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The fear and the masks, making safety possible from the artisans to the makers

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ABSTRACT
The COVID-19 Pandemic has brought a strong hit to human society, the creative and design environments suffered the needed and correct restrictions applied as countermeasures to the spreading of the virus, but at the same time, it reacted on its way. To contain the risk of contagion one of the most efficient devices is the face mask, which quickly rose to be a sort of iconic symbol of the Pandemic period. In this paper, a short excursus about the story of protective masks and gas masks bring to the present days where the tentative about creating 3D printed solutions have tried to integrate the numerous solutions proposed to contain the contagions. After a general analysis of the proposal and solutions advanced by companies and makers using 3D printing solutions, a specific and original case study will be presented as a conclusion of the whole process, integrated by a critical test operated on a small group of users to verify the resulting functionalities and comfort. The complex scenario of the pandemic event will be analyzed from the point of view of the creatives and designers giving help in the difficult situation applying their qualities to find solutions to safety issues.

KEYWORDS
pandemic, 3D printing, face mask, respirator, 3D digital modelling, COVID-19, ergonomics, virus.

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I. INTRODUCTION

With the spreading of the New Coronavirus Epidemic event in March 2020 the need for proper safety devices came out as a mandatory need for all the people: in the tentative to stem the contagions the facemask is one of the most and relevant solutions, named most of the time simply 'mask'. In Italy, during the initial spreading of the pandemic, the supply for the masks has been quite problematic, with various issues in the delivery (Tarquini 2020), production (Savelli 2020), organization and several 'black market' and inflated prices (Lombardo 2020). The main strategies in facing the emergency were the use of face masks, the personal cleaning of hands by washing off or with the use of sanitizing gel products, the use of disposable gloves and the use of face shields or fixed transparent panels in the working environments. The self-isolation and the suspension of all the group/social activities is the second strategic measure to contain and mitigate the impact of the virus spreading. The combination of lock-down and use of personal devices have reduced the consequences of the event, thus the reluctant behaviour of some individuals and the poor reaction from some countries has caused a messy situation and probably the increment of cases and victims (Haque, 2021). The introduction of personal accessories like the masks in the everyday 'equipment' has introduced a strong, almost mandatory, subject for the designers, from the fashion industry to the materials and technology sectors, a strong effort was made to satisfy with the most various solutions the subject of the personal masks, pointing to efficiency, brand, original aspects, a myriad of new items have populated the online shopping websites, in the turn of few weeks many brands, companies, accessory producers, startups and shops directed their proposals to more or less original products, declining the offer from extremely technological solutions to materials and fashion charms. This can be seen as a great creative challenge, where design solutions meet safety and practical needs from the 'new' everyday life.

A STORY THAT IS ALREADY HISTORY

From the outbreak in China and Italy to the declaration of the Pandemic event

The story of the pandemic event reconstructed at now started about the end of 2019: from the 31st December 2019, Chinese authorities informed the WHO (World Health Organization) China office of pneumonia cases in Wuhan City, Hubei province, China, with unknown cause (World Health Organization Website, April 2020). After the 22 January 2020 WHO confirmed human-to-human transmission of the virus (World Health Organization Website, January 2020).

With the gradual spreading of the epidemic out of China, Italy was at the beginning the most afflicted country, with a rapid diffusion in the Northern part of the national territory and high rates of contagions and deaths. In the period between the beginning of March and May 2020 the guidelines of the Italian Ministerodella Salute (Thematic site Influenza, 2006), defined a series of measures to stem the diffusion of the virus, with the use of the masks, the accurate cleaning and the self-isolation as main personal and collective strategies against the Virus. The COVID-19, the 'COVID', soon became a well-known word, continuously used. Italy was one of the first countries in Europe to receive the impact of the virus. Following the Ministerial Decree of 8 March 2020, the Italian Government imposed great restrictions, making the whole of Italy a red zone. The state of 'Pandemic' was declared on the 12 March 2020 (World Health Organization Website, March 2020 The new pandemic arrived on quite specific conditions, after almost one century since the last significant one (the so-called 'Spanish Flu' spreading worldwide with the main outbreak in 1918-1920) and after various threatening epidemic events that never rose to be a global menace (McMillen 2016), with an extremely enhanced evolution of technology and medicine in front of any past similar situations, but also with a very 'globalized' world, where people and goods move continuously from anywhere to anywhere and the population is increased of almost five times in one century. In this context, the needs caused by the lock-downs operated as accelerators of certain ongoing processes, like the 'online teaching' (Mishra, Gupta, Shree 2020), the 'smart working', the 'online communities', the 'dematerialization of social relationships', the 'online shopping', the online migration of functions and services and the use of 'online entertainment' (Koeze, Popper 2020).

Short story, from the gas masks to the FFP3 masks

War often generates and anticipates the great inventions of history. It happened for respiratory protection as well. In 1915, the German army during the First World War released 168 tons of chlorine-based gases on the allied deployment near the Belgian city of Ypres, causing thousands of deaths in a few minutes. Not even the Germans had imagined such devastating effects of their attack. The only protection for the unprepared soldiers were handkerchiefs soaked in urine.

