EasyChair Preprint

№ 5809

Design Solutions to Improve Medical Protective Equipment During COVID-19 Pandemic.

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June 15, 2021

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Abstract. The current pandemic situation caused by SARS-Cov-2 has highlighted that collaboration between different sectors can represent a winning way for emergency management. However, even today, the design is often considered an "aesthetic" element and not a strong strategic instrument able to bring innovation to different sectors. This paper, therefore, proposes to highlight how design can be a strategic medium during such situations. The research aims to identify and strategic design solutions to improve first responders' comfort and well-being during the emergency of COVID 19, referring in particular to the medical personnel employed on the frontline during the pandemic. The research investigated the aspects related to the specific scenario of the COVID19 pandemic emergency through different interviews and questionnaires with health workers and a co-working activity with design students. The co-working activity with design students aimed to individuate new technologies and innovative material in relation with health operators' needs and proposed innovative design solutions of PPE. Finally, the research proposed a set of open rules for designing innovative medical PPE to be used during a pandemic, considering the communication aspects in order to improve final user's comfort.

Keywords: Design, Covid19, Emergency, Communication Design, Education, Interdisciplinarity.

1 Introduction

1.1 COVID-19 Pandemic Scenario.

COVID-19 is an infectious respiratory disease caused by a coronavirus Sars-cov-2 that has soon become a pandemic. This unexpected infectious disease has hit our society very hard, changing our lifestyle, the interaction between people, and the concept of self-care. In a few weeks, the virus spread worldwide, increasing the number of infected people every day. On the other hand, the Covid-19 pandemic disrupted the health system, forcing it to change entirely in a while. The healthcare professionals are at the frontline working to contain the spread of the epidemic. Doctors, nurses, and paramedic operators were not prepared to face this kind of emergency, and they adapted to the scenario with great difficulty. Environments, clothing, and their working routine were reorganized, and new hard rules and procedures were introduced to ensure medical operators' and patients' safety. Consequently, all the healthcare and medical personnel began to use additional personal protective equipment (PPE), try-

ing to avoid infection and ensure their work performance. In March 2020, the Italian Institute of Health published a document indicating the allowed types of personal protective equipment (PPE) and their right use for medical use, first responders, and common citizens according to different uses and scenarios. The document recommended ensuring a set of rules for adequate respiratory protection. Medical staff also has to wear a clear polycarbonate shield to protect themselves from droplets released by infected people through coughing or sneezing, or simply breathing.[10] Facial protections are generally very uncomfortable to use for a long time (the length of a hospital work shift is about six/eight hours) and adhering to the face causes redness and bruising. The infection could also be spread by touching hands, clothes, or objects which have come into contact with sick people because the virions live for many hours also on surfaces. According to these contamination peculiarities, first responders have to wear in addition to the traditional gown another water-repellent garment - often a full jumpsuit - able to protect all the body and protective disposable headgear. The above protective equipment is generally very uncomfortable and requires a very long dressing time, as well as undressing. For this activity, it is often necessary the help of another person to avoid contamination. Moreover, to protect their hands, the healthcare workers have to wear many pairs of gloves on top of each other to avoid contamination during undressing. The number of pairs depends on the use and the scenario. These multiple uses of gloves provoke loss of sensitivity to touch. Consequently, they also have difficulty in the use of medical instruments and the examination of patients. Garments, gloves, healthcare headgears, and masks are generally disposable while the visors are sterilized for multiple uses. Due to the use of a lot of PPE by healthcare professionals during working activities, the communication between them and the patients has been becoming very difficult. Masks and visors reduced quite the visibility between people, making the dialogue impossible and even people recognizability. This situation contributes to the dehumanizing, even more, of the hospital environment and hospitalization path.

1.3 Emergency Design and COVID 19 Pandemic.

The emergency scenario is a completely multidisciplinary field. During an emergency, many disciplines are involved with the sole purpose of dealing with and overcoming a crisis with the least possible damage. Many of these disciplines have been so involved in such situations that they have developed branches to study in more depth some particular phenomena. It is important to underline that the actors involved in an emergency are multiple and have very different needs. If, on the one hand, there is the population in difficulty affected by any emergency, on the other, there are all the operators who work non-stop to restore the pre-emergency state. Therefore, it is essential to consider mainly the first responder user, as it is the one subjected to greater prolonged stress as it has an active and indispensable role during the crisis. During an emergency, in addition to the most obvious consequences of the scenario, it is essential to consider all the psychological implications that a given crisis can cause. The type of user-described so far, called "First responders," has specific needs to which you cannot pay attention to make it more bearable and less tiring their work. Despite, as previously explained, the design is a highly cross-disciplinary discipline, it is not

