people achieve healthy ageing and maintain their autonomy. People live longer, but with an increased risk of diseases or of developing disability, due to a decrease in physical functioning. Linked to physical decline, one of the major healthcare problems associated with ageing is that of falls. The number of fallers each year has been estimated at 30% for people aged over 65 years, rising to 50% for those aged over 80 years [1], [2]. Falls constitute a major cause of death among older people. In addition to the medical aspect of falls, there is also a considerable societal impact due to the increased vulnerability of the faller and the difficulties for their entourage [3].

Part of the solution to this large-scale problem is prevention. The key issue is the possibility of detecting those at most risk of falling in order to be able to perform a targeted intervention [4]. Innovative technologies can play an important role in remote monitoring and early identification of elderly people who suffer from functional decline [5]. Thus, an adapted prevention or rehabilitation program could be put in place, with progress followed over time [6]. A screening tool that could detect elderlies with risk factors for falls could therefore be useful. Indeed, the early detection of gait impairment for estimating falls risk is the first step to reduce falling rates among older populations. This detection leads to the implementation of proper interventions that can engage behavioral changes, environmental modifications, and better health management.

Currently, detection and falls risk estimation is made through measurements of balance quality, routinely made as part of clinical evaluation of balance: The Berg Balance Scale [7], the Timed up and go test [8], the Tinetti test [9], are the three most currently used tests in the rehabilitation centre, partner of this research study. Laboratory-based measures of balance, e.g. with the Satel force plate, are made complementarily to the clinical evaluation. Physiotherapists explain that coupling these two types of evaluation allows to confirm their diagnosis, completing their visual analysis with objective measures.

However, the major drawback of these measurements of balance is cost. Therefore, these evaluations prove inadequate to be implemented as part of long-term evaluation program or a large-scale prevention protocol. Any evaluation tool needs to be easy to use (non-professional users), socially acceptable (community dwelling elderly) and relevant with respect to well-established clinical tests [6].

II. Proposed solution for falls risk identification

A. *Balance Quality Tester*

Based on the observation of the restrictions of the existing evaluations described above, the Balance Quality Tester (BQT) appears as a promising solution for early detection of falls risks. First, the cost would make it accessible: it was developed as a low-cost balance assessment tool based on a commercial bathroom scale (estimated cost of around €50 per device) [10]. It looks like a bathroom scale which measures weight, and is therefore an ordinary practical device, but it also measures balance like a force plate. The BQT calculates four parameters of balance, that are then scored (over 16) and weighted, thus creating an overall indicator of balance quality. A BQT empirical score of less than seven can detect fall risk in a community dwelling population. In terms of data collection and processing, after the weighing process is completed, the data are transferred from the BQT device to a local receiver (mobile phone, tablet or PC), which in turn sends the data to a remote server for storage. A prototype application – initially targeting healthcare professionals – enables to visualize the score.

1) Previous work

Previous research from our colleagues have examined: i) the relationship between frailty indicators and balance assessment [11], ii) the technical validity of the BQT (see [10] for details), iii) the accuracy of calculation of balance from a clinical perspective (see [12] for details), iv) the usability and acceptability of the BQT during a longitudinal pilot study [13].

III. Present study

A. Utility: Perceived and Actual

The insights that needed to be examined at that stage were: what more (other than technical and clinical validity) is needed for the BQT to succeed in being a useful tool for large-scale prevention of falls? Like for other AAL products, in order for older adults to voluntarily adopt a technology, the benefits of use of a product/service must be made clear [14]. This perception of a device as being useful will ensure that it is adopted and actually used. It is only at this condition, i.e. that older adults at risk of falling *use* the BQT on a *regular basis* for long-term home-monitoring, that the BQT will play an important role as part of an adapted prevention or rehabilitation program. Therefore, the first level of Utility – of the device as perceived by users – impacts the second level of Utility – to be considered at a global level of falls prevention for autonomy. Thus, where to start this virtuous circle?

1) Research questions

For this utility to be clearly perceived by the end-users, two issues empirically emerged from the needs analysis as being important for stakeholders: ease-of-use on a regular basis and trust in the validity of the data acquisition.

Thus, the main research questions which guided this study:

1) To what extent usability of the device and application supports the everyday ease-of-use?
2) How to ensure trust in the validity of the data acquisition?

