# 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 main 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 is useful to confirm their diagnosis, completing their visual analysis with objective measures.

However, the major drawback of these measurements of balance is that of cost. Therefore, these evaluations prove inadequate to be implemented as part of a 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].

### A. *Balance Quality Tester*

Based on the observation of the organizational restrictions linked to 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: the BQT 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].

### *B. 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 can support the everyday ease-of-use?
2) How to ensure trust in the validity of the data acquisition?

## II. Material and Methods

Based on these research questions, a usage study has been made, where usability and ease-of-use guided the co-design from a practical perspective, with trust in validity of data acquisition being the final objective to attain. Before presenting in detail the insights gained in the "Results" section, first, the related work, the approach and the first step of the design process, are presented.

### *A. Usability and ease-of-use: 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, as well as empowering the users [15]. Based also on insights of self-care monitoring studies, where data visualization is a determining aspect, the research hypothesis to be examined 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.

### *B. Approach used: Living Lab approach*

The approach to research and design that has been used is the Living Lab approach, which combines these 3 characteristics: Human-centered, Participatory and Iterative.

#### *1) Human-centred design*

For Bannon [16], Human-centred interaction design would be HCI "*centered on the exploration of new forms of living in and through technologies that give primacy to human actors, their values and their activities*". It takes as a starting point human (elderly) capabilities, with a focus on how to support, develop and extend people's capabilities through the latest technological developments [17]. A radically reworked agenda is therefore proposed, for example, on the theme of Ambient Assisted Living. Instead of a technology-first or even medical-first approach, Bannon recommends to consider first the fundamental needs and concerns of the ones at the centre of the investigations – the elderly people – so that these AAL technologies could be, of course life-saving, but also actually add to elderly people's dignity or empowerment.

In order to consider elderlies' needs, Ethnography has been used, both at elderlies' homes and in a rehab hospital, combining interviews (mainly informal) and participant observations. Indeed, Ethnography offers the opportunity to reveal needs or practices of users, which they may not themselves attend to, because they take them so much for granted that they do not think about them, or are too busy [18]. This inability to articulate "needs" is even more true of dependent elderlies.

#### *2) Participatory design*

Participatory design (PD) is a cooperative design process, with a focus on enabling different stakeholders with different perspectives and competencies to cooperate. It comprises active user involvement and participation in the design of IT artefacts and systems in professional settings, where it is largely and increasingly used. Designers invite future users to participate in all phases of the design process [19]. PD is generally united by an ethos of empowerment and 'meaningful' involvement for stakeholders in the design of the systems they will use.

Participatory design has traditionally been useful in the design of technology applications or the co-realisation of a more holistic socio-technical bricolage of new and existing technologies and practices. Moving away from the traditional computer and "user" notion, e.g. with Ambient Assisted Living technologies [16], like connected objects or social robots [20], there is indeed the need for participatory design.

#### 3) *Participation – to what extent ?*

Following the participatory approach adopted to design this specific new technology, the very role and participation of stakeholders in this research requires reflexive questioning. Indeed, the three professionals of the rehabilitation centre, involved in this research, would be considered in more traditional Ethnography-based needs analysis as *informants*. Adopting this PD approach – whose principle guided the fieldwork, but without any *a priori* planning about how this participation would actually be achieved – the three professionals are considered as *participants*, i.e actors who have a greater implication in our research than simply "informing" it. What actually emerged during the fieldwork and were achieved in a naturally-organized way [21], are co-design sessions as part of the observations being done. Therefore, this *in situ* co-designing implies a degree of participation and a role in the design process in which the participants become / achieve being *co-designers*. It is therefore, in a voluntary attempt to reflexively examine what is at stake in "participation-in-action" that this research pushes PD a step further. The authors argue that it is necessary to find a way to consider the effective participation of the co-designers in collaboratively producing the design ideas, which are the "results" of this design-oriented research. This recognition of contribution in the participatory design process, as a further degree in participation and greater agency to the participants, takes the form, in this research, of co-authoring. One of the participant/co-designer is also a co-author of this paper and others that have been published from this research [22], [23]. The two other participants/co-designers are cited and receive special thanks in the Acknowledgment section. This reflexive discussion about participation, role and categorization being done, in order to pragmatically ensure clarity in the rest of paper, they will simply be referred to as the "professionals".