yet adequately incorporated into the response phase during an emergency. Even today, the design is often considered an "aesthetic" element and not a strong strategic tool able to bring innovation to different sectors. During the Covid19 epidemic, this problem was often highlighted by numerous international designers, including Neri Oxman, in one of the meetings of the "MoMa Virtual Views" YouTube series organized by Paola Antonelli.[12] Neri Oxman drew attention to the fact that no designer was in one of the scientific committees created to cope with the emergency when instead, other professionals were. At present, there are very few academic courses dealing with this subject. In Italy, regarding university education, the emergency design has not yet codified and structured legitimacy. The only experiences in this regard can be traced back to internal laboratories born on the reference teacher's specific interest. However, design can be a valuable strategic tool to address an emergency better, as it can see foreseeing needs and problems sometimes invisible to other professionals. In this perspective, especially during the current pandemic situation, debates, conferences, and initiatives flourished in which designers from around the world tried to explain how design could help. Worthy of note is the initiative conceived by Paola Antonelli and Alice Rawsthorn, "Design Emergency." The project was born in May 2020, on the Instagram platform, to investigate design response to COVID-19.

2 The aim of the research.

This paper refers to the study and the analysis of the processes related to the use of the design in First Responders' service, focusing on the application area of design for emergencies caused by the COVID19 pandemic. The main purpose concerns not only a reflection on the ever-new possibilities of using design in this reference field but above all, it is an investigation of its intrinsic ability to adapt, finding different solutions concerning the variables characterizing the other crises and defining its various uses. The areas investigated are related both to operative activities and psychological and emotional approaches. Referring to the first one – operative activities- a focus was directed to the protective uniform and all the other PPE at the disposal of first responders and the medical devices necessary for the routine activity and exceptional one. Referring to the psychological approaches, the research focused on the first responder's necessity to communicate with victims from the welcoming phase to the more strictly operational ones to make them feel comfortable and safe. On the other side the research considers also the needs of the victim to communicate with the healthcare people and be understood. The research aims to investigate in order to find innovative solutions, to improve the following aspects:

1. The ability of medical staff to communicate with other first responders and the victim and the possibility to be easily recognized and the other way around.
2. The comfort and the breathability of the uniforms to ensure a constant body temperature, avoiding dehydration, avoiding sweating, not tightening the various parts of the body, and ensuring freedom of movement.
3. The ease of dressing and undressing in terms of employed time, the necessity not to be helped in dressing up and out by other people, and furthermore, the ease of not being infected during the undressed phase.

4. The possibility to carry and use personal accessories (such as notes, pens).
5. The possibility to comfortable PPE like mask and visors or full mask that do not leave marks on the face or body, allowing to breathe without fogging.
6. Lack of PPE designed specifically for neck, ankles, and wrists.
7. The compatibility of different PPE with the uniform.
8. The difficulty of sterilization of PPE avoiding long times and polluting procedures.
9. The possibility of using the stethoscope to auscultate victims in medical practices and other medical devices.

3 Methodology

The scientific society recognizes the strategic role of design able to establish itself as a collector of different disciplines. This holistic approach is fundamental to designing products and services taking into account different points of view. This multidisciplinary approach of design, in its various forms, is opposite to specialization, and indicates the necessity of going beyond knowledge based on the specificity of a single discipline. This way of designing needs of a constructive exchange of techniques, methodologies and know-how linked together into innovative design solutions. The present research method used a cross-disciplinary approach, involving many different disciplines such as emergency psychology, biology, medicine, and engineering. The contributions of each field represent the key knowledge necessary for the final design proposals. The research refers to the UCD approach as the main method to the design process. Besides, it also concerns the human centered design (HCD), starting with understanding users' needs and behaviors according to the scenario and psychological and emotional traits and features typical for users. This approach also focuses on the importance of involving users in the design processes. The research investigated the aspects of the specific scenario of the COVID19 pandemic emergency through different interviews and questionnaires with health workers to easily understand the strengths and the weaknesses of the existing products and users' habits, behaviors, and points of view. Moreover, the research organized a coworking activity with Design Students of the master's degree in design of the University of Florence. The first purpose of the activity was to individuate new technologies and innovative material concerning health operators' needs. After that, the students involved proposed a series of innovative concepts regarding design solutions of PPE They focused on improving the comfort of health first responder and on the aspect related to different kinds of communication.

