When Human Body Meets Technology: The Designer Approach to Wearable Devices

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The huge impact of emerging technologies has been changing population's capabilities (physical, sensorial and cognitive) and lifestyle (works, leisure, living and social interaction).

Currently there is a great inclination to modify sport and well-being concept by changing the technology in 'wearable'. Wearable technology represents a potentially large and rapidly increasing research and development area, involving several cross-disciplines such as biology, physiology, physics, chemistry, micro-nanotechnologies and material sciences, industrial sectors like medical devices, electronics, microchips, textile, telecommunications and engineering disciplines. Such devices can perform functions such as sensing, communications, navigation, decision-making or actuation.

The paper will describe an approach that is the result of a combination between different approaches (design thinking, participatory design and ergonomics). The effectiveness of such an approach is shown through case studies. The text will picture the role of technology in human body changing and perception, the ergonomics, the wearability issue for a better approach in designing wearable devices, a succession of inspirations for new products and that can be interesting for designers because it brings people and their experiences together at the core point of an innovative approach.

***Keywords**: Paper format; instructions; use of template*

Introduction

Wearables refer to a class of devices really integrated in daily life, used all the time, wherever the user goes. There is an important distinction to be made: wearable has to be actually *worn*, and not just carried or held. A wearable needs to both work and look good and be worn in the same way

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the user wear clothing in order to achieve the paradigm *anytime, anyplace, by anyone* (Marculescu, 2003).

Although there is a wide range of commercial wearable devices there are few products, which truly become ubiquitous and accomplish end-user real needs.

User doesn't really understand the advantages of wearing such a device and mainly he feels uncomfortable and perceives a sense of alienation wearing it. This happens because wearables are not thin, flexible, adaptable, attractive and appropriate for housing the body yet. In order to become wearable in the same way of a t-shirt or pants, they have to be designed to be *worn on the body*.

The expression wearable device refers to electrical or mechanical systems, which are worn on the human body by means of incorporation into items of clothing, or as an additional apparatus, which is fixed, by straps or harnesses.

This kind of device is made up of 'wearable' sensors. Wearable sensors and systems are defined, as wearable sensors/actuators and sensor-based communicative systems that can monitor and/or stimulate, and/or treat, and/or replace biophysical human functions.

Due to the intimate interaction between technologies and human body, the mobile electronic devices has created the potential for wearable technologies which are mostly embedded into garments or accessories that function constantly and are worn comfortably on the body. Although wearable technologies are seen as solutions to create a more comfortable usage of technology, the designers should approach embedding technologies on human body in different levels which are both physical and social.

Starting from the human and spreading to the society, the wearables should be taken as interfaces which are not only the most intimate artefact to the human body but also the first surface which they are in contact with others and the environment. While filling the gap between technology and human body, wearable technology also introduces new social concerns, as it can mediate the ways in which a person is perceived by others, interacts with others, and manages his/her own physical space.

Besides, new technologies simulate body functions and strengthen the organic features. Clothing and prosthesis are instruments thanks to which body redesigns itself. For this reason the wearable should be not an overlapping structure or close architecture but an enveloping film, 'a second skin'.

The human which is the main actor of the social life is now surrounded by numerous technological devices which enable him to connect, discover and learn in every condition and place.

The contact with digital technologies changes human body. It becomes a fluctuant body, which crosses the border and enlarges its perception. Technology that invades the body transforms the clothes, accessories and ornaments. The body's limits dissolve and it becomes expression of the technologies.

'Wearable Computing' as a technology deals with computer systems worn as unobtrusively as clothing.

The development of a wearable requires a study on placing objects on the human body with regards to mass, size, shape, mechanical properties.

In the design of wearable device the main issue to face is wearability that literally means ability to wear and concern the physical shape of wearables and their active relationship with the human form. Designer has to address the big challenge to shape the technology in a desirable and acceptable way for the user. For these reasons it is necessary to create a shared language thanks to which designer is able to communicate with researchers coming from the relevant areas of expertise. He has to understand the complexities of such a class of products and have the skills to talk with competence with a disparate mix of background involving ergonomics, textiles, manufacture, engineering, medicine.

