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Persuasive Technology as key to increase Working Health Condition. The Case study of a Wearable System to prevent Respiratory Disease

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Abstract: According to occupational disease registries and voluntary reporting schemes in various European countries, the annual incidence of respiratory diseases is estimated to be 2– 5 cases per 100 000 working individuals. Nowadays the use of personal protective equipment is the only way for workers to prevent disease but it is highly sparse. Authors suggest the development of a wearable novel system that, exploiting persuasive technologies can build an environmental sensing networks to share information about user health and work related risks. We want to elicit a conscious behaviour in the user and, consequently, improving the working health condition.
The paper investigates how persuasive technologies work and could change behaviour; describes a user analysis carried out in working environment; then defines the requirements of the wearable system in order to motivate the workers to the use of the PPEs by making them aware about work-related risks and their health status.

Keywords: Persuasive technology, wearable technology, health, human-centred approach.

1. Introduction

A report of the Scientific Committee on Occupational Exposure Limits (SCOEL) highlights that work-related exposures are estimated to account for about 15% of all adult respiratory diseases. Volatile organic compounds (VOC) are - within working environment - one of the highest causes of asthma, lung cancer, chronic obstructive pulmonary disease (COPD) and respiratory tract infections. The last INAIL (Istituto Nazionale Assicurazione Infortuni sul Lavoro) report on occupational diseases showed that the working places with the highest percentage of respiratory diseases are agriculture, manufacturing and transportation sectors. Among them, the manufacturing sector, with 5.172 cases of respiratory diseases in 2014, was the most dangerous one.

In this paper, we refer to an on-going Transnational Research Project (SAF€RA Joint Call 2014) called "POD-Plurisensorial Device to Prevent Occupational Disease" run from July 2015 until June 2017.

POD Project is developed by a consortium made up of Department of Design of Politecnico di Milano, Department of Design Engineering from Delft University of Technology and Comftech s.r.l., an Italian company that designs and manufactures wearable biomedical systems.

The research project aims at developing a novel concept of wearable system to prevent respiratory diseases inside the specific working environment of a coating plant.

According to the International Labour office the prevention is the best way to reduce disease's numbers and improve the workers' health. There are two levels of prevention: (i) environmental monitoring and (ii) the use of personal protective equipment (PPE). The PPEs are mandatory by the law but, despite that, their usage is comparatively sparse. A way to encourage the use the PPE could be to make workers aware of work-related risks they undertake and their health status by exploiting persuasive technologies. Persuasive Technologies are defined as "computer based tools designed for the purpose of changing people's attitudes and behaviours" (Fogg, 2003).

During the research project authors want to investigate how to exploit medical (i.e. wearable monitoring systems for physiological parameters) and military technological solutions (i.e. the electronic nose developed by Nasa) to improve working health conditions. In particular, the aim is to increase - through the technology - the use of PPE by enhancing the users consciousness of their working risks and by generating a meaningful interaction with the device. Technology is useless without providing an interaction perceived as valuable by the final user. Authors are indeed developing the entire research activity by using a human-centered design; an approach to problem solving that incorporates the wants and needs of end users of a product or service in every stage of the design process.

The user has then been involved in the process using design thinking process - a creative human-centered discovery process followed by iterative cycles - that shapes the design process in five phases: empathy, define, ideate, prototype, test. (Brown, 2008; Leavy, 2010; Cross, 2011)