Respiratory protection, still at the beginning of the 20th century, was based on empirical experience and no less frequently from mystical and ancient traditions.

'Their caps with glasses are designed, their bills with antidotes all lined' (G.L.T., 1965: 267)

This sentence describes a part of the costume worn by physicians during the plague of 1656, perhaps the more ancient form of protection against the invisible dangers presents in the environment.

Today we know that this practice would have had no filtering capacity compared to pathogenic agents such as bacteria and viruses or for the defence against dangerous or potentially lethal substances.

The folkloric image of the plague doctor's mask, reminiscent of the first gas masks used in WWI.

Respirators and gas masks appeared for the first time during the conflict. The first models covered completely the face of soldiers to protect both the respiratory tract and the eyes. These masks were the evolution of the simple tampons of gauze soaked in calcium carbonate. These masks were equipped with a filter (in the same way as those of the seventeenth century) loaded with chemical agents that were supposed to neutralize the effect of toxic gases. These masks were called multipurpose because they should have filtered any chemical agent employed by enemy forces.

Yet, sometimes, they proved ineffective due to the lack of knowledge of chemistry in that period, such as during the attack of 29 June 1916 by General Boroevic on the village of San Martino del Carso, with the chlorine-phosgene gas and the hyprite gas. The endowments of the Italian army were not sufficient to neutralize these two substances, in one action the Italian losses amounted to almost 3000 men (Figure 1).

The production of the first gas masks dedicated to the protection from chemical substances or mixtures began between the two world wars. Surgical masks intended for the non-diffusion of pathogens assumed their first configurations in 1887 with the doctor and surgeon Paul Berger (Figure 2) who began to use protection for the nose and mouth during surgical interventions (Lowry, 2020). He did so after reading Carl Flügge's study which showed how a conversation was enough for the user to spread pathogens and infect surrounding people (Flügge, 1872).

The mask used by the Parisian surgeon Berger was composed of six layers of gauze sewn at the bottom of the apron and tied behind the neck at the height of the root of the nose. In 1922 Berger proposed the results of this practice to the Surgical Society of Paris as a decrease in the cases of postoperative infection was evident. Yet at the end of his speech he said:

I do not blind myself to the fact that this is too great a shock to custom for it to receive a much more favourable welcome than that accorded by the German surgeons to an analogous communication by Professor Mikulicz (Berger in Phillips 1938: 4).

The idea that the doctor/surgeon could be a carrier of the disease, and sometimes the death of a patient was taboo in the scientific community of the time. In some cases, doctors who claimed the responsibility of doctors in the diffuse of infectious diseases lost their careers.

In the following decade, other doctors began to support the need to use masks both as protection from infections, such as scarlet fever and the possibility of avoiding sepsis in hospital settings not only in the operating room but also for nursing staff during medications.

At the end of the first decade of the twentieth century, the functionality of this type of mask was clear, like it comes from the studies of Wu Lien-Teh during the Epidemic of Pest in Manchuria in 1910-1911 (Yu-Lin. 1985). So, there was the possibility of improving the life expectancy for hospital patients, but the first experiments on the different types of surgical masks have to be dated by the end of the second decade.

In 1918 Doust and Lyon tested three types of fabric, two gauzes of different densities and finely plush cotton originally used to wrap butter called butter cloth. This comparison led to the definition in the following year of a minimum mesh density of the first standard gauze for the manufacture of surgical masks: 'Weaver found that mask efficiency was in direct ratio with the closeness of the mesh and the number of thicknesses of gauze. He recommended a fine mesh gauze with 44x40 threads to the inch.' (Weaver, 1919: 218)

The 1930s saw the beginning of the experiments of different types of materials in the construction of surgical masks. To achieve the 'germ proof' effect, some attempts included materials such as 14 karat gold thread, washed X-ray film as the deflector material or cellophane. In 1938 McKhan, Steeger and Long compared two of the most used masks at the time and two more proposed by them. The four types were absorbent and deflector ones, both already in use, and a waterproof one with a diverter for the air expelled behind the user, and one called a filter composed of two layers of gauze inside which a state of compressed cotton, proposed by them. The latest proposal was the most effective.

The interest in maintaining the sterile environment during dressings and surgical interventions as well as the interest in pathogen control devices such as masks decreased with the miracle of antibiotics introduced thanks to Ernst Chain and Howard Walter Florey in the 1940s. Only in 1961, the production of masks introduced the concept of disposable masks, consisting of a plastic shell performed on the human face in which the filtering material was inserted.

In those years, we also began to worry about the bacterial load present in the environments and how the deflector models protected the patient from the direct projection of the bacteria but did not protect him from those remaining suspended in the air. Besides, the wide-mesh gauze masks are completely abandoned as they are ineffective, mainly because of the humidity produced by breathing and by how they were worn on the sides of the face.

The filter-type mask is the most efficient and to wear a mask of absorbing gauze, especially of wide, coarse gauze, means poor protection to the patient. Many hospitals are using and buying improper masks. Since we have standards of sterile techniques in hospitals, it would be of benefit to the hospitals to have a standard setup for masks, so that absorbing masks of coarse gauze and improper thread count are not used (Rockwood, O'Donoghue 1960: 963).