2) Methodological approach

A usage study has been made to think further the issues of utility, and linked to it, the issues, of: usability and identification of target users, based on understanding of needs and professional practices. The first step was an analysis of existing practices and tools, so as to understand the needs and values of different stakeholders: elders at risk of falling and their entourage, as well as health professionals. One main insight identified from the needs analysis was the need to redesign the BQT, in order for it to fit the needs concerning ease-of-use and validity of data acquisition. Informed by these empirical insights, the redesigning work that has been done relates to: hardware design, interface design, interaction design, and most of all to standardizing the protocol of stepping-on the BQT. The approach to research and design is Human-centered, Participatory and Iterative. From the needs analysis to the validation of the new design proposals, participants – whether seniors (part of the community *Amis du Living Lab*) or health professionals. The seniors have participated in the user tests (5 in all) of the intermediary design. They evaluated the different aspects – hardware, interface, interaction, stepping-on protocole and use scenario – on a Lickert scale of 5. The results are generally very positive (cf. Section C 2 *infra* for a succinct presentation, and more results in the detailed version of the paper, *forthcoming*). All users find the new test protocole simple (4 users give a rating of 5/5 and 1 rates 4/5) and find that follow-up of their balance quality would be useful (3 users: 5/5; 1 user :4/5; 1 user :2/5). All the users' feedback (positive and critical) allowed to improve the design during a second iteration. After these improvements, these new design proposals were submitted to the 3 health professionals (among whom the second author of this paper) for validation of the design ideas that they had proposed during the needs analysis phase (cf. section IV C1 below).

The 2 next sections describe the questionings based on related work, method used and insights gained which informed the design, and the design idea itself – following a *why*, *how* and *what* structure. Usability and ease-of-use guided the co-design from a practical perspective (described in detail in Section IV), while trust in validity of data acquisition appeared the final objective to attain (discussed in Section V).

IV. Usability and ease-of-use

B. Related work

Recent research shows that improving the usability of falls assessment technologies will have a positive impact on healthcare, helping users identify subtle changes in gait and balance, improving the reliability of parameters and measures and empowering the users [15]. Based on insights of self-care monitoring studies, where data visualization is a determining aspect, the research question was that usability of the BQT application for balance score visualization could play an important part in this perceived utility of achieving a proper balance follow-up.

C. *Method and insights*

As part of the needs analysis, in-depth interviews were made with: elderlies and their informal caregivers, and health professionals (MDs, geriatricians, pharmacists, physiotherapists). Ethnographic observations of clinical tests and force-plate assessments were also made at the rehabilitation centre, in order to understand current professional practices [16] and the use of existing tools.

This allowed to understand the parameters of the force-plate, patient data that are required, how these data allow to recontextualize the assessment made, especially for follow-up (e.g. patient wearing orthopedic shoes). Also, the insights about how efficient diagnostic explanation is achieved between health professional and patient have inspired the important values that needed to be implemented in the interface design of the BQT application.

We will focus only on 2 aspects: standardization of position, visualization of data.

1) *Standardization of position*

Contrary to the initial design and protocol of the BQT, the force-plate strongly constrains the body position: the feet are positioned by the wedges inserted in the force-plate (picture left), and the patient is asked to look at the red line projected by the video projector in front at eye level. The position of the feet - glued knees, “duck” feet - is not very pleasant. However, looking at a fixed point in front indeed helps to remain more stable. The absence of any markings on the BQT emerged from the collaborative sessions with the 3 professionals as being a failing.

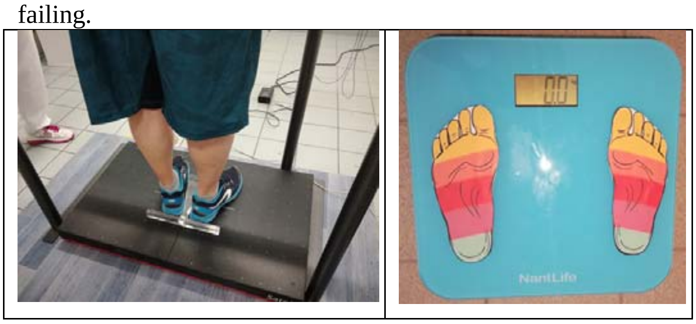

Figure 2. Left: highly standardized position of force-plate
Right: standardization at home with BQT

Also, left free to step on the BQT (without any instructions), all of the three professionals started by looking at the display, like a traditional bathroom scale, then straightened up to look up right in front of them, i.e. a position in which you have the best balance. When asked about that, which they did naturally without realizing, one of them answered “(Laughing) *we know the techniques*”. Following this understanding, this “technique” (that can be found in the force plate protocol also), has been implemented in the design of the BQT (right), compromising the ease-of-use of the BQT (ordinary bathroom scale) and the need to standardize both the feet position and the standing position, so as to guarantee the rigor of the measures for an efficient follow-up. Simple stickers have been proposed: the first time, the stickers are positioned with a health professional, considering patients’ height and size as well as comfort perception. During everyday use at home by the elder person, the stickers allow a standardization of the feet position.

2) *Visualization of data*

Like for stepping on the BQT, the health professionals were voluntarily left to make sense of the results by themselves, as if they were any user, without information about the indicators and how they are measured or the designers/developers’ intentions and previous research.

