

Conference Paper

State of the Art - Ergonomics and Modeling of Functional Clothing Products with Biosignals Sensor Integration

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Abstract

This literature review aims to introduce and investigate the topics addressed in the development of this project, where we assess the development of functional clothing with integration of bio-signals sensors, exploring the textile materials, ergonomics, andrometry, usability and wearability.

Keywords: Ergonomics/Andrometry, Biosignals sensors, Usability/Wearability, Conforto, Textile materials

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Received: 26 November 2019

Accepted: 13 May 2020

Published: 2 June 2020

Publishing services provided by
Knowledge E

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Selection and Peer-review under the responsibility of the ICEUBI2019 Conference Committee.

1. Introduction - General Definitions

1.1. Ergonomics

Ergonomics is the science that studies the interactions between the human being and the elements of a system where it is included taking into account the principles of its profession, data and performance methods, in order to optimize human well-being and the overall performance of a system. Ergonomics can also be understood as the science that studies the relationship of all aspects of human life, from work, entertainment, reasoning and dedication, to a wide range of interests and applications [1].

1.2. Usability

The symbiosis between the product and the tasks for which it is intended, as well as the suitability with the user that will use it and the suitability for the context in which it is to be used, can be considered a definition for the concept of usability by simplifying, convenience in the use of the products, both in domestic and professional environment. The products can be "friendly, easy to understand, easy to operate and not very sensitive to error" [2].

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2. Ergonomic Functional Clothing Products

At the present, given the increasing expectations average and quality of life of citizens as well as the consequent increase in the level of satisfaction and demand to which technological evolution is associated, it is indispensable to investigate, invent and intensify the potentialities of different textile substrates, endowing them with differentiating characteristics in order to complement their intrinsic properties.

Thus, this search for new solutions has given rise to a number of possibilities that add more value to the traditional textile substrates through the increase of different functionalities, either by the use of new fibers, by the development of new structures, by the application of new finishes or even by the integration of electronic systems [3–10].

The resilience power of the Textile Industry in recent times has altered the manufacturing paradigm once it has been adapted and researched in order to diversify its main focus of fabric production for the development of higher value-added products in order to rebalance the volumes business and markets that has weakened, especially in developed countries due to the global economic environment. Because of this fact, the areas of technical textiles, functional fabrics and also the wearable technology concept are of great importance in the recovery of the textile industry since they are an integral part of this new focus of attention. Thus, there is a huge number of industries interested in diversified technological areas such as the automobile, health, personal protection, construction and architecture [11].

The interdisciplinary of the different areas of development and formation of new products, thus solving the challenges and business opportunities. The development of this type of product is without much fun for the need to research, develop, experiment and validate new articles for a textile industry. An innovation is facilitated when as relationships and surroundings of different areas promote and fund the exchange of ideas [12].

The application and use of electronic-based technologies, sensors or communications is now a daily reality [13]. The use of so-called conventional textiles in applications such as clothing for newborn or elderly children; fabrics used in the automotive upholstery and the camouflaged fabrics used by the military in the war scenarios are already beginning to present intelligent interfaces, so there is a need to integrate these technologies into the fibrous materials so that traditional textiles can be transformed into intelligent and interactive structures considered high-tech having end-user properties or functionalities that a "normal" tissue would not have [11].

The clothing and its aspects of ergonomic quality contribute to the comfort of the individual and consequently to his well-being. Usually a garment is developed for the individual's body; which in turn is variable in terms of anatomy, since, at times, it is at rest and in others in movement. The consumer for a clothing or accessories product has requirements in terms of quality, functionality, comfort and aesthetics - before, during and after use [14].

Ergonomics applied to the development of new products focuses essentially on the use, in their learning, efficiency, safety and comfort for the objectives that are intended to achieve; both in terms of needs and the level of desires. For this we have to know the anatomy and anthropometry of individuals; populations [15].

It is fundamental the anatomical study in the area of the functional products of clothing, since the support of this type of products, is the human body that is a three-dimensional and articulated structure, and as the garment performs practical functions, when it is projected, one must know the perceptions caused by the main lines of the body, since it must be considered that the process of developing a garment starts from the observation and characterization of the body [16].