#### 4) *Living Lab approach to achieve "adequate design"*

Therefore, combining the best practices of Human-centred, participatory and iterative design, the Living Lab approach, the authors argue, allows to achieve "adequate design". The most important principle is to adopt the participants' perspective and use the empirical insights gained through the different methods mobilized as part of the approach, to relevantly inform design.

### C. *Empirical insights constantly guiding the design process*

The main insight that emerged from the analysis of practices and understanding of needs was the necessity to completely redesign the BQT. This redesign appeared as essential, in order for the BQT to fit the requirements 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 protocol design, in terms of standardizing the protocol.

of stepping-on the BQT. (cf. presentation of the design recommendations in the "Results" section *infra*.)

these have been evaluated, and iteratively improved *with* senior users' participation. In fact, as shown in Fig 1, throughout the design process - from the needs analysis to the validation of the new design proposals - the participants, part of the community *Amis du Living Lab*, whether seniors or health professionals, have been actively involved in the different tasks. Starting with the needs analysis, observations and in-depth interviews were made with: elderlies and their informal caregivers, as well as with health professionals (GPs, geriatricians, pharmacists, physiotherapists), including the ones from the rehab hospital.

## III. RESULTS

As part of the first step of analysis of practices, ethnographic observations of clinical tests and force-plate assessments were made at the rehabilitation centre. The objective was to understand current professional practices [24] and the use of existing tools: 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). This understanding of practices, as well as the insights about how diagnostic explanation is efficiently achieved between health professional and patient, have inspired the important values that needed to be implemented in the interface design of the BQT application.

Important design ideas have emerged, focusing on 4 aspects:

1. Hardware design
2. Interaction design
3. Interface design

4. Protocol design

## A. *Hardware design*

### 1) *Method: Analysis of practices*

The observation from the analysis of practices is that, contrary to the initial design and protocol of the BQT (see Fig 4, left), the force-plate strongly constrains the body position. The feet are positioned by the wedges inserted in the force-plate (Fig 2, 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 in front of oneself, indeed, helps to remain more stable. The (till then) absence of any markings on the physical device of the BQT emerged from the collaborative sessions with the three professionals as being a failing, that required improvement.

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 one has the best balance. When asked about that, which they did naturally without realizing it, one of them answered “(Laughing) *we know the techniques*”. This “technique” is the best balance position according to the rules of proprioception.

### 2) *Design idea: Standardizing position with stickers*

Following the understanding of this “technique”, that can be found in the force plate protocol also, this *good practice* has been implemented in the design of the BQT (Fig 2, right). The design needed to find this compromise between, on the one hand, the ease-of-use of the BQT (ordinary bathroom scale) and, on the other hand, the need to standardize both the feet position and the standing position, in order to guarantee the rigor of the measures for an efficient follow-up. To ensure this necessary standardization, the use of simple stickers have been proposed by the co-designers: 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 guarantee the standardization of the feet position.

## B. *Interaction design*

### 1) *Method: observation of sense-making in interaction*

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 about the designers/developers’ intentions and previous research.

In trying to make sense of how the BQT worked and how the indicators figured in generating a score, the professionals tried it several times and compared the different scores that were generated. One of the main questionings was about the “time” indicator. Seeing that each one of them had different scores, they were wondering: Is time calculated when the “0.0” display appears (see Fig. 2, right), which would then be a relevant signal for the user, or can the user step on anytime? These difficulties in understanding how the data were measured, and all the sense-making discussions, led to this need identification: the necessity 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 in that case, a “classical” visual analysis would probably be more effective. However, the professionals’ opinion was that, for a domestic use, a start signal could be useful. Indeed, this utility was confirmed by the user tests’ results.

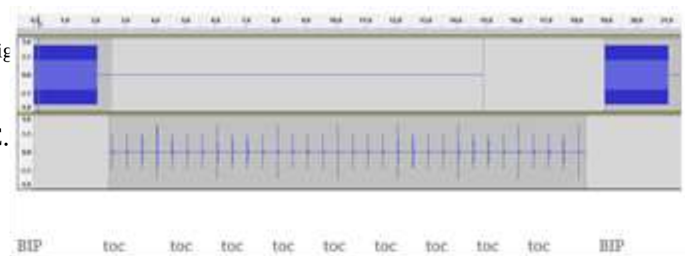
### 2) *Design idea: Adding sound signal*

Therefore, the interaction design included an audible signal (volume that can be customized) to indicate the time for stepping on and stepping down, each with a distinctive high-pitched “beep”, as well as an accompanying sound (rather neutral watch sound) for the duration of the test, as shown below.