Technology and human body

Today the technological progress has extended the capability of the senses of the human being, that moves towards a stimulation and extension of the sensoriality. Sensorial experience has become now an integral part of whatever type of planning that involves technology. The universe of machines, of ICT and of biotechnology has produced new ways to perceive the surrounding reality and the frenetic development of science, strengthen by technological application, has given life to new and unexpected scenarios and possibilities. The development of medical science in the field of bioengineering, of aesthetic surgery and biogenetics, has brought into question the own organic nature of the human being, paving the way to the advent of a hybrid being with inedited characteristics, technologically characterized. In this point of view the body becomes the surface to interpret, to sign, and appears as a construction, resulting from a project, fruit of a strategy: being a artefact.

Clothes, products that we wear, become prostheses of the skin, of its seductive and communicative power. In this way is not clear anymore where the body ends, or which barrier distinguishes the diversity. On the surface goods meet biology and anatomy.

The body itself becomes always more technological: from the wearable computer of 'intelligent clothes' to the incorporated computer (display on the retina). The body becomes by itself expression and representation of innovative images and functions through technology.

The continuous technological development brought to the birth of the wearable that, being a construction surrounding the body, on the body, of the body, should be really as a second skin.

By being a second skin wearable device destabilizes the barriers between body and clothes and becomes cloth, while the cloth, textiles and objects become more and more similar to the body and imitate its characteristics of portability.

Technology has always had a role in extending capabilities in work, leisure, social and recreational events, and in our journey into, through, and from these worlds. We live in an era characterised by new media, low-cost computing power, client server architecture, miniaturisation, and high volume data storage. In this new scenario, technology exists in interaction with their surroundings and can't be anymore considered as an isolated aspect.

The development of always more sophisticated technologies, guaranteed by the vertiginous progress of science in the fields of transmission of information on one side, in the field of bioengineering and biogenetics, and in general of medical science applied to the manipulation of the individual, has comported a real and proper perturbation of the constitutional dimensions of the human existence.

The human being assumes individuality deeply influenced by technology because media has permeated its natural barriers with the external world.

In a constant flow of information that determine human being essence, the corporal container revaluates itself through technology itself, in pursuit of new standards of perfection and uniqueness, what ends up resolving itself only through forms of homologation.

The body becomes a working machine that tents to the world of prostheses, and to instruments that dilate the moving, manual, intellectual capacities and its senses.

It is a body to reconsider and by consequence all what has been in contact with it, is deemed to evolve always more towards a system of

corporal prostheses, able to elaborate data, and to supply services. The clothes and accessories are always more populated by bits able to guarantee our wellness, our health, to represent us and to make us communicate easily (W.Whitman: body electric).

These changes have a deep impact on designing wearable technologies and have to be faced through an user centred approach because it makes designer aware of user needs. Designers have to take in account of how to avoid potential sense of alienation towards technology that requires to be converted in product requirements by meeting user expectations.

Hereafter with the term needs authors will refer to the set of goals, purpose and objectives of end-user. Understand, meet and analyse user needs in design process means to answer questions such as:

- Who is the final user (gender, age etc..)?
- In which contest the product will be used?
- What do users want to accomplish using the product (requirements and features)?
- What are their overall goals?
- What do users need from the system to accomplish these goals?

The approach to wearable devices

When designing wearable technologies to understand the needs of potential users/consumers become crucial.

Wearable devices as a technology deal with computer systems worn as unobtrusively as clothing. As such, wearables further effect the person's interaction with his own body bus also with the world.

Consequently technology has to be shaped by consumer choices also in term of social impact, for example workers wearing special glasses with a screen attached to them get a different perspective on their surroundings and as a consequence they treat it differently and behave in it in a different way.

In this sense, in order to succeed in wearable field, researching user needs, (in term of requirements of the final product) and focus on social impact by insisting on a human centric design is essential.

This is an approach typical of the user centered design (UCD) a design philosophy where the end-user’s needs, wants and limitations are a focus at all stages within the design process and development lifecycle. Products developed using the UCD methodology are optimized for end-users and

emphasis is placed on end-users needs and expectations from the final product. (International standard ISO 13407)

In an UCD approach, users appear as the ultimate experts, those who can properly assess design prototypes, propose changes, and ultimately, integrate end-products within their routines. For many years product designers have been aware of how important users are within the design process. Incorporating the 'wearer' into the design process will be essential for designing appropriate wearable systems, which are acceptable to people outside the 'wearables' community.