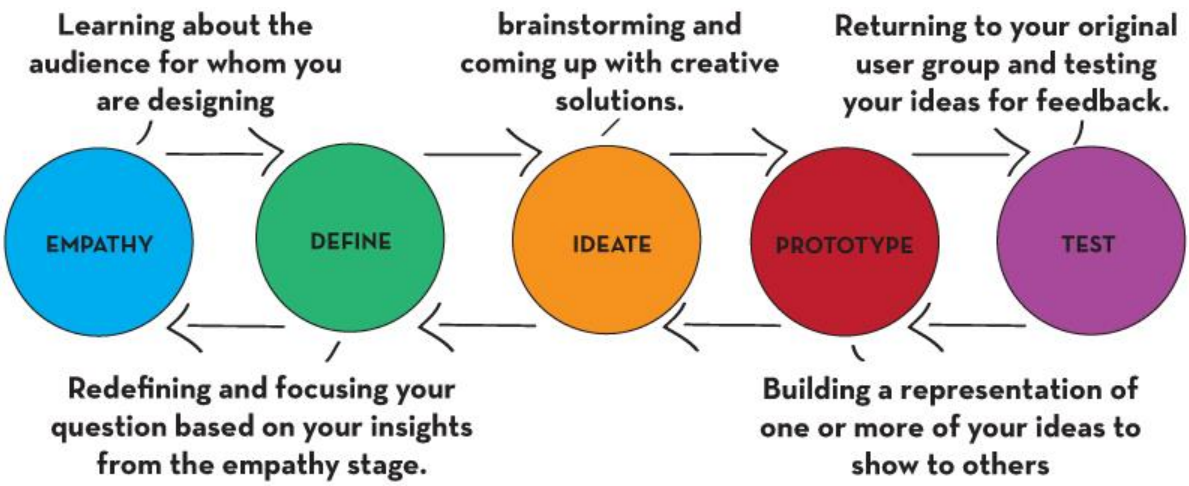

Figure 1. Design Thinking Process

In this paper, we present the first part of the research about the empathy and define phases. Aim of the activity was to define the users' expectations and, consequently, the design requirements for the entire system. The paper explains the results of the empathy phase in term of system features;

define how to give the persuasive technology a “shape” (considered purposeful for the final user) by making it a powerful tool to improve working health condition.

2. Persuasive Technologies

The main aim of this paper is:

- To figure out and define the features and the requirements the wearable system should have to encourage the use of the PPEs;
- To make the workers aware of work-related risks and their health status by exploiting new emerging technologies;

In order to achieve those aims, it is important to understand why, where and how technology is used.

Donald Schön (et al. 1967) defined “extension of human capabilities” as a main goal of technology. The philosopher Peter-Paul Verbeek added the principle that technology is not something that humans work with, but something that is part of being human; technology is not just a pole of the interaction but a mediator between human beings and the World (Bodker, 1989). Different technologies change the way the people behave (interact) and also define the behavior of artefacts, environment and system. (Forlizzi, J. et al., 2004) New Technologies have become deeply embedded in our ordinary everyday experiences by improving the way products and systems, help, inform, engage and or entertain us, coding new languages of communication and interaction. (Smartphone, smart watches, smart meter, run trackers etc.)

As Fogg (2002) stressed, technology can be persuasive and change user behaviours. “Persuasion is a non-coercive attempt to change attitudes or behaviours” (Fogg, B.J., Cuellar, G., and Danielson, 2002) Interactive technologies have been—and will continue to be—created to influence (persuade or motivate) people in different fields of application. Hereafter a list of twelve examples related to the most known applications of persuasive technologies.

Table 1. Domain of Persuasive Technology (taken from Fogg, B.J., Cuellar, G., and Danielson, 2002)

Context of Persuasive Tech.	Examples
Commerce—Buying and Branding	To buy a certain product
Education, Learning, and Training	To engage in activities that promote learning
Safety	To drive more safely
Environmental Conservation	To reuse shopping bags
Occupational Productivity	To set and achieve goals at work
Preventative Health Care	To quit smoking
Fitness	To exercise with optimal intensity
Disease Management	To manage diabetes better
Personal Finance	To create and adhere to a personal budget
Community Involvement/Activism	To be a volunteer
Personal Relationships	To keep in touch with their aging parents
Personal Management	To avoid procrastination

The way various interactive products shape the persuasion and motivation principles will evolve accordingly to the technology advances and as people adopt a wider array of interactive systems for a wider range of human activities.

Although nowadays the most frequent and commercial application of persuasive technology is the use of computers to sell products and services, there is a great potentiality in applying them to increase human health and well being.

New emerging technologies and information Technology (ICT) solutions might be the proper tool to elicit conscious health life style, such as doing exercises (Kidd and Breazeal, 2006; Ruttkay et al., 2006; Bickmore et al., 2004; Goetz et al., 2003; Gockley and Mataric, 2006); giving social support (Kidd et al., 2006; Kriglstein and Wallner, 2005); helping with lifestyle change (Bigelow et al., 2000; Looije et al., 2006).