The sound modality was successfully evaluated by seniors during the user tests: 3 out of 5 users rated the sound utility on 5/5; 1 user: 4/5; 1 user: 2/5). Rather than a neutral accompanying sound, during the second iteration, this issue was discussed with the professionals, and the proposal was that the BQT could play a different music for each weighing session. The objective is that the music’s role, of course, is to “accompany” the test (like the watch sound, which had been positively evaluated during the user tests) but also to both distract and disturb the user. Indeed, on the one hand, the objective of “distraction” is that the patient has a better balance than if she were focused on thinking about her balance. On the other hand, older patients sometimes have difficulty speaking and walking at the same time, while in a real situation of functional activities, they often move around doing other things. The objective is to bring the test as close as possible to an ordinary everyday situation, in which falls occur.

Fig

C.




Another main insight is that the interface with the 4 indicators (Figure 4, left) was very difficult to understand and did not make any sense to the professionals: "*It doesn't speak to me*" or "*the way it's represented, it doesn't remind me of anything*." This representation of information made even less sense to senior users.


Figure 4. Previous interface (left), new interface (middle, right)

One important information, the professionals 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 professionals 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 forceplate data. The main understanding of needs is the necessity 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 on.

2) *Design idea: Clear and understandable visualization*

The interface was considerably improved to cater for the clarity of the visual representation of information that need to be shared with patients, so as to explain the assessment to them (cf. Fig 4, Middle and right picture). The first criteria to be catered for, linked to the research questions and objective of usability for utility, is the factor of *accessibility*, also called Universal Design or Design for All factor [25]. Universal Accessibility is a HCI concept whose main objective is to produce systems that can be used by everyone, regardless of their physical or cognitive abilities [26]. Accessible software is, therefore, a software that all people (people with disabilities, elderly people, people in special environments, etc.) can perceive, understand, navigate and interact with. The distinct concepts of software accessibility and usability are therefore related [27] and, according to the principles of Universal Design, it is more effective to address them together during the inclusive design process.

Accessibility emerged as a relevant factor to be addressed linked to the Usability research question because two distinct categories of end-users emerged out of this study: professional users and elder users. Elder users at risk of falling are those users whose age also implies reading, hearing and sometimes cognitive impairments. The idea was to make the two main information – weight and gait score – easily accessible to them, in terms of understandability and readability. Presented in a minimalistic way, the weight is simply indicated in terms of kilograms, and the gait score in terms of "balance". These information are visible at a glance at strategic places – centre top and down – in a size big enough and sufficient contrast (black on white background, bold). It was also suggested that in some cases, to encourage patients' efforts, like undergoing rehabilitation in order to gain back some functional capacities or following a diet to lose or gain weight, it could be interesting to include the progression, in the form of arrows (Fig. 4, right). However, in the case of an ordinary everyday follow-up, this function would be avoided, in order to avoid discouragement effect.

Then, coherent with this objective of understandability for patients and sufficient detail for professional use, the 4 important design ideas are:

1. The area is indicated by a pelota - that would allow the patient to see how far he or she is "pitching"
2. The colour code - green, yellow, red - depending on the alert level: Green - score of 10-16 ; Yellow - score of 7-9 ; Red - score of 1-7
3. The size of the foot – indicates on which side and the degree to which the body is leaning

4. The details of the analysis with the precise data for each of the 4 indicators will be immediately accessible on the BQT application.

On the current version of the application, the detailed information, as regards the 4 indicators, is found in a separate folder, not immediately accessible to the user. Till then, the use case scenario was a domestic-only use. This research revealed that a professional use was considered useful – by health professionals themselves (a geriatrician, a general practitioner, physiotherapists from 2 centres who participated in the needs analysis) – as long as the detailed information would be available. Coherent with this new professional use scenario, the need to have more detailed data took the form of a general level for patients and a more detailed level for clinicians, with a flowchart organization to access to details, only if needed.

## D. *Protocol design*

### *1) Issue at stake : 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 presented right.

| **Previous protocol** | **New protocol (home scenario)** |
|---|---|
| (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 |

Figure 4: Previous protocol (left); Newly co-designed protocol (right)

### *2) Method: Achieving previous stepping-on protocol*

Although no specific position of the feet was required in the former protocol, the relatively small size of the scale (320 x 295 mm) did not allow for much variation in position. Likewise, no precise 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]. Like for the other design requirements that emerged, the professionals were left to step on freely on the BQT, so that their *in situ* sense-making and questions that emerged, could inform the values that they attach to such a procedure. As described already, they all looked up, after stepping on, explaining the “technique” for optimal balance, which appeared naturally to them. Also, before looking up, they had all looked at the BQT, to check the display, and mind the height, cautious not to fall. The new designed protocol was inspired by their action and its underlying principles of proprioception.