The results obtained by McKhan, Steeger are the basis of contemporary disposable surgical filter masks. These masks are made up of three layers of non-woven fabric and perform the task of protecting those in front of the user. The protection is therefore unidirectional. Each layer of which the mask is composed has specific functions and densities capable of filtering particles of different sizes.

To obtain bidirectional protection both from and to the person wearing the mask, masks must be used which are the conjugation between the surgical and the gas ones: the facial filters. The properties of both combined allow air filtering both during exhalation and inspiration, although the basic composition is the same and is based on mechanical action. The filtering potential of the fabric and the adherence of the mask face filters better than the previous make them suitable for contaminated environments.

This type can also be integrated with a valve inserted in the body of the mask, but the valve, although improving the comfort of breathing, once again leads to a unidirectionality of the protection this time towards the user who, however, can emit the aerosol of his secretions outwards.

The safety level: state of the art

The most important difference between the face masks is given by the direction of protection:

- The surgical face masks protect from inside to outside. (Figure 3)
- The respirators with exhalation valves protect from outside to inside. (Figure 4)

● The respirators without exhalation valve protection are both from inside to outside than from outside to inside. (Figure 5)

The first type falls among the surgical medical devices of which, for the Italian legislation, the legislative decree 24 February 1997, n. 46, while the second and the third are individual protection devices (PPE). This difference also falls within the UNI standards that govern their characteristics from production to use.

Surgical masks are regulated by the UNI EN 14683:2019 standard. (EnteItaliano di Normazione, 2020)

In the standard it is indicated that the surgical masks are not all the same but that they are instead divided into two categories Type I and Type II, this division is due to the filtering capacity of the mask. Type II is then further subdivided according to its splash resistance, indicated as factor R. The factor R defines the degree of penetration to a liquid projected at a given pressure.

The standard defines the methods by which to perform the various tests for classification in the different categories in which the surgical masks can fall and the minimum requirements they must comply with.

At point 5.2.7 of the standard Summary of performance requirements are indicated the four parameters for which they are tested:

Bacterial or BFE filtration efficiency, the differential pressure that indicates the respiratory comfort of the mask, the splash resistance pressure defined above and the microbial or bioburden cleaning.

The BFE indicates the percentage of bacteria that must be mechanically filtered by the mask states, Type I must have an ability to filter at least 95% of the bacteria while Type II and Type IIR must reach 98%. For this parameter, the standard specifies with a note that:

Type I medical face masks should only be used for patients and other persons to reduce the risk of spread of infections particularly in epidemic or pandemic situations. Type I masks are not intended for use by healthcare professionals in an operating room or in other medical settings with similar requirements (UNI EN 14683:2019 Table 1 — 'Performance requirements for medical face masks' point 5.2.7).

The respirators, with or without filter, referred to in Legislative Decree no. 475/1992, instead are user protection systems and must meet the requirements of UNI EN 149:2009. (EnteItaliano di Normazione, 2010)

The correct definition given by the standard is particle filtering half mask, its intended use is to protect the user not only from liquid but also solid aerosols such as dust present in the environment. These devices can also be equipped with replaceable or not exhalation valves.

The classification of these devices in FFP1, FFP2 and FFP3 depends on their ability to filter particles with an average mass of 0.6 μm. The test according to the standard is done inversely compared to the previous surgical mask it is indicated as the parameter 'Maximum penetration of the test aerosols' or the requirement requires that the penetration percentage for the FFP1 class does not exceed 20%, for the class FFP2 is not more than 6%, finally for FFP3 1%. Other values that define the class of belonging are respiratory resistance and the total loss of seal towards the inside. Both of these characteristics define ranges that allow the filtering masks to fall within the different categories.

It is worth noting that in Italy and probably worldwide there is a specific 'social' approach to the masks with an exhalation valve(s). In various cases, they are indicated by the 'popular opinion' as 'selfish' while they filter well towards the user who dresses them but is criticized for the quality of the filtering in the breathing out operation. This is a little complicated situation, while this kind of mask is supposed to work as a practical solution to make it easier for the user to breathe out/in reducing the possibility of fog eyeglasses and augmenting the amount of air passing in a single breath. The use of filter respirators was also not recommended since 20th March 2020, through the dissemination in Italy of a document like 'Vademecumutilizzomascherine' (Asso.Forma, 2020). The document prepared by a training agency accredited by the Piedmont region indicates the respirators with exhalation valve as indicated only for healthcare personnel in contact with potentially or certainly infected patients. Yet in March 2021 it is easy to find situations in public 'medical' situations (like hospitals or vaccination areas) where operators like doctors or nurses may ask the subjects wearing a mask with a valve to remove it and use a basic surgical mask in its place (Hunt, 2020). It is then important to notice that this kind of mask may present two main possible situations: the valve 'filterless' toward the user, so it is open to the passage of the air of the breath or it has a filter (most of the time a standard PM 2.5 tissue). In the first case, the mask is a 'selfish' mask, while it may allow particles to exit. In the second case, the filter should block them or at least slow them down, the filter construction in itself may even block the exit acting with filtering. The difference between model one and two depends completely on the model and is not possible to see it from the outside, besides, there may be the risk that the user may have not changed for a while or neither inserted the PM 2.5. filter. So, in the impossibility to verify which kind of safety level has this kind of mask for real, it is easy to understand the tendency to apply countermeasures to these models even when they may be as safe as any basic surgical mask.