There are three types of anthropometric dimensions: static, related to the dimensions of the still body, the dynamics linked to the movements of the body parts, and the functional that involves the joint movement of other parts of the body and to obtain the measurements is fundamental the establishment of objectives such as the definition of the necessary measures; duly referenced anatomical points; choice of measurement methods; selection of samples; implementation of statistical measures and data [17].

The ergonomic studies will help the general clothing area in the creation, evolution and solution of functional clothing products projects of daily use in the most differentiated tasks that are developed at any moment, when considering the well-being of the man in the accomplishment of tasks of the day-to-day ergonomic studies are important, since they will contribute to the projects of development of products of Fashion are understood with differential of quality [18, 19].

Ergonomics of clothing products can be understood as being the studies of the relationship between man and his work, equipment and environment and in particular the application of knowledge of anatomy, physiology and psychology in solving the problems resulting from these relationships [18].

In the Fashion / Clothing industry, a product is not just an object itself. It means the possibility of affirming individuality in a group and the relation of "status" - values, with the environment and its interlocutors; in this way, a project of an objective product, a dynamic interdependence between the relationships of the individual system / clothing

/ relationships / social codes, in an attempt of an ideal functioning of the elements for ergonomic product designs. Although Fashion products are developed industrially, based on "standard" tables of the target audience, in order to cover most of them; the scope becomes narrower, and the reasons that limit this range are, to a greater degree, the intimate relationship established between the use of the product and the human body. The wide diversity of clothing styles and segments, the launching of products without marketing tests in the face of the high cost of these tests, and the ease with which a new idea is copied, there is always a consideration that the Fashion / Clothing product is exhausted in the as it is appropriate, once used loses the characteristic of being novelty, is no longer "new", ceasing to be Fashion [18, 19].

Thus, there is an intimate relationship between the Ergonomics of functional clothing products, the Usability, Wearability and the Comfort of them.

2.1. Usability

Usability and the principles of ergonomics are associated with the way a garment product has to wear the body, and usability should not be sacrificed by the appearance of the product (although this feature plays an important role in the process of communicating with the user) average which is a basic requirement for the competitiveness of the product, a commercial ally that increases sales, so the so-called "aesthetic appeal" will contribute to the success of the products, when it respects the expectations of the user, not only contributing to the fact that clothing is an easy product to be used but with the affectivity that occurs during the process of use, caused by the satisfaction of the wearer of a garment. The particularities of the body's involvement with clothing are translated through the comfort and well-being feelings of the wearer of that clothing, so the usability formulates performance goals for the product at the beginning of the process of creating garments [20].

So when a user is wearing a garment that is perceived by the user as not valuing the aesthetic factor, either because the garment does not "fit well" on the user's body or because of other reasons, users often report a feeling of uneasiness and discomfort, followed by the desire to change clothes as quickly possible, but if, on the other hand, a garment is well designed observing the desirable qualities, the person feels comfortable, experiencing the session of the body and clothing to merge, this being his/her "second skin" [20].

According to ISO 1981 [28, 29] usability is defined as: “[...] the effectiveness, efficiency and satisfaction with which specific users achieve specific goals in particular environments”. When the objective of a project is fulfilled, Effectiveness is achieved, that is, Effectiveness is achieved when a garment, designed to perform a certain physical action, allows the individual to perform in a natural and safe manner. Regarding Efficiency, “[...] this refers to the amount of efforts that the individual accomplishes to achieve his goal”, so if the product of the clothing was designed for the person to perform a certain professional task, with strategic devices to facilitate the fulfillment of the work, and if this was accomplished, then efficiency is achieved, so we can state that the concept of achieving efficiency for the fashion / clothing product is very comprehensive, especially with regard to aesthetic and symbolic, as in the case of Satisfaction, as this is related to the level of comfort and acceptability of the users when using the clothing product, therefore Satisfaction is considered as a very important aspect of the usability of the clothing, since it involves the user’s feelings about the product, with respect to the comfort and acceptability that the garment transmits to them. Whenever the garment facilitates the body to assume a position of comfort and pleasantness, for certain physical action such as walking and moving the arms, without restrictions will cause Satisfaction to the user of that garment [20, 21].