3.1 Applied method

Direct interviews and questionnaires with COVID-19 doctors and rescuers.
The research started investigating the aspects related to the specific scenario of the Covid-19 pandemic emergency, during the first Italian in March and June 2020. Based on the design purpose, a series of different questionnaires were elaborated (using both multiple-choice and free answer) and submitted to different kind of healthcare professionals and volunteers using Google forms in accordance with the

privacy legislation for the processing of sensitive data. Besides, some interviews were conducted in digital mode, using web platforms such as Google Meet. The first objective of the interviews was to identify in detail the real needs of health workers, which, until then, were only hypothesized through the photos and images circulated on the internet and in newspapers around the world. Parallel to identifying the needs, it was necessary, for the purpose of the research, to identify all the problems associated with them, both physical, psychological, and communicative. While the primary need for protection was evident, several problems were caused by the many personal protection systems that had to be worn. Both the above activities involved about 350 health workers from all over Italy, including doctors, nurses, and paramedics, who worked both in COVID units and other departments and general medical practitioners who carried out their activities in a private office or at patients' homes. An accurate evaluation of the PPE they used was requested to questionnaire interviewees (in addition to gender, age group, level of education, and membership category). In particular, the questionnaire aimed to evaluate the PPE in terms of availability, comfort, ease of use, ease of dressing and undressing, risk of contagion, possible difficulty in carrying out work activities, physical discomfort, difficulties in movements, difficulties in communicating with colleagues and patients, difficulties in visiting patients, and also their opinion on the environmental impact assessment of PPE deriving from their sanitation or disposal. Interviews with healthcare staff focused on personal protective equipment and dressing and undressing procedures. In some cases, medical personnel provided photographic documentation of the protective equipment worn. In addition to highlighting the main issues closely related to the comfort, protection, and ease of use of the PPE, the interview activity has highlighted many communication issues. The personal devices, covering most of the body of health care workers, do not allow to recognize each other, and above all, do not allow visual contact with the patient.

The workshop with students.

According to the research aims, a workshop was organized with the students of the master's degree in Design at the University of Florence. The workshop had the aim of identifying new technologies for the Design of new PPE. The workshop took place in digital mode through the Google Meet platform during the Italian lockdown in March/June 2020. About 50 students were involved and divided into working groups of 2-3 people to optimize the project. The first step of the session was a specific brainstorming for the definition of scenario, in which the first responder works. Working groups focused on different devices: some focused on masks and others on gowns and gloves. Subsequently, each working group carried out an analysis of the state of art on current personal protective equipment for the Covid-19 scenario. This phase highlighted the criticalities of current devices on wearability, material, and waste. As previously mentioned, a problem that has emerged is the disinfection and disposal of PPE. According to the DPR 254/2003, these products are considered "special" and hazardous waste. The students studied a literature review on innovative, smart, and sustainable materials (on the market and in development), guaranteeing the doctor's well-being and facilitating work and communication. The next phase of the workshop was a focus group with some doctors and first responders. The focus group allowed students to understand the operator's real need and the critical issues of the

PPE that they wear. In March, the first sketches and concepts were carried out, and subsequently, they were verified with experts of the reference scenario.

4 Results analysis

As previously mentioned, the first phase of the research, through interviews and questionnaires to health professionals, has made it possible to highlight recurring and major needs and problems. Through questionnaires, it was also possible to have an accurate assessment of the PPE and identify the different personal protection devices used by operators. Concerning the PPE, following the responses of health professionals, a categorization of the devices was made according to the part of the body of interest (hands, ears, eyes, respiratory system, body, head, feet). The categorization analysis showed how many of the protective devices are worn on the face to protect the respiratory system. It is possible to divide materials into subcategories according to their durability, resistance and also if they are biodegradable. According to this, we could obtain disposable and reusable PPE. This choice is fundamental because disposable PPE usually generates very large quantities of waste, while reusable PPEs have the problem of correct disinfection. All of them represent a threat to the environment in terms of pollution. The questionnaires also highlighted the many related problems. The first, and by far the most frequent, is linked to the physical discomfort and not breathability of the PPE. The device's material, being disposable, does not guarantee adequate breathability. Moreover, the process of dressing and undressing is complicated, in particular, the undressing process exposes staff to a high risk of contamination. The questionnaire and the interviews highlighted that 86.5% of participants believe that the quality of the PPE they use is sufficient or good supplied, 75.9% are equipped with a face shield but do not always use it during all the operations they have to carry out because of discomfort (65.3%). 95.5% use disposable PPE, 97.5% of them consider the environmental impact related to the disposal of these PPE to be significant or very significant for the environment and, finally, 96.5% have positive evaluations regarding the 96.5% have positive evaluations regarding the creation of disposable PPE realized in biodegradable material with antimicrobial and / or antibacterial properties. Starting from the interviews and questionnaires, the students have designed innovative PPE concepts to improve health operators' comfort, usability, and devices' communicative aspects. During the designing process, it is also necessary to consider all the communicative aspects of the PPEs. Health operators have to communicate easily with each other during stressful activities. The communication has to be immediate, accurate, and fast. Sound problems could influence the quality of the communication and directly influence the activity itself. PPEs must not hinder proper communication between health professionals. It is also necessary that each professional and its specialization are properly recognizable in order to facilitate the rescue activities. The communicative aspects are also relevant in order to make patients feel at ease. The hospital environment and the disease could stress and depress the already debilitated patient. Health professionals, wearing the many necessary personal protective equipment, do not appear reassuring to the patient.