Furthermore, research on persuasive technology (Fogg, 2002) and affective computing (Picard, 1997) is providing technological (partial) solutions for the development of systems and devices able to cope with health issues and awareness.

Among emerging – persuasive- technologies, the wearable ones have the potential to build motivation by increasing health awareness through timely feedback. (Ananthanarayan, S., Siek, K., 2012) Indeed, Motivation is a key element in any system designed to assist users in changing behaviour.

Wearable technology represents a potentially large and rapidly increasing research and development area, involving cross-disciplines such as biology, physiology, micro- and Nano technology as well as material sciences and industrial sectors like medical devices, electronics, textiles, telecommunication and engineering disciplines. Such devices can perform functions such as sensing, communications and decision-making. (Author 1., 2012)

So far, in the field of health, the wearable technologies have predominately focused on diet and physical activity, such as weight loss, motivating physical activity, maintaining exercise routines, and an overall better understanding of an individual's health. (examples....)

Despite those applications, a wearable system could give more control to the user by focusing on the prevention and helping people to manage their life style. In this perspective, the application would go toward a more user-oriented health consciousness, rather than just toward the diet or fitness fields.

Arguably, one of the strongest areas of innovation in the near future regards the preventive health system (IJsselsteijn et al., 2006).

In several fields, there is indeed a strong need for external incentives and motivations. The research project, here discussed, has the objective of developing a wearable system with preventive and protective purpose. The system shall be a wearable interface for monitoring the workers' health status, the surrounding environment and the potential risk sources, giving them useful real time information and/or alarms. It should also allow data transmission with a body gateway to share information and with a high-level risk management service.

Authors want to develop a new system able to change workers behaviour in order to improve their working health conditions through the monitoring of both themselves and the environment. This way, we can make them "aware" of working and health conditions and concurrently "motivate" them to adopt the PPE.

We can summarize the approach to the system development in three words: self-monitoring, awareness, and motivation.

3. Method

The research project aims at developing a wearable system addressing issues by meeting not only technological requirements, but also user needs with a human-centered approach. When designing wearable technologies it is important to understand the needs of potential users or consumers. The project then develops using a combination between different approaches (design thinking and participatory design).

Taking on a human-centered approach requires an investigation of demands of the workers, in terms of behaviour, environment and peer group. This means to figure out both product requirements and proper application for emerging wearable technologies in order to gain appropriate functionality and true usability for the identified user. (Author 1., Ugur S., 2012)

In this section, authors describe: (i) the Empathize phase from design thinking, with the aim to understand the people for whom the project is designed and the context in which the system will be used; and (ii) the Define Phase where the user needs are translated into requirements for the wearable system.

3.1 Participants

For the user analysis, the choice of the proper participants was relevant. We decided to choose workers of coating plants. This choice is strategic for the project execution for two main reasons: workers of this environment are highly exposed to the inhalation of several damaging agents (volatile organic components, organic dust, chemical contaminants, paints, varnishes) that cause respiratory disease; the high level of proportion between number of operators and sales volumes all over Europe. Thanks to the support of Anver (Associazione Italiana Verniciatura) three SMEs from northern area of Milan were identified.

The three companies perform similar activities within their Coating Plants such as coating of furniture and small-medium mechanical parts. Main reason for choosing these companies was the understanding that in big companies the operation of lacquering or finishing is automated and not performed by workers. Besides, in small companies it is obviously easier to have direct contact with workers and observe their behaviour at work. The chosen Coating Plants have less than 20 employees.

The first company is specialized in finishing and lacquering of metals and polymers, the second one in finishing and lacquering of wood, steel and metal, so is the last one.

3.2 User Analysis: Empathy Phase

The user analysis, performed in each of the three chosen companies was divided into two parts:

- Observation: focused on the analysis of the users and their behaviour in the context of their work in order to understand the way they use the current PPE;
- Interviews: done with workers and employers, in order to understand what is their perception about the risk in the working place working, what is motivating or demotivating them about wearing the personal protective equipment and how much they are willing to accept the advanced protective monitoring system.

Both observation and interviews involved a total number of ten workers and were carried out between December 2015 and January 2016.