In sum, efficiency and efficiency are components of more objective and performance appraisal, while satisfaction is more significant, since the characteristics of the degree of subjectivity are:

- Isolated aspects - feeling of discomfort;
- Neutral aspects - no discomfort;
- Positive aspects - sensation of pleasure, emotion and predilection;

Within the scope of application, there is no suitable component with the type of comfort, giving rise to considerations of dimensions other than physical comfort, so that use is interconnected with computer systems, although you are already seeing an increase to products and services still showing some departure from the apparel product [22].

2.2. Wearability - Ergonomics Assessment Metrics

In order to minimize the gap between usability and apparel products, the definition of usability and its field of use has been appropriated through a conceptual transposition into wearability.

First of all, it can be useful to make an approximation between the concepts of usability and wearability, i.e., DRESS and WEAR which can sometimes be used as synonyms.

Thus, the verb TO WEAR has as meaning: to have on the body or to reduce the quality of the appearance by constant use.

And the verb TO DRESS usually means: to put on one's clothes.

Therefore, at an initial approach it can be said that a particular individual wears a garment since he/she wears that garment while it remains wrapped around his/her body.

The need for a term like Wearability is due to the fact that some specifics are noticeable in dismembering the word dress:

1. cover (up); clothe - action of wearing a particular garment
2. wear as clothes, wear, dress - action of being dressed in a garment
3. fit the body (a piece of clothing); fall - adjusting the garment to a body

The factor that impels us to analyze the approximation between wearability and usability relates to the fact that the incorporation of the parameters of effectiveness, efficiency and satisfaction of usability as well as the quantification through specific metrics for each of these parameters. Since several authors use the term Wearability when referring to ergonomics in garments, i.e. when approaching methodologies for designing and developing garment collections, Wearability tests are used to evaluate potential problems [23].

Gho (2014), when designing a bra for mastectomized women to perform physical activities, stated that he evaluated the Wearability of said bra although he considered as Easy only the ease of wearing and undressing [24].

According to Gersak, in the light of ergonomics there is a direct relationship between wearability and the behavior of the garment when worn, as well as relating wearability to all activities and movements performed by a body, the fabric and the process. creating and producing clothing products [25, 26].

Thus, based on ISO 9241-210: 2019 Ergonomics of human-system interaction - Part 210: Human-centered design for interactive systems, wearability was defined based on the definition of usability as the way a garment can be worn and worn. by a particular group of users in order to achieve specific objectives, effectively, efficiently and satisfactorily in a given context [22].

Using the definitions of usability parameters, a transposition was made for wearability as shown in table 1.

TABLE 1: Usability Parameter Transposition (ISO 9241-210: 2019) for Suitability; Source: [22].

Parameters	Usability (ISO 9241-210:2019)	Wearability
Effectiveness	Relationship between user goals and the accuracy and completeness with which these goals can be achieved	Relationship between users' goals when wearing a particular garment and the accuracy and completeness with which the goals are achieved.
Efficiency	Relationship between the level of effectiveness achieved and the consumption of resources or effort applied. If the effort is low, the efficiency is high.	Relationship between the level of effectiveness attained when wearing a garment in a specific contest and the consumption of resources, and the resources are related to the human effort required during the act of dressing, adapting and undressing the garment, as well as the effort required for the wearer to stay dressed
Satisfaction	When users do not feel the discomfort and how to adapt to wearing the garment	When users do not feel the discomfort when wearing a garment in a certain context and their well-being (comfort) when wearing a garment

In addition, the parameters of Usability can also be set based on those of Usability as can be seen in Figure 1.