### *3) Co-designing the new protocol*

Therefore, based on sense-making and “best practices” in balance assessment (force-plate practices as well as the rules of proprioception), 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. First, an efficient follow-up (no false alerts) depends on that condition. Second, 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 actually *use* the BQT on a *regular basis.* Thus, the first issue is the research question and design objective of usability: that the device – as well as the protocol, and the interface – is easy to use on a daily basis. Linked to it, the second issue is whether elder users perceive the BQT as an efficient tool, which is capturing exact measures. As discussed *supra* (the stickers contribute to fixing the feet position), 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 the rehab that follows – a new protocol was designed with two variants: one for the home environment, and one for the professional context (new use scenario that emerged from this study). The Fig. 4 above presents the home scenario. The test is performed once, one looking in front of him, at a fixed point at eye level, which allows the best balance position. This newly co-designed protocol has been evaluated very positively during user tests: senior participants find the protocol easy to follow and non-constraining.

For the professional context, all the professionals explained that, for a first screening, a balance score with the BQT would be useful. However, it would be insufficient to gather the same data as with tests traditionally used, like the Tinetti tests or evaluations with the force plate where, gait is also evaluated with the closed eyes position. Therefore, as a compromise, it was suggested that the professional use protocol would include the tests being done twice, once eyes open and a second time with the eyes closed. Unlike the home scenario, where the risk of falling (while, most probably being alone in one's bathroom) would override the benefit of data acquisition, in the professional context, the patient would do the test with a professional, secured with a walker or fixed support.

## IV. Discussion

Coherent with the participatory and iterative approach, the "results" presented in the section above, that is, the design ideas that emerged from this design-oriented research, have been tested and validated with the relevant stakeholders. This final section discusses the insights and the professional participants' feedback about the approach.

### 1) *User tests*

At middle stage of the design process, senior participants (5 in all – following Nielsen's recommendations [28]) have evaluated the design ideas during the user tests of the intermediary design. The user tests comprised predefined tasks and a questionnaire-based interview. The different design aspects have been evaluated: hardware, interface, interaction, stepping-on protocol. Also, feedback has been sought concerning the two use scenarios: home and professional. In order to gather objectified data, a Lickert scale allowed users to give a formal score of 1 to 5. This score was complemented with open feedback, comments and suggestions that users were invited to give. The insights from the tests, in terms of user satisfaction, are generally very positive.

Due to space limitations, only the results linked to main research questions are succinctly presented here. All 5 participants find the new test protocol simple: 4 users give a rating of 5/5; 1 rates 4/5. They also find that the follow-up of their balance quality would be useful: 3 users rate 5/5; 1 user rates 4/5; 1 user rates 2/5. All the users' feedback (both positive and critical) allowed to improve the design during a second iteration.

### 2) *Validation of design ideas*

After these iterative improvements, the new design proposals were submitted to the three professionals for validation of the design ideas that they had proposed during the needs analysis phase.

First, the Home scenario protocol was collectively discussed, including the latency time (rate of ascent) which was considered relevant. In this respect, the start and end beeps were considered as good indicators. Also, the idea of music was seen as relevant, and the idea of changing music with each weighing session emerged collectively.

When the interviewer explained mock-up of the pelota and the colour code, their reactions were "*Oh yes, this is great*", "*this is evident right now*", "*like this, it speaks very very well*". Then, the size of the feet was immediately understood: "*there, you have more support on the right, is that it? That's great!*", "*like this, it is very understandable*". Concerning the display of the percentage of tilting, the need to have two levels – one general for the patients and one detailed for the professionals – – was confirmed. Also, the new graph to access to the details, so that the information are relevantly available for patients' follow-up, the professionals confirm its usefulness to them.

Most importantly, regarding standardization – which was absent from the initial protocol and which had raised many questions on their part – they were delighted to discover the stickers, whose idea they had put forward. Regarding the integration of the criteria "eyes open, eyes closed" in the professional use scenario, the professionals agree that the presence of a professional will cater for two important aspects: first secure the test, second explain the protocol to the patient clearly, without the need for a specific display on the BQT itself. Therefore the same tool with the same interface, with a simple variant in the protocol (making the test a second time with eyes closed) can prove useful in two complementary use scenarios.