These respirators meet standards from other countries such as the USA or China. The American

standard NIOSH-42CFR84 is the standard that contains the standards for N95 masks and the Chinese standard GB2626-2006 is intended to define the standards of the KN95 masks.
Also, for these devices there are more classes for example for the American type the N95 depending on the number after the N we will have a higher percentage filtering capacity. (The National Institute for Occupational Safety and Health (NIOSH, 1996).
In Italy the recent Legislative Decree of 17 March 2020, n.18 introduced exceptions to the production and placing of surgical masks and filter masks, but these exceptions only concern the CE marking procedure, therefore the UNI EN standards govern their characteristics and performance remain valid. The decree allows also to enter devices without the CE mark, but only after having a product assessed by a certifying body.

1. (…), and as long as the state of emergency declared by the Council of Ministers on 31 January 2020 continues, by way of derogation to the provisions in force, it is allowed to manufacture, import and market surgical face masks and personal protective devices. 2. The manufacturers and importers of the surgical face masks referred to in paragraph 1, as well as those who market them and who intend to benefit of the exemption provided for therein, shall send to the National Institute of Health a self-certification in which, under their sole liability, they certify the technical characteristics of the face masks and declare that they fulfil all the safety requirements provided for in the regulations in force. (…). 3. Manufacturers, importers of the personal protective devices (…), shall send INAIL a self-certification in which, under their sole liability, they certify the technical characteristics of the aforementioned devices and declare that they comply with all the safety requirements provided for in the regulations in force. (…) 4.Should the results of the assessment referred to in paragraphs 2 and 3 establish that the products do not comply with the regulations in force, without prejudice to the application of the provisions on self-certification, the manufacturer shall immediately cease production and the importer shall be prohibited from marketing (Decree-law no.18 2020 Art.15).

A very high number of both types of masks have been imported in the face of the COVID emergency -19, which have not been subjected to the procedure for affixing the CE mark.

It is worth noting that in Italy and probably worldwide there is a specific ‘social’ approach to the masks with a breathing/respiration valve. In various cases, they are indicated by the ‘popular opinion’ as ‘selfish’ while they filter well towards the user who dresses them but is criticized for the quality of the filtering in the breathing out operation. This is a little complicated situation, while this kind of mask is supposed to work as a practical solution to make it easier for the user to breathe out/in reducing the possibility of fog eyeglasses and augmenting the amount of air passing in a single breath. The effective safety of this element depends on its filtering capability. In the correctly assembled masks, this filter has a secondary layer (commonly the main PM 2.5 replaceable filter in the mask), but in various ‘cheap’ masks it may appear ‘naked’, directly exposed to the face in the inner side of the mask. In this way, all the air entering from the outside will be filtered, while the breathing out air is at risk of being poorly filtered.

Around the world institutes, manufacturers or makers start the design of self-made respirator other than those listed above cannot be assimilated to the two previous categories but can still be produced and marketed under the responsibility of the manufacturer. In Italy is possible from March 17 2020 with the Legislative Decree of March 17 2020, n. 18 to Article 16 paragraph 2 until the end of the state of emergency declared on January 31, 2020.

This freedom has given rise to a series of self-production experiments carried out by makers or simple users.

An example of this approach is the N95 Replacement Mask developed by the Barrow Innovation Center (Barrow Neurological Institute, 2020) in Phoenix which combines 3D printed parts, a silicone mould and commercial filters of the N95 and N100 (3M™ Particulate Filter) type meeting the NIOSH-42CFR84 standard.

This project is entirely downloadable and the conjugation of the print to the silicone mould allows the body of the mask to be adapted to the most diverse facial features.

The Phoenix Institute project is designed to produce respirators for healthcare personnel and rescuers.

There are many other projects intended for DIY (Do It Yourself) proposals from various official institutions, agencies, designers, and creative people. From the most popular to the very underestimated solutions, a simple search in Google Search ‘DIY COVID Mask’ (with DIY as a mandatory term), done in January 2021, returns about 23.5 million results. it is worth considering just some of the most interesting solutions at the moment of the writing (consumer.org, 2020).

At the same time, it is worth considering the difference between the real safety level and the ‘need’ to feel safe. This may lead to strange behaviours but also some creative appreciable result. In the example, the everyday need to open doors, push buttons and touch objects used by several people, may become a reason for stress and concern, to simplify this new troublesome condition exploiting rapid prototyping solutions there is the birth of a new class of tools that allows opening, pushing and pressing, without direct contact with the elements. Items like ‘The Handy Touch’ designed to be easily 3D printed and thought to be used constantly to handle everyday situations avoiding direct contact (Buti, 2020). The solution based on such a personal device appears much more interesting and practical than other 'mitigation' solution, like the 3D printing of accessories to be mounted temporarily or permanently on door handles, like the 'Hands-Free 3D-Printed Door Openers' designed by Materialise (Materialise, 2020).