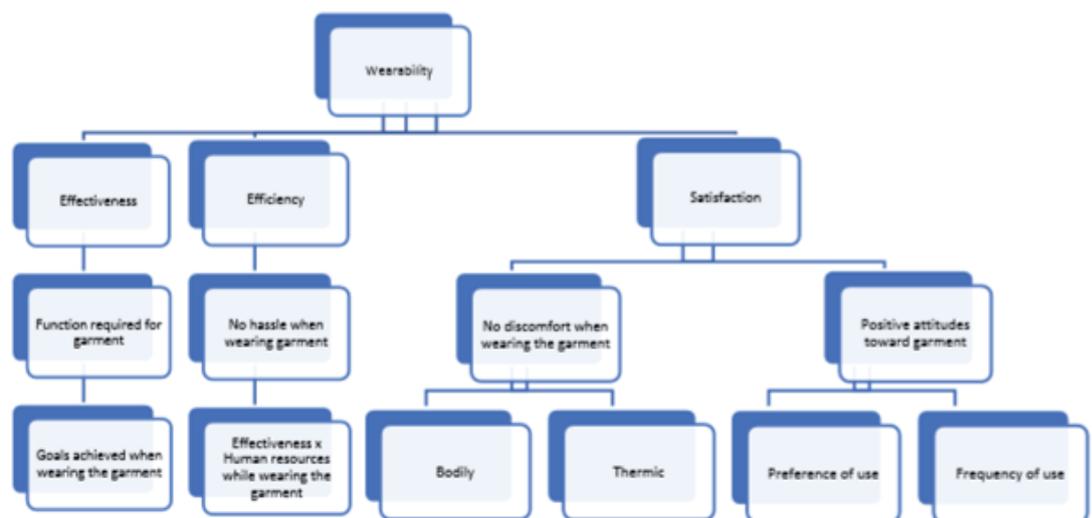


Figure 1: Theoretical and Methodological Scheme of Wearability; Source:[22].

Looking at the scheme and the scope of the Wearability we have that the Effectiveness is related to the function for which the garment is designed and the function for which it is intended, should for each type of garment identify the main functions. taking into account the user interaction / environment of use. Efficiency, on the other hand, is

related to the small or lack of effort when wearing the garment in a certain environment of use, which can be translated by the ease of wearing, adapting the garment to the body and undressing and the adaptability in optimum conditions when wearing the garment [22].

A garment needs to accompany the stretch that the body skin is subjected to when contact is made directly - garment / human skin but if not direct the garment should allow for further expansion as movements will lead to changes on the surface of the human body and direct impacts on the garment's performance / behavior, thus giving rise to folds and wrinkles resulting from dimensional changes that will also be influenced by the fabric with which the garment is made [25].

In the case of Satisfaction, the evaluation factors were outlined assuming: the degree of freedom of physical and thermal discomfort that the wearer of the garment in a given environment; the positive attitudes felt by the wearer when wearing the garment by the preference and frequency of wearing the garment in a particular environment [22].

It is proposed by several researchers that Wearability is one of the dimensions of ergonomics, directed to the study of interaction between the functional objectives of a garment and its anthropometric characteristics of the user in a specific environment of use. Therefore, by defining Wearability as the extent to which a garment can be worn and worn by a particular group of users in order to achieve specific goals of effectiveness, efficiency and satisfaction in a particular environment, it will make possible the evaluation and identification of metrics for each parameter and their application in assessing garment unemployment during wear and user satisfaction [22].

2.3. Ergonomic Clothing with bio-signals Sensors

Due to the high degree of innovation observed in textiles today, functional clothing products have emerged that use bio-signals sensors to monitor an individual's health status, where sensors are integrated into textiles and provide a discrete method of continuous monitoring of physiological parameters during daily activities and where non-invasive chemical body fluid analysis is a new and exciting area of wearable personalized health care systems [27].

The BIOTEX project falls within this theme, a project funded by the EU as the goal of the development of textile sensors to measure the physiological parameters and chemical composition of body fluids, with particular interest in sweat. Thus, a portable detection system was developed that integrates a textile-based fluid handling system for sampling and transport with a number of sensors including Sodium, conductivity

and pH sensors. Sensors for sweat rate, electrocardiography (ECG), electromyography (EMG), electrostimulation (EE), respiration and blood oxygenation were also developed. For the first time, it was possible to monitor a series of physiological parameters along with the sweat composition in real time. This was done through a network of portable sensors distributed around the body of an individual. This has enormous implications for the field of sport and human performance and opens a new field of research in the clinical context [27].

