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Research Lines to Improve Access to Health Instrumentation Design

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Abstract

This document seeks new areas of research in musculoskeletal health instrumentation development, under the current context of the Internet of Things (IoT) and the design needs of achieving more efficient, profitable, and better user experience in healthcare-related products and services. Three health measurement instrumentation case studies are presented, which show latent barriers and needs as well as possible methods of solving these situations. The cases deal with instrumentation related to motion capture (MoCap), balance control measurement, and muscle strength measured by dynamometry. Using the cases, a scheme that includes the key elements involved in a health instrumentation system is proposed. The scheme is ideated to facilitate the creation of health development tools (HDT) that are intermediate tools that designers, developers, or researchers can use to implement health products and services in a more efficient, and accessible way.

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1. Introduction

The current context of intelligent objects interconnected with each other and the cloud in the Internet of Things (IoT),[1] has led to needs that transcend the mere profitability of technology products; issues such as usability, simplicity, intuitiveness, suitability to the user, or user experience improvement,[2] are increasingly essential for product success and to really improve people's lives. Therefore, it is necessary to consider how this context affects the development of health instrumentation, which refers to health measurement devices to obtain patient information. In this regard, Andersen et al.[3] described the concept of 'improving health care access', which means

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enhancing everything that facilitates personal health service usage and overcoming barriers that hinder them, improving the alliance between health systems and the population by providing adequate services at the right time.

This concept leads to the development of the idea to 'improve access to health instrumentation design', with the same general objective as that of Andersen et al.[3] It focuses on facilitating health instrumentation development, considering the sector characteristics, requirements, limitations, and potentialities. Applying this approach will enable achieving technological solutions to specific health problems. The concept may have some parallelism and even contribute to the smart health field.[4] Consequently, it is understood that reaching and developing truly accessible technological solutions is not obvious and requires an adequate combination of research, experimentation, and creativity, which are issues that justify the inclusion of this concept in the scientific community.

The paper focuses on health instrumentation development aimed at assessing the musculoskeletal system by recording and analysing bio-signals related to movement, balance, and muscle effort, which respectively allows assessing personal functional capacity in terms of joint mobility, control of balance, and loss of muscle strength. These systems have a great impact on society as they imply a great user interaction opportunity, providing information to professionals, both directly (individual capacity, range of mobility of a joint, muscle strength, etc.) and indirectly (habits, physical inactivity, etc.).[5,6]

According to the above, the need to generate knowledge on the health instrumentation design field is justified. This would improve products and services aimed at professionals, such as doctors, physiotherapists, nurses, or occupational therapists. The tangible benefits and applications of this knowledge could be the following:

- Allowing the physicians to assess the musculoskeletal abilities of a patient at a certain point with different objectives, such as complementary diagnosis, job adaptation, treatment, or training objectives.
- Provide instrumentation that allows rehabilitation or training due to the 'biofeedback' in real time.[7]
- Establish a doctor-patient communication pathway, providing objective information about changes.
- Enable data collection outside the clinics or hospitals, promoting therapeutic activities in the home and improving personal autonomy.

These advantages combine with those described in *Strategic Research Lines of Horizon 2020* item 8, 'Health, demographic change and wellbeing',[8] supporting the development of information and communications technology (ICT) systems that fosters a high quality and economically sustainable healthcare system, responding to the strategic priority of 'Welfare and Quality of Life' ensuring 'healthy aging' and 'eHealth innovation in empowering the patient'. Additionally, note that systems designed within the framework described are not intended to replace the optional autonomous systems; they are expected to increase their knowledge and experience of tailoring treatment to each patient in line with the approach of 'personalised therapies'.

From the mentioned problem, it is expected that the scientific community will be aware of the problem and that this will transcend to other researchers and developers to improve the technological context of health. Therefore, three case studies of instrumentation are presented, showing some latent needs and pathways that can be oriented towards their solution. From these cases, a scheme is presented that includes the key elements of a health instrumentation system, and a future research line aims to facilitate access to this type of product development.

2. Case Studies

Three case studies that are related to monitoring and evaluating the musculoskeletal system are presented. They briefly describe the state of the art, the identified needs and barriers, and the possible factors and sources of inspiration that can improve access and determine their development. The cases focus on three types of systems: motion capture (MoCap), measurement of human balance, and measurement of muscle strength using dynamometry.

2.1. Case 1: Motion Capture (MoCap) Systems

MoCap systems that are used to analyse and study human motion are widely recognised for their usefulness and application in different fields, such as health, sports, or leisure.[9,10] MoCap technology usually uses elements that are placed in certain body points to identify movement, angles, and positions between them. Markers can have embedded electronic sensors, inertial measurement units (IMU), or elements monitored by cameras located around the capture zone.