Young designers need to know an approach, which is able to identify the right relationship between the user and the wearable device, especially in the project with features, such strong social value, use of innovative materials and technologies, and finally significant impact on quality of life.

Creating wearable computers that fit well on people's bodies is not easy to do. This is because our bodies are soft organic shapes and are constantly moving. The internal components to any computer contrast that with hard rectilinear shapes. Resolving this conflict between human bodies and computer components takes some work but it can be done. The development of the wearable device design needs to accomplish the requirements of comfort and adaptableness connected to the anatomy of human body. To focus on end-user's needs designer has to look at the relationship between design and the body, addressing the implications of anatomical features shape, physiology and psychological impact wearables.

For a design methodology to claim that it is inclusive or universal it must address the real requirements of the body from the outset not design for the technology then place it in a softer shell. It is the impact of our anatomy on our shape more correctly termed morphology and consequent physiological effects as a result of our environment (whether that is a building, the outdoors or our clothing) and what we do there, that affects our needs and us. Anything a designer does should take into account our anatomy and its impact on our physiological needs. The form follows the function is a principle associated with modern architecture and industrial design in the 20th century. The principle is that the shape of a building or object should be primarily based upon its intended function or purpose. This classic phrase 'form follows function' is very well known in design, but its origins are essentially from biology. If we look at the body, we can see that form follows function. The knee allows movement only in one direction. I can flex and extend, whereas a more mobile joint like the shoulder allows for greater movement; but with that comes a greater vulnerability it is more

likely to dislocate than the knee. Looking at the inter-relationship between the body and smart clothing or wearable technology is an essential part of the design process, not just in terms of fit but of how the wearables affect the body's ability to function. To fully understand the needs of the end-user, in the field of wearable devices, a designer should have some knowledge of human movement and of human physiology. It is also important to recognise that a sport or occupation can affect the body; indeed, that wearing anything can affect our function and, a longer period, lead to physical changes in our body. These aspects require a study about the ergonomics and 'wear' 'ability'.

International Ergonomics Association (2000) provides the following definition:

> *Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.*

Therefore, the study of the anthropometric measures of the human body and of the equilibriums between the various zones of the body, becomes essential. The other issue to deal with is 'wearability'. Wearability literally means ability to wear and concern the physical shape of wearables and their active relationship with the human form. All the kinds of design is around the man, his physical and psychical abilities, his limits and necessities, and the type of activity he has to face. Every time, the user is the starting point of a project. In this field much more than in all design processes these aspects get necessary and fundamental. The study of the anthropometric measures of the human body and of the equilibriums between the various zones of the body, becomes essential. The target is to define the interaction between the human body and the wearable object, by trying to figure out a flexible shape without interfering with human motion. Wearable products need to fit the three-dimensional shapes of the dynamic human body. A designer has to design a wearable computer, which is able to fit the human body and designing the component placement on a printed circuit board to meet the complex and organic shape of the computer shelter. The goal is the exploitation of the device as a natural and consolidated form of contact between the body and the object. In this case the interface is expressed as a place of exchange of physical information moving from one place to another. Inserting the device in a common context, like clothing, the

function of monitoring becomes more understandable because the user reacts in a usual way. Also, it is possible to have continuous and long-term contact between the body and the clothing. The aspects that complete a wearable system with the necessary characteristics are principally focused on the dimensions of the body part and the user, with notable individual and cognitive variables. The brain perceives the presence of the sensors much more than the body, and such perception is modified according to multiple reasons, tied to the physical state and the development of the body. This perception is also associated with variations in dimensions and form so the human body is taken as a whole in order to create the accessibility of the object on it. Designing a wearable system needs to find inspiration from the human body, in respect of the many ways that form follows the function. Designer's objective is to achieve an 'anatomically correct design'. A wearable is a second skin for the human body, a protection shell, a housing that changes body shape. The wearables fix body silhouette inhibiting or making easier movements and postures through ergonomic and enveloping shapes. The target is to define the interaction between the human body and the wearable object, by trying to figure out a flexible shape without interfering with human motion. It's fundamental for a product in close contact with human body to be totally adaptable to human anatomy. From this point of view, the wearable is not an overlapping structure or close architecture but an enveloping film, 'a second skin'. A wearable needs to be designed to be worn on the body according to the principle the form follows the function.