The Observation phase was fundamental to immerse into the field of application and have first thoughts about workers behaviour. Thanks to this phase we first learnt that a Coating Plant designed according to the law needs an aspiration system in order for the Coating powder to be taken away by flowing water. In fact, the operation of the coating should take place in coating cabin with an aspiration system. About the PPE, the workers use two different masks: (1) Disposable Protective Mask (with a small valve that helps the respiration) and (2) Reusable Half Mask with carbon filters (solid or liquid particles gas and vapour) (See figure 2).

The selection of the typology of Mask depends on different parameters: Typology of coating, Typology of pollution, Density of Coating Powder and finally the Comfort. The Reusable Mask lasts no more than one month and the filters are changed according to the number of usage hours. After the use, the reusable mask must be carefully placed in a specific box in order to avoid the expiration of the carbon filters.

Figure 2. Disposable Mask (on the left) two typologies od Reusable Mask (on the right)

During one-hour observation (Figure 3) in each coating plant we realized that the workers occasionally use the mask. They use it when they need to paint complex geometry that usually generates a cloud varnish so-called “overspray”. We realized that the decision of wearing the mask is based on personal perception (when they smell bad odour or see and feel the overspray)

Figure 3. Workers in a cabin

The Interviews led in each company were helpful to confirm some findings of the observation phase and to understand better workers’ needs and requirements for PPE and working environment. The interviews were carried out on ten workers, four from company number one, four from company number two and two from company number three, through an open questionnaire.

The questionnaire was framed in four (4) main topics:

1. Working activity and protective equipment;
2. Mask's aesthetic and comfort;
3. Safety perception;
4. Personal devices

About the topic of working activity and protective equipment, all interviewees asserted that they decide autonomously when to wear the mask, which is personal and stored in a drawer. They usually wear the reusable mask for 1,5 hours a day. The decision of wearing the mask depends on their subjective smelling of some annoying odours or on the geometry of the piece. Indeed some geometries are more complex to varnish and tend to create overspray.

Workers are aware that the use of the mask is mandatory but also useful for their health but because of the aspiration system in the cabin they don't perceive it as necessary.

When it comes to the mask's comfort and aesthetic, according to all the workers the mask is uncomfortable due to several reasons such as the rigid elastic connection to the face (too tighten), not breathable material, lack of breathing (the valve is not efficient to achieve a good breathing). They all asked for a new mask designed with more attention to the wearability and comfortable materials.

The interviewees were asked about the perception of safety. Eight interviewees on the total number of twenty are aware of the level of risk connected to the work they do because of the toxicity of the paint. They asserted that the protection level of the mask is good. They would like to have information about the quality of the working place and the personal health condition.

Finally, the interviewees were asked about the possibility of wearing personal device equipped with sensors to detect both their personal parameters and environmental one. Seven of the workers were positive on wearing a mask with some sensors able to detect the air quality and would like to try the personal device to detect the healthy condition (breathing and heart beat) but also have the information through an application on the phone. About the type of information, they would like to know about daily data (environment and personal health) but also seasonal ones. Two workers, (the ones not aware of risks related to the working environment) completely disagreed on having information about them-selves or the environment. They gave us answer like: "I don't want to have any information" "If I had information I wouldn't work anymore". On the other hand, they all would like to know when it is necessary to wear the mask (hazardous condition).

3.3 Results: Define Phase

The results coming from the user analysis are:

- Generally, workers prefer not to wear the mask. That is because they think their work is not that dangerous (they think that the factory facilities are designed well enough to protect them), apart from some specific occasions in which they do wear the mask.
- Workers also do not wear the mask because it is very uncomfortable.
- Workers would like to know more about the health condition of their working activity.

During the observation and the interviews, we surprisingly realized - contrary to our first thoughts - that the most important thing for worker is not the *safety* but the *comfort* of the mask. Workers need to be able to move easily, have a good and wide visibility, to sweat as less as possible and to be concentrated. Requirements for Design imposed respect to the problems described previously, would be:

- Provide filtered, better air quality to workers (mask);

- Offer monitoring and sensing system that would be connected with some sort of device and application with possible alert (portable device);
- Possibly, anti-allergic breathable and light materials;
- Form and dimensions of the product shall respond to anatomy of the user and be as small as possible.