WHAT WE SAY WHEN WE SAY '3D PRINT A PROTECTIVE MASK'

The pandemic event started in January 2020 was the occasion for seeing various approaches in mixing technologies to social and humanitarian efforts to face a dramatic emergency.

The answer from the 'makers'

'We need a backup to the backup' Dale Dougherty - Victor Hwang (Grinstein, 2020)

The difficulties encountered by hospitals and people in the first phases of the pandemic event are well represented by the rapid shortage of masks and breathing devices and the hospitals in need to expand the number of available places in the intensive care units. From the online communities, the will to give support and bring a contribution took various ways, the one from the 3D printing/manufacturing communities was very direct and practical, with the production of various components and solutions, from open source ventilators to surgical mask straps. The intervention was inspired by the spirit and characteristics of this specific environment, the makers' movement (Voigt, 2020) can be well defined by the quote from Mark Hatch:

Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. Things we make are like little pieces of us and seem to embody portions of our soul (Dougherty, 2012).

This movement grew up on a global scale in recent years, exploiting the diffusion of digital production and reaching soon appreciable results. The main structure of the movement can be summed up in three main points:

- the people taking part in the movement: maker (creatives producing new physical results/products), hacker (creatives producing alterations on existing products, both software/digital or physical.
- the places where the movement develops its activities: makerspaces, hackerspaces, fablabs; all with a constant interface with the online dissemination and social media.
- the activities as a concrete application environment: DIY, 3D-printing, making, hacking, maker_education. All oriented to express the concepts of the movement, but also to change it according to new needs and developments.

The philosophy supporting the movement can be well resumed with:

The maker movement exploits a gap in what Kuhn refers to as 'normal science'. The maker movement promotes experimentation and whimsy. It equally embraces old and new materials and technology in pursuing the maker's vision of the completed object. Making typically provides immediate visceral feedback on a design's performance which produces tacit knowledge [...] makers are not pursuing science, they apply science often in an unscripted, unconstrained fashion. This freedom to make mistakes and pursue apparently random approaches has the potential to avail surprising and radical results (Ask 2016:86).

The sense of 'community' was well consolidated in the makers' movement (Moilanen, Vadén, 2013). and their continuous interchange of information through the social networks created the perfect conditions for the rapid reply from the movement to the emergency. It would be wrong to imagine it as a massive and unitarian reaction, but all the people involved in the 3D making and/or with access to 3d making/hacking and with sensibilities compliant with the logic of this movement were stimulated by the situation and defined personal, small or large, experiences in contributing to the emergency (Peth, 2020).

Self-made mask

Since the first advice of the pandemic issue, different Chinese doctors, universities and makers showed how to produce face masks at home (Bao 2020) (Cannix, 2020). Some seem very poor (Wong, 2020) because they were made in kitchen paper (Cannix, 2020), but this solution was proposed by the University of Hong Kong-Shenzhen Hospital and approved by the Consumer Council of Hong Kong. This mask proved to have achieved 80 to 90 percent of the function of regular surgical masks in terms of their filtration of aerosol and droplets (Consumer Council, 2020). (Figure 6)

Also, on Italian television, it was possible to see a face mask made of baking paper, an idea supported in the same program by a doctor (Mottola, 2020). It was the end of February, mask and hand rub gel were very difficult to find, necessity suggested new solutions. The World Health Organization WHO, for example, suggests a solution for hand sanitiser to do at home (WHO, 2020).

For masks, however, the discussion is more complicated. There was a lack of background culture on the use of masks and types: several voices have risen against 'homemade' solutions. It is possible to consider wearing homemade masks as ‘good practice’ (De Giorgio, 2020). Compared to surgical masks, they block the outgoing droplet less. The fact of having a mask gives a false sense of security (Adnkronos, 2020), if it is not the right one for the situation, it is not worn correctly or is not properly sterilized (Center for Disease Control and Prevention, 2020).

Until the decree of 27 April 2020 (Decree-law 17 March 2020), that authorized community masks (Cottone, 2020), homemade masks (Carillo, 2020) were not allowed in Italy.

We can see two different philosophies (Hussein, 2020), the first that is based on the culture of security and the rules of the European Community market, the second that responds with the times of emergency and ‘better than nothing (Catherine, Clase, Fu, 2020)’.

We could divide the homemade masks into two types, in the first we can put those cut and sewn by skilled seamstresses, professional (Littieri, 2020) or grandmothers (Casali, 2020), masks produced by hand one by one. Other typologies are those prepared by makers. Faithful to this philosophy, projects are often shared via the internet available to everyone. One of the first designs was projected by Carmen Russo (Russo, 2020a) and released under Creative Commons license in collaboration with Fablab Catania (Russo, 2020b). It is a simple shape with holes in the ears and prepared to be laser cut. The materials are lycra© or non-woven fabric.

Another design is the ‘writing paper’ mask proposed by Gerlando Maglio (Maglio, 2020) through Facebook. In this model the material chosen does not seem very functional, however, it collects discreet applause from the community. This uncritical approach, ‘I like and I share’, is typical of social forums, and we observed many different solutions of this kind, at the beginning of the pandemic period.