The Institute for Complex Engineered Systems (ICES) developed a study about this topic, 'Design for Wearability', by outlining a design guideline for wearable products. The wearability parameters set by the Institute of Complex Engineered System (ICES) are:

- formal language: the way the different shapes blend with each others;
- size: cross section variation of human body;
- human movement: the way the form of body changes whit simple motion;
- unobtrusivity: body areas less obtrusive for wearable products.

They also found the most unobtrusive areas for wearable objects: collar area, rear of the upper arm, forearm, rear, side, and front ribcage, waist and hips, thigh, shin, and top of the foot (see figure 1).

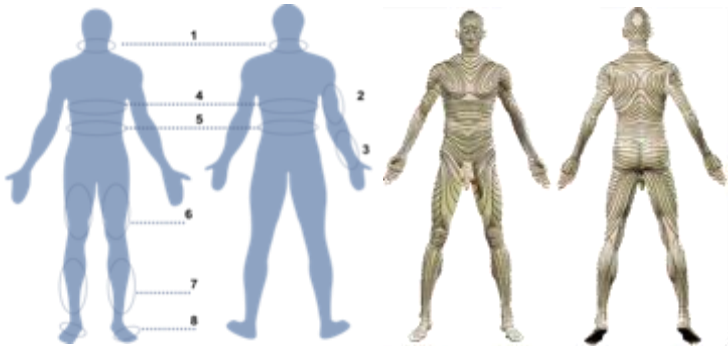

Figure 1 Ri-elaboration of unobtrusivity areas by Gemperle at al. (left) Langer's Lines (right).

Starting from these studies we have identified a surgical theory, which provided a scientific approach to wearables. We believe that the identification of design guidelines could be improved by matching the unobtrusive areas with Langer's Lines. A Langer line, called also *cleavage lines*, is a term used in medical field to define the direction within the human skin along which the skin has the least flexibility. The direction of these lines is very important for surgical operations.

Surgeons during operation cut the body in the direction of Langer's lines, because these types of incisions generally heal better and produce less scarring (see figure 1 on the right).

A user-needs driven design methodology is proposed. It addresses a breadth of technical, functional, physiological, social, cultural and aesthetic considerations that impinge on the design of clothing with embedded technologies, that is intended to be attractive, comfortable and fit for purpose for the identified customer. If a product does not look good or work, the customer will not be satisfied. Form embraces aesthetic concerns and the importance of respecting the culture of the end-user, and Function embraces the generic demands of human body and the particular demands of the end user or activity. In order to aid decision-making, the design process requires an overview of the profile of the target customer in terms of gender, age group, and an indication of the proposed category of smart textile product to be developed. Successful wearables design is the result of designers becoming thoroughly conversant with the culture, history and tradition associated with the particular end-use or range of activities. A design that is considered attractive for a wearer from one community or age group may be totally unacceptable for another. Concerns social and cultural

issues, historic context and tradition, corporate and work culture, participation patterns and levels, status, demographics, and the general health and fitness of the wearer will impinge on the design of smart clothes and wearable technology. An investigation of the lifestyle demands of the wearer, in terms of behaviour, environment and peer group pressure is needed to provide an awareness of both clothing requirements and the application of emerging wearable technologies that have appropriate functionality and true usability for the identified user.

This is and approach typical of design thinking' 'a creative human-centered discovery process followed by iterative cycles'. In other words, design thinking is human-centered innovation. Design Thinking has been considered the quickest organizational path to innovation and high-performance, changing the way creativity and commerce interact (Brown, 2008)

Design thinking shapes the design process in five phases but the core objective is to gain empathy with and identify the specific needs of individuals (e.g., Kembel, 2009).

Figure 2 Design Thinking approach.