5 Conclusions.

The results of the analysis of the previous activities are summarized in a set of open rules for designing innovative medical PPE to be used during a biological emergency as follows. The following points indicate the proposed actions necessary to design a new generation of PPE to be used in Covid-19 Department at Hospital starting from users' needs and behaviors. The starting point is to associate a series of requirements to each kind of PPE. The indications try to summarize the wearable PPE into two large categories:

1. PPE to protect the respiratory system of healthcare people to wear on the face;
2. PPE to protect the body.

Each of the above PPE has to contain a series of specific elements necessary to obtain the prefixed goals. These two categories have in common the main function: to totally protect healthcare workers from biological hazards. This peculiarity is reached using specific materials; international standard rules indicate a list of allowed materials for this purpose. It is possible to divide materials into subcategories according to their durability, resistance and eco-compatibility. According to this, we could obtain disposable and reusable PPE. This choice is fundamental because disposable PPE usually generates very large quantities of waste, while reusable PPEs have the problem of correct disinfection. All of them represent a threat to the environment in terms of pollution. The use of specific materials is not sufficient to have a useful and comfortable PPE and the design discipline has the important role to combine user functional and emotional needs together with innovative materials and technologies to design products formally innovative. Referring to the results of the research, it is possible to indicate the following peculiarities of Facial PPE:

1. **Comfortable**. To reach this goal, the PPE has to be ergonomic shapes, adjustable parts, soft surfaces, breathable fabrics, elastic materials, easy to fit, available in different sizes. It could improve comfort, reducing the number of protective facial PPEs, such as integrating the visor with the mask. The PPE should be easy to dress and undress, in order to reduce the risk of contamination of the users.
2. **High Protection**. The use of smart innovative material and coating could improve the PPEs' standard protection. Innovative self-sanitizing biobased fabrics and molecular copper-based coating increase the level of PPEs' protection, reducing the risk of contamination of the users.
3. **Communication aspects and recognizability**. The use of transparent material, the possibility of customization, availability of different colors and applications of logos/ pictures could improve the communicative aspects of the PPEs. Moreover, the integration of ITC in PPEs can communication issues related to sound and simplify patients' medical records' monitoring methods.

Referring to PPE for the body they have to be designed according to the following characteristics.

1. **Comfortable.** To reach this goal the PPE has to be ergonomic, designing the model and the pattern according to the ergonomics and the anatomy of the body, able to allow free movements and the natural touch. In addition, the design must take into account the needs of the different areas of the body in terms of breathability, mobility and friction. Moreover, it is necessary to use different sizes of PPE according to the health workers biometric data.

2. **High Protective**. Favoring one-piece suits with easy closure allows dressing and undressing activities alone, without the help of other people and in a few minutes, designing a closure system able to open and close using one hand. Avoiding touching the external part of the garment. Innovative self-sanitizing biobased fabrics and molecular copper-based coating increase the level of PPEs' protection, reducing the risk of contamination for the users.
3. **Communication aspects and recognizability**. The possibility of customization using colors, graphics, allowing to attach pictures/graphics/messages can improve the communicative aspects of PPEs. Different colors and graphic signs can help in identifying the different professionals' workers within the hospital environment, thus facilitating workers/workers and worker/patient communication.
4. **Integration of ICT**. The integration of ICT in PPEs can improve sanitations issues of work daily objects such as pens, notes, smartphones. A removable smart self-sanitizing pocket could reduce the risk of contamination for the users.

Moreover, each type of PPE should consider the Life Cycle Assessment. If not mono material the PPE has to be easy to disassemble. It is preferable to not use glues, to choose Biodegradable or reusable materials, preferring innovative natural biological materials. In conclusion, the analysis highlighted the need for each type of PPE to be compatible with the others, in order to improve user comfort, to reduce the risk of unintended contamination and to simplify the processes of dressing and undressing.

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