Filter holders

Filter holders are those masks that use interchangeable filter systems. It is a solution that therefore allows the use of third-party filters. Compared to surgical type masks it is possible to use ffp2 and ffp3 certified filters.

A good cad designer can create both the facial chamber and the connections to the filters depending on the availability of resources, and many designers share their cad file in sharing sites like Grabcad or Thingiverse. However, we should consider technical points of view like the fit of the mask for long times, the level of sealing or the possibility of sterilizing the mask.

Like other emergency solutions, the first ideas of filter holders come from China. From February 2020, 3d models (Wathmaker Lam, 2020) and video (Milktea3D, 2020) tutorials are spreading across the web. Following the spread of the epidemic across the world, new makers give their contribution (David, 2020).

If we are unable to model the mask by ourselves, dozens of makers (Thingiverse website 2020) make their expertise available, releasing ready-to-print models. Other makers and editors contributed by creating on specific sites (3d Heals website, 2020) collection of information, PPE models or created thematic channels on social networks (Rowe, 2020).

In the face of the enthusiasm of many, the contrary contributions are interesting, which form the dialogue through comparison. The contribution of GXLAB (Avveduto, Romagna 2020), lists some critical issues of the 3D printed masks, especially with FFF technology: rigid and porous materials; difficult to sterilize, non-functional design, plastic residues.

These problems can be seen in many models, such as in the Open source mask (Vacca, Occhipinti, Occhipinti, 2020). (Figure 7) In this case, we can also see how there is a distortion inside web communication media: this mask was so much celebrated by media as a brilliant solution (Rutigliano, 2020), that the authors had to underline the emergency nature of the proposal (Opensourcemask website, 2020) (Raniolo, 2020). It is difficult to evaluate whether these are operations made to gain visibility (Gollinelli, 2020), taking advantage of a moment of crisis or if it is a genuine desire to contribute according to one’s possibilities. There is nothing wrong with erring in seeking a solution, but telling defeat could equally help improve one’s mistakes. [open source mask-vanvitelio.jpg].

We can see a realization of a DIY mask, with a more careful approach to the problems exposed above in the work of SilviuStroe (Stroe, 2020) and the development of the design cycle.

A possible solution for the sterilization of the mask is proposed by Kentstrapper (Kentstrapper website, 2020): this model has a flat design that makes it very quick to print, it is innovative for the use of an antibacterial material (Copper3d website, 2020). The filter system is supported inside and held in place by a bracket. The mask can be sterilized with ethyl alcohol. Other solutions for sanitizing printed objects and compatibility with FFF printing materials can be found in this document (OSCM, 2020), edited by Open Source COVID19 Medical Supplies.

At the end of 2020, after the first moment of emergency was over, it is possible to find more scientific contributions that demonstrate how FDM printed masks are not comparable to CE or NK95 standards (Duda, Harting, Hagner 2020), but are acceptable as a stopgap measure (Dalla, Bacon, Ayers 2020).

Face shield

It is a safety device that protects the face from splashes, drops and droplets. It is used in combination with other protective devices, such as masks and goggles or separately. Among the various self-manufactured systems, there are some of them using FDM technologies and plastic sheets, and others use laser plotters. The FDM is slower to produce than the laser cutter.

While face masks were the first object printed, with the problems analyzed before, the face screens were some of the latest articles that the maker's community decided to print.

One of the first models was released on March 6th in Grabcad 3D by Gizeh Triana (Gizeh, 2020) from Mexico. It is very simple but functional and resolves the problem of sterilization with a disposable design. This choice was followed by Joseph Prusa (Prusa website, 2020). Starting from March 16th, Joseph started working on Gizen design. Prusa is a well-known manufacturer of 3D printers in FDM in the Czech Republic (Figure 8). The company has a factory of 500 3d printers available. In the following days, Prusa improved the design of the face shield and presented this new model to the Czech Minister of Health, Mr Adam Vojtěch. The model was submitted to the KrálovskéVinohrady University Hospital in Prague for test purposes. At present, they are capable of producing more than 800 pieces per day, and they print more than 55,000 protective 3D screens in less than three weeks. In a second moment, they studied and advised on disinfection. In Italy, 15 producers follow and work on this project. Through the website doctor Prusa disseminates all the necessary information for the use of the device and the geometry in an open-source way even if the website clearly states that 'the shield is not an officially certified piece of medical equipment

Similar experiences can also be found in Italy, for example, #shield19 (Lanza, 2020) or 'Makers Pro Sa Sardigna' (UniSS website, 2020).

Other solutions are possible with different technologies such as laser cutting, for example, University of Portsmouth (Daltry, 2020), Foster & partner (Foster and Partner website, 2020), HappyShield University of Cambridge (Bukauskas, Koronaki, Lee, 2020) and Trotec (Lasersytstemeurope website, 2020) are working on the effort to provide medical protection themselves.

At present, it is the most popular safety device manufactured by the makers' industry; it is easily manufactured and remains a device that provides additional protection.