Nobody can design without paying attention to user needs. For this reason concepts should be realized, (prototype, mock-up, three-dimensional or computer model) if the need is truly fulfilled, the design is legitimately evaluated, and the design activity have been purposeful and worthwhile.

According to the authors a designer can approach a wearable using design thinking approach and applying to the project development two useful tools:

- Unobtrusive areas found by Carnegie Mellon
- Langer Lines

Case studies

Hereafter three projects developed in a workshop by students of Master Degree in Fashion Study at School of Design of Politecnico di Milano will be described. The projects showed the application of the approach described by the authors.

1. A safety suit for kids
2. A t-shirt for runner
3. A shirt to practice box.

The students were asked to design an advanced product for sport and or safety exploiting the potentiality of wearable technology.

All the project were developed following the design thinking approach and using the guidelines to achieve wearability:

Understand: Students carried out an analysis to figure out needs and requirements from the end-users. All the projects were developed just in four weeks so they had limited time for the ethnographic research. The teachers (authors of the presented paper) suggested to carry out a preliminary bibliographic research and then to interview at least ten persons. The interviews were framed through a questionnaire with the aim to understand the profile of the user for whom the project would have been designed (men, women, babies, runner, amateurs, boxeurs etc..) the purpose (safety, self-improvement, training, competition, self-motivation) and the occasion of the use.

Define: After the analysis of the context and the interviews they set the product requirements (brief) and check with users they interviewed if those requirements met their expectations.

Ideate: A brainstorming session helped students to develop their idea. They designed both the device taking in account body shapes and unobtrusive areas.

Prototype: Students were asked to create a mock-up in order to show the wear-ability of developed projects. Making a real prototype gave them the ability to immediately test and see the results during the design process while trying the prototypes on their own bodies. Indeed because of lack of time they could not test the results on the final user.

1. A safety suit for kids.

With this product students wanted to respond to parents needs to live the holidays at the seaside serenely and happily. In summer, when little kids try to learn how to swim, parents are always afraid of hazardous situations.

Parents need to be sure that their baby is safe in every moment. With the interview the students understood that the user is this case was both the parents and the baby. Indeed, the product consists of different interactive devices.

The first item is located inside the baby's swimsuit and it consists of two piezoelectric sensors placed in a specific band at the base of the breastbone. Isolating silicon protects them. Their function is to monitor the heart rate, estimating the little mechanical stresses, and the respiratory frequency, evaluating the variation of chest's circumference. The values, gathered by the sensors, are transmitted through Bluetooth technology to a waterproof solar bracelet and eventually to a smart device (as smartphones, tablets) with a specific application. The bracelet emits sounds and vibrates in case of emergency (not normal values), whiles a buzzer, integrated in the swimsuit, emits an acoustic signal as an alarm.

Another inserted device is a GPS receiver, placed in the same band of other sensors that recognize the baby's location when activated using the specific application. The location data transmitted can be displayed on a map in the application. Finally Following the unobtrusive area they placed the entire electronics component on the ribcage.

Figure 3 Safety suit.

2. A t-shirt for runner

The t-shirt here described was designed for runner amateur and especially for those users who need motivation to do exercise. In this case study, some students of the group represented the users.

They designed a t-shirt with a portion made up of LED lights with the purpose to light up progressively according to the amount of calories burned, gradually displaying a predefined colour on the fabric.

They created an article of clothing that also comes with a world of services behind it, starting from a dedicated area on the brand's website that will serve as a tracking record of the progresses made so far by the user, keeping track of the miles run and of how many calories they have burned in addition to showing how much of the led colour present on the article of clothing they have 'unlocked' up to this point.

The colour will, at first, be common to all clothes but, once fully completed, the customer will be able to unlock another one and download it into the device present in the clothes by plugging it into their computer and syncing it with their account. This way the colours will not only be a mean of auto motivating oneself, but also a way to show others how much progresses they have made so far (social impact)

The t-shirt is realized with a removable device that's easy to recharge and makes the garment easy to clean. The whole is able to track how many km users have run and how much kilocalories they have burned, comparing those info with other runners in the same area.