Monitoring system could appear in many forms, from small portable devices to apparel or both. Only possible protection for respiration is the protective mask. Positioning of sensor and its modus operandi could have many possibilities. When it is about information, it should be about simplicity, comprehension of information and motivation that the given information could evoke in user.

The table below displays User's Needs, Purpose and requirements for Design in order to understand problematic of the system and impose precise objective.

Table 2. Design Brief

User's needs	Purpose	Requirements
Need to breathe easier and breath better air quality	Health protection and respiratory disease prevention.	Provide better air quality due filtration of Volatile Organic Compounds.
To feel comfortable and concentrated during the work	In order to work better and avoid potential injuries caused by poor concentration.	Provide comfortable devices, easy to manipulate, put on and remove it. In case that device is part of apparel or it is apparel where to position sensor.
To be aware/informed of the risks in the work place	Raise consciousness of workers; give them a reason to use regularly protective equipment.	Information storage and shearing on personal level; provide information that are understandable and that can be of worker's interest.
To be motivated and interested about his/her health	Better everyday life (personal and professional) and health quality.	Have a graphic representation that can motivate and tell him/her progress results.

The definition of the features and the requirements to give the wearable system met authors main intentions so that, motivate the worker to use the PPE by making it more comfortable and making them aware in real time about work-related risks and their health status by exploiting persuasive-technologies.

4. General Discussion

Fogg (2002) believes that successful products, the ones user will continue to use after the novelty, will be those that incorporate "hot triggers" to help people change their behaviours for the better. According to the Behavioural Model developed by Fogg:

> "For a target behaviour to happen, a person must have sufficient motivation, sufficient ability, and an effective trigger. All three factors must be present at the same instant for the behaviour to occur"

Fogg Behavioural Model (FBM) suggests that, first of all, we need motivation, that is, the factor that thanks to certain ability can "trigger" target behaviour.

Motivation is indeed stimulating people to do the action, or to demonstrate certain behaviour rather than some other. It does not go always in direction "to do", but also in direction "not to do". Motivation can be explained also as a reason for doing certain things or behave in certain manner, or as a desire, willingness to do something. Motives are inner factors that are directing and coordinating people to reach goals (Argyle M., 1976).

In the field of working environment, we faced with the behaviour problem related to the responsibility and the willingness of wearing the protective equipment. We have few questions that should be answered: Could an individual approach like self-motivation generates consciousness about risks the workers occur? How the sense of hazards and injuries could let them understand health risks and change behaviour?

We want then propose a Wearable System able to address the main problem of "motivating" by raising self-awareness about health issues.

Besides the theoretical literature, the generated brief brought to a first overall idea of the system composed by three devices: two able to detect the health conditions of the workers and one devoted to the environmental working condition detection and for transmitting the monitored data to the user in real time (i.e. alert him when an hazardous situation occurs and he is not wearing the mask). We then suggest a system made up of three devices and a simplified application (see Figure below).