Safety box for medical operation

This kind of device is known as the Arbat box, from the name of the inventor (Nandan, Deshpande, 2020). It is a transparent box, made of acrylic sheets that cover the head of the patient and minimize the aerosol infection with negative pressure during a medical operation. It is an innovative gear and is very simple to build, as doctor Arbat tells on his web site: 'using existing acrylic sheets and plastic materials available in the hospital as all vendors were shut due to the lockdown (Arbat, 2020)'.

Assisted respiratory masks and Ventilator

An application that is well suited to the world of makers are projects with an electronic component such as PAPR, or Positive Air Pressure Respirator (Krishnan 2020) and BMV.

There are different solutions developed by makers and fablabs, among the most credible solutions, Zefiro (Valpreda, 2020) developed from Politecnico di Torino, FABLAB Torino, Dad (Figure 9) e Virtualab and My Space Helmet di Wasp (Moretti, 2020). Both prototypes were declared understudy and awaiting experimentation.

There are different studies about the automation of a manual resuscitator – BMV (Nickson, 2020). The first machine is the PVP (Graansma, 2020), the pandemic ventilator project of Clarence Graansma. The first prototype of this machine was developed for the 2008 Bird Flu. Another study is E-vent (Hanumara, 2020) and comes from MIT or OpenLung Emergency Medical Ventilator (Stadnyk, 2020). Hopefully, it will be rare to see one of these machines next to a man, in a hospital, but sundry university and Fablab works in the development of those medical tools with a look towards countries with health and economic problems (Pearce, 2020).

Masks 'Made in Tuscany'

At the beginning of the medical emergency, Italy experienced a clear lack of PPE. On the 4th of March 2020, former Tuscany's President Emiliano Rossi in a press conference presented a mask made in Tuscany called 'TNT a 3 veli Toscana 1' for medical staff and after some days authorizes its use (Regione Toscana Website, 2020), according to the 'art. 34 del D.L. n. 9 del 2 Marzo 2020'. (Figure 10)

Those PPE were not marked CE, but their filtering power was certified from the UniversitàdegliStudi di Firenze (Zambelli, 2020), (Osservatorioliberto Website, 2020), with the law decree 'Cura Italia'(DECREE-LAW No. 18 2020), the government recognizes the state of emergency and decided that for the PPE, manufacturers and sellers have to give a self-certification of the compatibility with Uni-En requirements to INAIL (INAIL Website, 2020), and for the surgical masks (medical devices), manufacturers and sellers have to produce a self-certification of the compatibility with Uni-En requirements to 'IstitutoSuperiore di Sanità' (ISS

Website, 2020).

From this point, other Italian Regions presented simplified laws: for example, Piedmont created a task for certifying masks, lab coats, and chemical reagents (Regione Piemonte Website, 2020).

TWO CASE STUDIES

Yet, most of the masks and respirators (for example, the masks that included in the design of third party filters and therefore certified) all of the maker production remained in the 'domestic' sphere or as defined by the 'community' standard. Even in cases where the proposed design has passed the standards to be considered efficient in protecting are the specifications on production that cannot be DIY:

'*This surgical face mask must be fabricated in an ISO 13485 compliant/current Good Manufacturing Practices certified facility under an appropriate quality management system*' (NIH 3D Print Exchange, 2020) or 'the mask must not be used as a medical-surgical device, because it is not certified. But in this period of shortage on the market, rather than going out without any protection, our idea can be useful and effective' (ANSA, 2020).

There is therefore a great limit imposed on 'home' production, namely the need to create something that actually meets the standards. A further difficulty linked to self-production in 3D printing is the need to possess skills both in the field of 3D modelling, in subsequent 3D printing including knowledge about the materials to be used in contact with the face skin and not presenting risky dangers in case of accidental breaks, last but not least, the ownership of proper hardware is fundamental according to which kind of mask is intended to enter in production.

The case studies described below focuses on one specific area, namely the adaptation of the mask body to the shape of the face. The uniqueness of the face shapes sometimes leads to problems with airtightness related to the adhesion of the mask to the face. It is not very well known, but for the use of FFPx respirators in the workplace you must be trained in how to wear, remove and verify the functionality of the PPE. (Decree-Law 81 2008: § 77.4.h § 77.5). Otherwise wearing PPE does not always mean being protected, and a perfect adherence between the mask and the face is a fundamental starting point in establishing safety.

Case study 'Cover' maker: modelling a personalized cover for surgical masks

In this case, the efficiency of filtering is delegated to commercial surgical masks. The hypothesis of printing in TPU suitable for skin contact. The geometry of the face was generated starting from a video made with a mobile phone without any precautions other than to remain still during the acquisition and have a non-homogeneous background and frame all the necessary areas of the face (under the chin, ears, nose etc.). A sequence of frames was extracted from the video that is sufficient to cover all the areas of the face affected by the mask. The resulting image sequence was automatically converted from .png to .jpg using the Adobe Photoshop image-processing script. The mesh was generated in AgisoftPhotoScan. The geometry exported to .obj was then used as the basis for modelling the 'cover'. The fundamental lines of contact with the face and the main profiles were extracted from the geometry imported into Rhinoceros (Figure 11). The modelling was done trying to create a composite shape of two shields, one fixed below and one above to be connected by interlocking which can vary. This also allows you to interchange the 'faces' of the mask. The first attempts have shown that in addition to adhesion to the face, another of the important elements for a correct fit is the positioning of the anchoring system which depends on the height of the user's ear and the shape of the zygomatic bone (Figure 12). A face fixing system was also evaluated even with an adhesive suitable for skin contact, however, it proved insufficient as it is susceptible to displacement if subjected to the stresses of movement. Furthermore, for this type of fixing the filter layer, in this case, must be placed in the empty window of the lower shield. Three versions were made for two different people to understand the timing of adaptation to the face of the geometry, the third was drawn on a mesh of the Head of Michelangelo's David 3d model of the SMK - Statens Museum for Kunst made starting from a scan from a cast of the original David by Michelangelo, a masterpiece of Renaissance art. The cropped bust was crafted in 1899 (SMK, 2017) (Figure 13). The first two prototypes were printed in PLA on Ultimaker printers, the third in PLA on Raise E2 printers (Figure 14).