However, adequate MoCap requires addressing requirements that are difficult to satisfy; thus, the applications that are possible with this technology are stunted by several technological and usability barriers. These barriers are the result of the technology itself, which is often faster than research, and can generate MoCap systems that do not ensure correct positioning or attachment to the body or are uncomfortable and do not provide enough precision.[11,12] All this justifies the need to create methodologies to design products that are suitable to the context and users.

In this sense, wearable devices are a source of inspiration in scientific and market fields, as they can help overcome these barriers. Wearables have a parallelism with MoCap markers placed on the body, a key point for usability and accuracy. This is observed through the three main wearable characteristics:[13]

> (1) The device is attached to the body and does not require muscular effort to remain in contact with the body, (2) it remains attached to the body regardless of the body's orientation or activity, and (3) it does not have to be detached to be interacted with.[13]

Therefore, terms such as *wearability*, which defines the interaction between the human body and the device, or *dynamic wearability,* which includes the movement of the human body in the design,[14] can be a starting point to improve the MoCap system user experience.

In addition, as Andreoni et al.[15] and Motti and Caine[16] discussed, wearables are themselves a multidisciplinary research challenge, so this multidisciplinarity is an extensive and transversal need in MoCap and in any health instrumentation.

2.2. Case 2: Evaluating Human Balance Control

Human balance is important for healthy living and healthy ageing. Although it may seem a simple task, maintain standing balance is a complex skill; it involves coordinating multiple motor and biomechanical sensory components.[17] In this sense, stabilometric platforms are devices that allow an objective and precise quantification of the ability to remain stable; thus, they are considered a contrasting tool of evaluation.[18,19] However, in these type of devices, there are also barriers to design adequate products, among which cost and use flexibility are highlighted.

Cost is a key factor that largely impedes widespread access to stabilometric platform usage in different environments.[17] Platforms used for biomedical research can involve investments of over ten thousand US dollars.[18,19] In this line, some applications, such as gait analysis, require more than one platform, which aggravates this fact. This need is also contrasted by the growing number of articles destined to validate the Wii console platform that costs less than 100 €.[20,21]

The flexibility factor also plays a significant role. Historically, stabilometric platforms have been restricted to research laboratories.[22] The development of tools with flexible hardware and software can improve the integration between systems and allow experimentation in a variety of places and applications that previously were not considered practical.[19] In this way, Postolache and Postolache[18] added that balance-related technology must depend on the ‘situational context’ and the ‘task demands’, for which flexibility is required.

Consequently, and given the effects of balance health assessments and the barriers identified (cost and flexibility), the need to design new devices that overcome these barriers and extend their applications to other areas that are not yet explored is justified.

2.3. Case 3: Evaluating Muscle Strength

The assessment of muscular strength is a necessity of the healthcare community. Since the first manual muscle testing protocols were developed in the early 1900s, dynamometric devices have been implemented to objectively assess muscle strength.[23-26] Despite their great utility, they also have barriers and needs to overcome that can be added to those described in the previous cases (usability, multidisciplinary, cost, flexibility, etc.).

Among the dynamometry devices, two types can be differentiated: stationary dynamometers and isometric dynamometers. Stationary dynamometers allow measurement of static or dynamic force (at different speeds). They are expensive equipment, require high preparation time, and are bulky.[23] However, they can be considered the dynamometric ‘gold standard’.[26] Isometric dynamometers are simpler and less cumbersome; they measure static muscle strength while the subject performs exercises in which the muscles do not vary in length (isometric effort). In relation to the latter type, several product concepts have been detected: hand-held dynamometers,[23,24] externally fixed dynamometers,[26] and dynamometry for specific muscle groups.[25]

Hand-held devices that are sustained by the operator have been accepted as clinical evaluation methods because of their high reliability; however, they can accumulate errors related to reproducibility, operator strength, joint position, strength of application, or stabilisation of the patient. Externally fixed dynamometers use load cells connected by one of its sides to a fixed point and by the other to a grip; they have high interoperator reliability, but ad-hoc solutions are needed to affix the devices, either to room points or to furniture, which hinders its implementation. Solutions for specific muscle groups, such as hand dynamometry[25] can be a resource for creating more usable and commercial products.

According to the above, it would be beneficial to develop instrumentation or methodologies to design instrumentation that aims to overcome these barriers. Developed instrumentation could also include electromyography sensors, which record muscle electrical activity and could be added as an additional bio-signal. In this sense, commercial electromyography sensors that integrate with electronic development platforms have a moderate cost, which could be an opportunity to experiment with innovative solutions.