The discussion also confirmed the BQT's interest in the motivational aspects of the elderly person – in a more motivating and fun way that simply 'weighing oneself' - and the efficiency of follow-up by the doctor, who would make visits at the patients' home (as is often the case for elderly people). In case the data are not tele-transmitted to the doctor and remain on a tablet or smartphone, it would be interesting for the doctor to have a look during the visit. Also, in the event that these balance data remain transparent to the elderly user himself (no tablet or smartphone), it would be interesting for professional or family caregivers to receive alerts, for example by email.

In conclusion to this participatory validation session of the design ideas, the very process of participatory and collaborative design was discussed. The professionals appreciate the general new design: "*it's better*", "*it's good, it becomes intuitive, more relevant*", "*more standardized*"; as well as the participatory approach in which they have been actively involved, saying: "*I'm proud*".

## V. Conclusion and Perspectives

This paper has presented the collaborative redesign of the BQT, so as to address two essential issues. In order that the BQT can actually be a useful prevention tool: first, usability and ease-of-use on a regular basis and second, 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. Most of all, apart from the observation of insufficient identification and management of frailty among the elderly population, this research revealed the lack of common ground for inter-professional collaboration in the follow-up of frail patients, especially regarding physical frailty. E.g., when a general practitioner prescribes physiotherapy sessions for a geriatric patient, his prescription is a (vague) comment addressed to the primary care physiotherapist. All professionals involved in this study agree with the hypothesis that a formal score generated by the BQT, could become a shared norm among health professionals and thus, has the potential to ensure a much more efficient coordination between health professionals.

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## References

[1] C. Todd and D. Skelton, "What are the main risk factors for falls among older people and what are the most effective interventions to prevent these falls?", Health Evidence Network Report, World Health Organisation Regional Office for Europe: Copenhagen, Denmark, 2004

[2] World Health Organization, "Global health and ageing", World Health Organization, 2011

[3] Guberman N, Gagnon É, Lavoie J-P, Belleau H, Fournier M, Grenier L and Vézina A 2006 Families' values and attitudes regarding responsibility for the frail elderly J. Aging Social Policy 18 59–78

[4] Hewson D.J, Duchêne J. and Hogrel J-Y., "Validation of balance-quality assessment using a modified bathroom scale", Physiological Measurement N° 36, pp. 207-218, 2015

[5] Vermeulen J, Neyens J C L, Spreeuwenberg M D, van Rossum E, Hewson D J, Duchêne J and de Witte L P 2012 Construct validity of a modified bathroom scale that can measure balance in elderly people J. Am. Med. Dir. Assoc. 13 665.e1–e5

[6] J Duchêne and R Jaber, Apport des technologies au suivi des personnes âgées fragiles, Techniques de l'ingénieur, 2015

[7] K.O. Berg, S.L. Wood-Dauphinee, J.I. Williams and B. Maki, "Measuring balance in the elderly: validation of an instrument", Can. J. Public Health 83 (suppl. 2) S7–11, 1992

[8] D. Podsiadlo and S. Richardson, "The timed 'Up & Go': a test of basic functional mobility for frail elderly persons" J. Am. Geriatr. Soc. 39 142–8, 1991

[9] M.E. Tinetti, "Performance-oriented assessment of mobility problems in elderly patients", J. Am. Geriatr. Soc. 34, pp. 119–26, 1986

[11] A Chkeir Jean-Luc Novella, Moustapha Dramé, Delphine Bera, Michèle Collart and Jacques Duchêne, In-home physical frailty monitoring: relevance with respect to clinical tests, BMC Geriatrics 2019 19:34

[12] J. Duchêne, D. Hewson and P. Rumeau, "Modified bathroom scale and balance assessment: a comparison with clinical tests", SpringerPlus (2016) 5: 472

[13] Duchêne J, Hewson DJ (2011) Using a modified bathroom scale for long-term balance quality assessment: relevance, usability and acceptability. J Telemedi Telecare 17(8):421–426

[14] Alaoui, M., Lan Hing Ting, K., Lewkowicz, M., « The urge for empirically-informed design of social oriented AAL applications – The example of 2 AAL projects », Procedia Computer Science, Volume 27, 2014, Pages 379-388

[15] Motti Genaro L., HCI Challenges in Human Movement Analysis: Quantitative Assessment of Gait and Balance, November 2018

Irish HCI 2018

Project: Improving the usability for improving the quality of data capture for health technologies

[16] Bannon. L. (2011) Reimagining HCI: Toward a More Human-Centered Perspective. Interactions, 18(4), pages 50-57

[17] Bannon, L. (2011) Re-framing HCI: From human-computer interaction to human-centred interaction design

[18] Randall, D., Harper R., Rouncefield M. (2007) Fieldwork for Design: Theory and Practice April 2007

[19] Bratteteig, T. and Wagner, I. (2016). Unpacking the Notion of participation in Participatory Design. Comput. Supported Coop. Work 25, 6, 425-475.