The product was designed with different layers:

- philips' lumalive:
- led fabric that can display a vast arrange of color gradation
- lightweight enough not to be a hyn drance when running
- thin silicon strips printed onto flexible materials that will measure metabolism and performance using embedded sensor

In the development of the product and the realization of the mock-up they were smarts and placed the 'technology' not only following the langer lines but also along the stitching.

Figure 4 T-shirt for runners.

3. Boxing t-shirt for beginners

Through the analysis of box sport and the interviews students understood that due to the speed of the training, one of the problem notified during the box training is the capability of recognize the exactly place where the punch has been done. The identification of the punched areas is an important aspect because some of them are forbidden. So, they developed a t-shirt with light system and pressure sensors. Through a pressure system the t-shirt changes colour in the specific area in which you punch it. The aim of the t-shirt is to help the boxer to improve his/her skills during the training.

The pressure sensors are sewed within the fabric on front of the t-shirt. The graphic of the garment helps to identify permitted areas and to avoid the forbidden one. The training starts by switching the circuit. T-punch design was thought to be fully wearable. Indeed the printed layer of Elastolite is designed following the natural curves of the body, allowing and facilitating the movements during the sport activities.

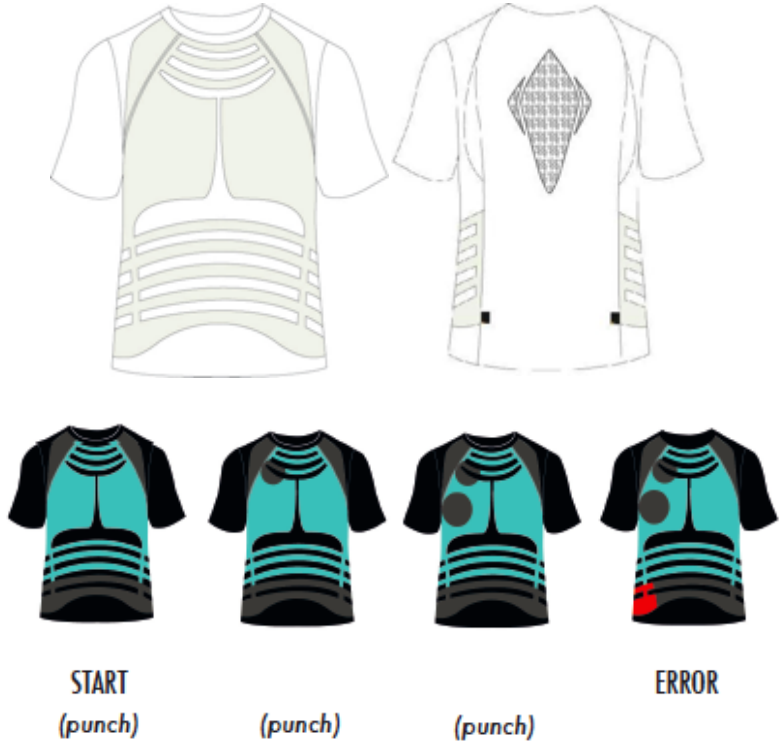

Figure 5 T-punch shirt.

Conclusions

While emerging technology is rapidly getting intimate to the human body in shape of various electronic devices, wearable technology can be a medium to facilitate the integration. The designers of the future technologies should consider the fact that human body is not a singular being but exists with its surrounding and its inner system. To bridge the gap between in and out, wearable technologies can provide solutions where technology is not any more arisen with a hard cover, but as flexible displays on the human body. By giving the intelligence to our garments, they could behave as covers, which obtain an optimum behaviour and increase the quality of life. Therefore, in this experimental study we observed that user

centred design approach could help the designers to better understand the needs of user, whose behaviour is influenced by emerging technologies.

Combining user needs with social needs can bring new perspectives to the role of technology in daily life. The nature of innovation changes: the sphere of technologies and forms bends with sphere of signifies and experiences. Designer, which is a bridge between the technology and the user in order to create user-friendly interfaces, needs to consider the social, cultural and personal changes. By keeping the user in the centred and doing research about social trends and how society is changing designer should be able to generate solutions not only tangible like new aesthetical look, but also focus on intangible values which are felt by experiencing. He needs to be aware of how to turn negative side effects of technology into positive ones, designing more human friendly interfaces and products.

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