Figure 3. Previous interface (left), new interface

Also, in trying to make sense of the 4 indicators (picture left), they tried several times and compared the different scores generated. One of the main questionings were about the “time” indicator. These difficulties in understanding how the data were measured, and all the sense-making discussions led to the observation of the need to have an audible sound to indicate the start signal. However, they explain that – in their professional practice – the indicator “time” does not appear to be relevant, except for certain pathologies, e.g. Parkinson, but where a "classical" visual analysis would probably be more effective. But for a domestic use, a start signal could be useful, as confirmed by the user tests’ results.

Another main insight is that the interface with the 4 indicators was very difficult to understand and did not make any sense to them: “*It doesn't speak to me*” or “*the way it's represented, it doesn't remind me of anything*.” One important information, they explained regardless of the user, is the centre of gravity: "*What would be significant from the current square is for the persons to know where their centre of gravity is. Imagine, you have the surface there, and he knows where his center of gravity is. For any user, us, patients, even a doctor. This is your square, you have your lifting polygon indicated, and you see that your center of gravity moves further to the top right, further forward, further back. You already know that there is a position in relation to this centre of gravity that can be disturbed. And that's super significant for everyone, I think.*" Indeed, the ethnographic observations of the tests conducted by the HPs with two of the rehab centre’s patients clearly show that patients easily understand the diagnostic when explanations are combined to the visualization of the force plate data. The insight is the need for clarity and understandability of data visualization. It appeared that representing the “centre of gravity” data with the BQT would allow rehab clinicians to know precisely on which type of rehabilitation exercise to work.

The start signal, together with a sound accompanying the test as well as an end signal, were implemented and successfully evaluated by seniors during user tests: 3 out of 5 users rated the sound utility on 5/5; 1 user :4/5; 1 user :2/5). The interface was considerably improved to cater for the type of information that need to be shared with patients so as to explain the assessment to them (cf. Fig 3). The need to have more detailed data in the case of professional use in a follow-up also emerged, with a general level for patients and a more detailed level for clinicians (Flowchart organization to access to details only if needed).

V. VALIDITY OF DATA ACQUISITION

Linked to usability and ease-of-use of the BQT on a daily basis, the issue of validity in acquiring the data appeared as a *sine qua non* aspect, both for health professionals and senior users. The previous stepping-on protocol, as described in [13], is presented left. The new iteratively and collaboratively designed protocol – co-designed with the health professionals, evaluated by elder users, and validated by the health professionals – is right.

Previous protocol	**New protocol (home)**
(1) Stand in front of the scale, thus triggering the infrared detector;	1. The user stands in front of the BQT, well in front of the foot marks
(2) Wait for the scale to display ‘0.0’;	2. The BQT instructs the user to step on, simultaneously by both display "0.0" and beep tone
(3) Step onto the scale;	3. The user climbs onto the BQT looking where he puts his feet, positions his feet on the marks, then fixes the label in front of him at eye level.
(4) Wait for the scale to display the body weight;	4. The BQT measures weight and balance, indicating - visually and acoustically - that the measurement is in progress
	5. The BQT indicates - by a distinctive audible signal (or ideally, the weight announcement), and the weight display (numbers) - to the user that he can step down
(5) Step off the scale.	6. The user descends from the BQT
	7. The weight display is replaced by the balance score display

1) *Previous stepping-on protocol*

Although no specific position of the feet was required, the relatively small size of the scale (320 x 295 mm) did not allow for much variation in position. Likewise, no specific position was specified for the head, after preliminary trials had shown that everybody looked down at the display, waiting for the weight value to be displayed [13].

2) *Co-designing the new protocol*

However, as described below, based on sense-making and “best practices” in balance assessment (force-plate practices as well as the “techniques” of good balance), it appeared that a more rigorous standardization would ensure: technical validity of measurements, and linked to that, trust in the validity of the data being acquired. Indeed, an efficient follow-up (no false alerts) depends on that condition. Also, in order for the BQT to be a useful tool as part of an adapted prevention or rehabilitation program, it is required that older adults at risk of falling *use* the BQT on a *regular basis.* The first issue is usability: that the device (as well as the protocol, and the application) is easy on a daily basis. The second issue is whether elder users perceive the BQT as an efficient tool, capturing exact measures. As discussed with the health professionals, standardization is key to this trust.

So based on this understanding of what is considered as important aspects to be measured from a physiotherapy perspective (both assessment and rehab that follows), a new protocol was designed, one for the professional context, and one for the home environment.

The test is performed once, looking in front of you at a fixed point at eye level, the best balance position according to the rules of proprioception. It has been very positively evaluated during user tests by seniors, who find the protocol easy to follow and non-constraining.

VI. CONCLUSION AND PERSPECTIVES

This paper has presented the co-design of the BQT, so as to address two essential issues in order that the BQT can actually be a useful prevention tool: usability and ease-of-use on a regular basis and trust in the validity of the data acquisition. Several avenues for future work are emerging from the knowledge generated in this study and of the next step in the development of the BQT application. This future work will focus, on the one hand, as a follow-up to this study, on prospective uses, and on the other hand, on research aimed at improving the algorithm for calculating the measurement, in order to guarantee optimal performance of the BQT.

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