3. Research Methodology

The case studies, the detected needs, and the view of the authors in different areas (biomedical, mechanic, and design engineering) have allowed ideating a scheme of the elements that comprise a health product service and its ecosystem (Fig. 1). It is expected to help structure the projects carried out. In the scheme, several elements are observed: processing, devices, environment, and usage. Moreover, there are two users involved: health practitioners and patients. As seen in the scheme and its interrelations (Fig. 1), the different elements interact with the two users, which shows that the work is intrinsically related to different design branches: interaction design, user experience design, and service design, among others.[2,27-29]

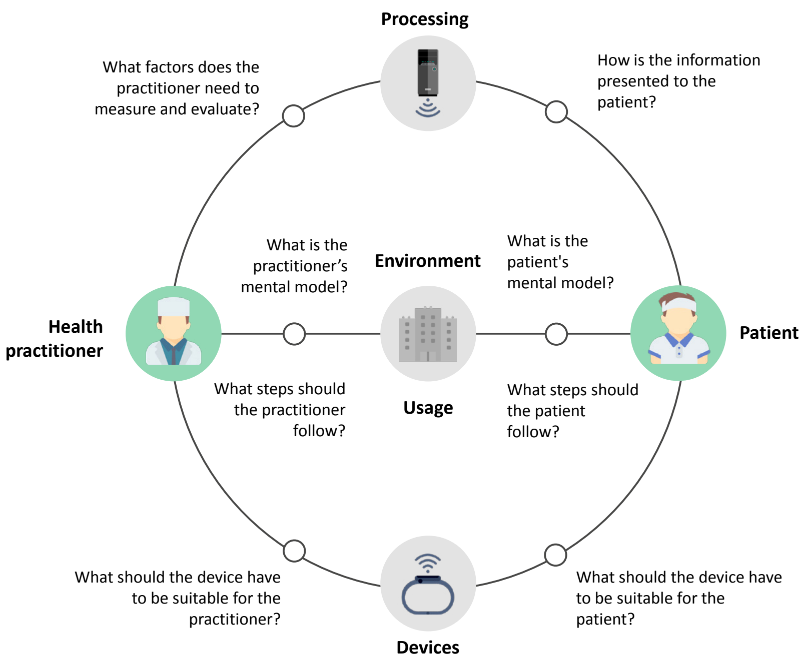

Fig. 1. Health Instrumentation and its ecosystem. Icons made by Freepik, Madebyoliver, and Alfredo Hernandez from www.flaticon.com

In view of the above, future research should focus on the creation of health development tools (HDT) that are intermediary tools that designers, developers, and researchers can use in a simpler and more efficient way to implement their projects and ideas, generating products and services that reach the final goal of improving access to health instrumentation. The creation of the HDT can be addressed using two approaches: development of physical prototypes or products (tangible HDT) and creating design methodologies or guidelines (intangible HDTs).

Tangible HDTs can be simply understood as an analogy to the Arduino product, an open development platform that facilitates the implementation of electronic projects. This philosophy could be extrapolated to develop solutions specifically targeted to health with its peculiarities and requirements. This could be useful in Case Studies 2 and 3, where the creation of simpler, more flexible, and economically balanced platforms or dynamometers could facilitate more optimal and accessible solutions. In this way, these HDT products could be easily reproducible by other researchers or acquired by them to experiment and to flexibly reach concrete solutions to the detected problems.

Moreover, intangible HDTs are a key point in the development of such complex instrumentation, which requires considering many aspects (Fig. 1). In fact, in Case Study 1, the requirements to be met in MoCap products could be addressed by a design methodology. These methodologies or guidelines could be useful in the phases of requirement extraction and/or the evaluation process. In any case, they should consider multidisciplinary factors in the entire process, ensuring joint work between technologists and users (patients and practitioners). This would help to extract realistic needs and generate solutions with greater acceptance,[30] promoting more efficient and useful health systems for society.

4. Conclusions

As a result of the current context of intelligent IoT objects, and with the goal of achieving quality health systems, this paper presents the need to improve access to health instrumentation development. This is discussed in the field of musculoskeletal monitoring and evaluation through three case studies. In them, it is detected that MoCap must overcome barriers mainly relating to usability and body attachment, balance, and dynamometry barriers relative to the cost or the flexibility of the systems – all this within a multidisciplinary approach. In this way, to achieve access to the development of this type of instrumentation, it is proposed to focus future research on HDT creation, developing tools specifically designed for the creation of health instrumentation.

The paper is expected to generate social and scientific benefits by approaching a specific problem from a general view. This motivates the PhD studies of one of the authors and is expected to raise interest in developing new products and services in the field of health, improving the user experience and the quality of people’s lives.

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