The integration of bio-signals sensors into functional wear products allows continuous monitoring of a person's physiology in their own natural environment. Currently, existing health monitoring systems that use electronic textiles are primarily intended for applications based on measurements of physiological parameters such as body movements or ECG or EMG or EE [27].

With the development of electronic miniaturization, the so-called clothing computers will soon become a reality, since their use for the construction of functional apparel products capable of monitoring people's health is already a reality, although serious difficulty: the development of sensors capable of capturing our vital signs [27].

2.4. Market of wearable products

“The global smart textile market size is expected to reach USD 5.55 billion by 2025, registering a CAGR of 30.4% over the forecast period, according to a new report by Grand View Research, Inc. Global demand for smart textile is mainly driven by increasing penetration of smartphones and other high-tech or smart devices, such as iPods.”[33]

A number of new solutions have been introduced in the market in order to lead a healthy life, a link between man and his body is essential. So, this relationship between social connection and health outcomes is the central reason why Myant Inc., the world leader in Textile Computing created the Skiin Connected Health and Wellness System, where continuous monitoring of ECG*, stress level, sleep quality, activity, temperature, among others (Figure 2). Other metrics is one of the most efficient and reliable ways to prevent potential health problems. This system provides a continuous connection with the human body, incorporating the ability to measure biometrics directly into everyday clothes. The system includes a variety of clothing options that can track your health, including underwear, bras, shirts and sleep masks, thus offering the option of 24/7 monitoring. These garments connect to the Skiin App, running on the Myant platform, analyzing your data and providing advice on lifestyle changes to improve your wellbeing, and you could share this information with your Circle of Friends or Family ensure you

are never alone on your journey to better health by improving the way we take care of each other (Source: Myant's, 2019).



Figure 2: Example 1 Myant Inc.



Figure 3: Example 2 Myant Inc.

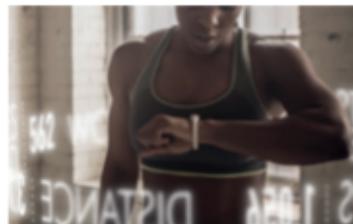


Figure 4: Example 3 Circuitex.

Other example is Myant's knee sleeve was designed to aid in post-injury and post-surgery rehabilitation of the knee. Sensors knitted directly into the sleeve have the capability to sense range of motion, activity, and EMG signals, helping patients and practitioners monitor and optimize the rehabilitation process (Figure 3) (Source: Myant's, 2019).

CIRCUITEX™ provides highly-conductive properties while maintaining the soft and flexible nature of fabrics, instead of using hard plastics or polymers. Products powered by CIRCUITEX™ are used in body monitoring, shielding, and heating for both hi-tech and consumer markets (Figure 4) (Source: Circuitex, 2019).

Other products and example were presented in the big exposition of Textiles in Frankfurt, Techtextil which occurs every 2 years (Figure 5).

Anastasova et al. [28] reported the development a wearable multisensing patch for continuous sweat monitoring with biosensors. The system (Figure 6) can also transmit

(size), ease of movement and application of anatomy, anthropometry, biomechanics, physiology and psychology. Therefore we think that as a more in-depth study of the influence of comfort on garments with the integration of biosignal sensors will be one more variable to take into account in this research [30–32].

4. Conclusion

The principal aim of this paper was to provide a comprehensive, state-of-the-art review and synthesis of the field of Ergonomics and modelling of functional clothing products with biosignals sensor integration, regards ergonomics, usability, wearability research issues in this paper, and some examples applications in the market of biosensors in clothing and accessories. These issues were addressed through dividing the paper into many sections and sub-sections where the relevant conceptual and theoretical subjects as well as thematic and topical categories were adequately elaborated on and thoroughly discussed from a variety of perspectives. We study also the market to understand what problem need to resolve or need to more studies. One of that are develop clothing or accessories and study biosensors application of observation and measurement of body movements, confirming that even without considering the application of muscular force, the simple movement of the body segments (arms and legs) causes dimensional changes, which result in different numerical measures take account the physical criteria: usability, wearability and comfort with different criteria of body movements.

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