[20] Lan Hing Ting, K., Derras, M., Voilmy, D., (2018) « Designing Human-Robot Interaction for Dependent Elderlies: a Living Lab Approach », British HCI 2018, 32nd Human Computer Interaction Conference, Belfast, Northern Ireland, 2-6 juillet

[21] Lynch, M., (2002) From naturally occurring data to naturally organized ordinary activities: comment on Speer, Discourse Studies, Vol 4, Issue 4, pp. 531 – 537

[22] Lan Hing Ting, K; Dessinger, G.; Voilmy, D. (2018) « Examining usage to ensure utility : Co-design of a tool for fall prevention », Jetsan 2019 : Journées d'Etude sur la TéléSanté, Sorbonne Université, Paris campus Jussieu, 23-24 mai 2019

[23] Lan Hing Ting, K., Dessinger, G., Voilmy, D., « L'utilisabilité pour l'utilité : nouveau design d'un pèse personne connecté », Journée d'études IHM & Santé, Université de Lorraine, Metz, 14 mai 2019

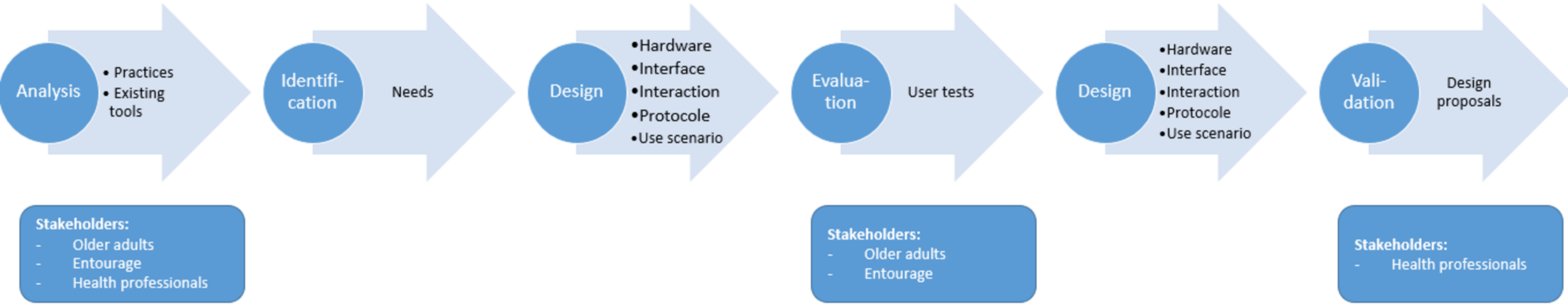
[24] Kuutti, Kari; Bannon, Liam J. (2014) The turn to practice in HCI: towards a research agenda. In CHI '14 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, New York, pp. 3543-3552.

[25] Iwarsson S, St°ahl A (2003) Accessibility, usability and universal design positioning and definition of concepts describing person-environment relationships. Disability and rehabilitation 25(2):57–66

[26] Abascal J, Nicolle C (2005) Moving towards inclusive design guidelines for socially and ethically aware hci. Interacting with computers 17(5):484–505

[27] Petrie H, Kheir O (2007) The relationship between accessibility and usability of websites. In: Proceedings of the SIGCHI conference on Human factors in computing systems, ACM, pp 397–406

[28] Nielsen, J., (1994) Usability engineering, Morgan Kaufmann Publishers Inc. San Francisco, CA


Analysis
• Practices
• Existing tools
Identifi-cation
Needs
Design
•Hardware
•Interface
•Interaction
•Protocole
•Use scenario
Evalua-tion
User tests
Design
•Hardware
•Interface
•Interaction
•Protocole
•Use scenario
Vali-dation
Design proposals
Stakeholders:
- Older adults
- Entourage
- Health professionals
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