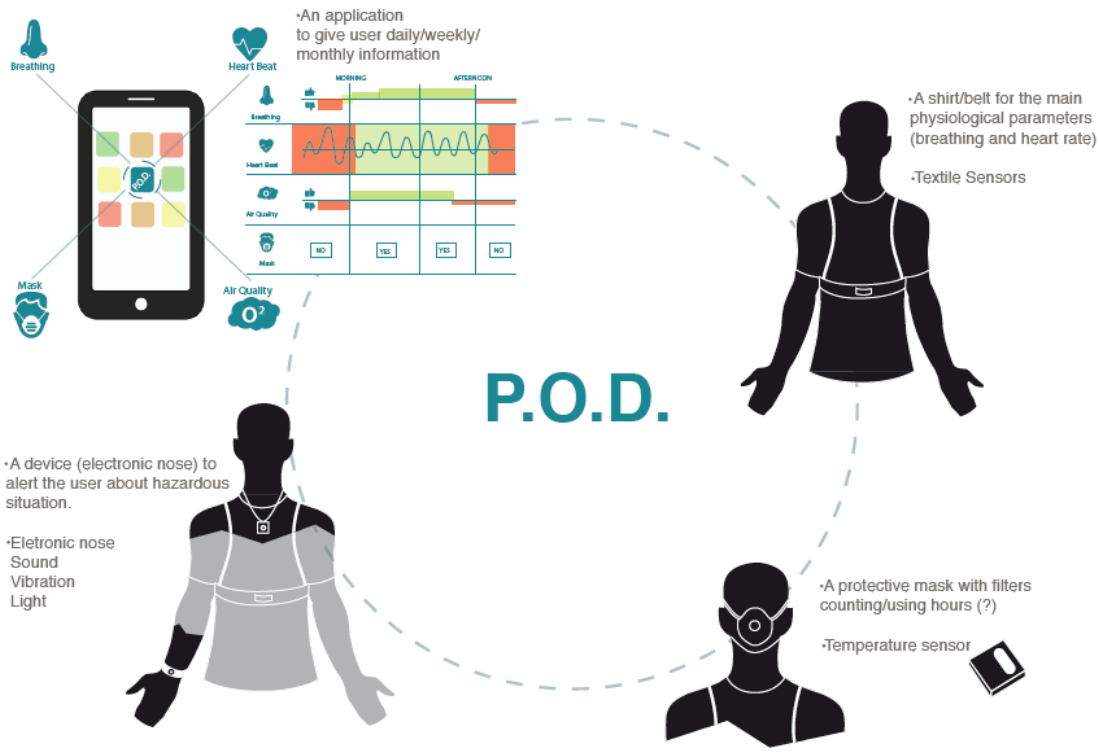

Figure 4. Pod System Architecture and its components

In such a system, the motivation starts from a new mask (equipped with temperature sensor) that will be redesigned with attention to the wearability and comfort, then the motivation will be elicited thanks to a wearable device equipped with a sensor able to alert the user in case of high level of Co2 or gas. In this case, if for instance the user is not wearing the mask he will be encouraged to change his behaviour. A smart shirt will finally make the user aware of his respiration while working.

The mobile application will match all the data coming from the sensing system by communicating the user three simple information:

1. If the mask is worn or not;
2. The level of air quality;
3. The quality of breathing.

The application will increase users' self-awareness. They will in fact understand how their breathing quality decreases especially in certain situation when they are not wearing the mask. The system will help, through the time, to trigger users' willingness to wear the mask generating a conscious behaviour and improving their working health conditions.

5. Conclusions and Further Developments

INAIL report on occupational diseases showed that the working places with the highest percentage of respiratory diseases are agriculture, manufacturing and transportation sectors. Among those, the manufacturing sector with 5.172 cases of respiratory diseases in 2014 was the most dangerous one.

According to the International Labour office the prevention is the best way to reduce disease's numbers and improve the workers' health. The best way to prevent disease is to use the PPEs.

Thanks to an analysis carried out in three coating plants the authors realized that workers are reluctant to wear the mask. We suggested that a way to encourage the use the PPE could be to make workers aware of work-related risks they undertake and their health status by exploiting persuasive technologies. Persuasive Technologies are defined as "computer based tools designed for the purpose of changing people's attitudes and behaviours" (Fogg 2003).

Authors want to develop a new system able to change workers behaviour in order to improve their working health conditions through the monitoring of both environment and themselves. In this way, we can make them "aware" of working and health conditions and concurrently "motivate" them to adopt the PPE. We can summarize the approach to the system development in three words: self-monitoring, awareness, and motivation.

In this paper, we described the first part of the research project: the definition of the users' expectations and the design requirements for the entire system.

The findings coming from this part confirm the aim of the research project that is to improve the health condition of workers of coating factories by two actions:

- Increase the awareness of health condition by monitoring environment and personal indicators in order to define the working conditions based on objective data;
- Motivate to use the mask by improving the comfort of use and redesign the mask or part of it and choose better materials.

Starting from the design brief here described we are currently developing different design concepts of the whole system. In the concept generation, users from the three chosen companies are going to be involved as well.

The design of the wearable system is going to be developed using a guidelines for wearable systems that stresses the importance of shaping the technology in an unobtrusive way suggesting also the suitable shapes to use in different body areas. (Author 1., 2012)

The Research Project POD started in July 2015 and it will run until June 2017. The next steps will be:

1. Chose the concept that meets the workers' needs and expectations;
2. Develop a functional prototype;
3. Test the prototype in the working environment.

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