Case study: self-made mask hack

This case of study focuses its attention on an existing model of the mask with interchangeable filters. Once printed the first batch of masks a first issue arose: the model was not fitting well on the face of the people used for this trial. To solve, or at least, reduce, this adaptative limit, it was decided to find a solution capable of introducing a set of variations in the model using the most and affordable processing. First, the mesh file ready for print has been converted into an editable NURBS model. This was done using McNeel Rhinoceros 3D release 7. In the first step of processing the mesh received a clean up of its topology. The number of the vertex was downed to 20% and then converted from triangular mesh to a quadrangular mesh for a better conversion into a NURBS surface. Using SubD geometry revealed to be an efficient solution in converting the mesh to a NURBS surface. The NURBS surface is then more easily editable, through control points, and it was possible to adapt the form of the mask to the face of people with little editing. A possible alternative was sculpting the shapes using software like PixologicZbrush, but after quick testing, it came out how faster it was to edit NURBS than working with Zbrush. Once the more practical solution for editing the shape of the mask was found, there was the need for finding a quick and practical way to get a digital model of the face of the people using the mask.

So, the second step was to digitalize the faces of people to allow the full personalization of the masks. The digitalization of the face was operated using an affordable and diffuse technology: a Microsoft Kinect controlled by the Occipital Skanect scanning software. The NURBS model of the mask was then adapted to the scanned mesh and printed the new version of the mask. This solution turned out to fit well to the face but with the force of the lace, it was not comfortable for long usage.

So, after a rapid study and some reflection about the anatomy of the face brought the attention to the sensible part where the annoyance was concentrated, they were all the parts where the skin is very thin like on the nose. So the model was refined and adapted to reduce the effect of friction on the skin and excessive adherence. After this refining, the third printed model revealed itself as being very comfortable.

The resulting process is very fast: starting from the 'template' NURBS model, in about 15 minutes it is possible to obtain a personalized face mask model, ready to print. (Figure 15)

II. CONCLUSIONS

The long story of 'protective masks' has arrived in the season (or in the age, just to be more 'sensational') of the 'makers'. The evolution of the approach of a large part of the population worldwide significantly varied across the first year of the pandemic event. People get gradually aware. They moved from uncertainty to using the commonly available safety devices. Along this arc, the impact of the proposals coming from DIY, makers, firms, industries, startups and artisans moved from a position that was 'filling' the needs for a not easily available tool to proposing specialized, cool, personalized solutions. Any aspects, from the more technical, to very specific needs, like for the facial masks, the allowing of the view of the mouth, limiting the fog effect on glasses, making more personal a depersonalizing accessory, and so on… These approaches all passed by a process of dimensioning, digital modelling, testing and refining, in most of the cases using limited testing conditions and exploiting in all possible ways the social network solutions.

The following process of 3D print and refining was mainly pushed towards DIY complaint procedures, moving to more industrial productions when the initial design was moved to higher quality and higher price proposals. But in all cases, the limited safety testing and the difficulty in having solutions perfectly safe on 'any faces' might reduce the trustability and real efficiency of the result.

Following the approach of this research, specific attention was reserved to observing the effects of portability and improving the comfort of DIY masks. Following this intention a group of volunteers from the staff members of the DIDALABS System take part in the testing, using the masks in their homes. A very simple set of basic tests was planned to have a check and feedback about the obtained results. All the participants told about themselves of being interested in technologies, concerning about the safety issues brought by the Pandemic event, oriented in giving a certain value to the quality and personalization level of their accessories, During the testing, to all the participants it was asked to fill a short report in which they described their impressions about a series of key aspects of this accessory, the report was done in the form of short interviews after any long session of use and with a final 'resume of the experience'/general impression. The main topics of the test were dedicated to: tightness check, Respiratory comfort, wearability, durability/efficiency of the face attachment system, impressions from the sanitation process, awareness about the production process and the printing speed.

The tightness check is a basic and simple first test for verifying the quality of the mask airtight. It is performed by plugging the filter hole with the palm, inhaling and exhaling, no air should pass by the perimeter of the mask. All the participants who made this test reported a perfect effect of insulation.

Respiratory comfort - The positioning of the cover above a normal surgical mask does not alter respiratory comfort as the front opening under the second shell has adequate dimensions to maintain a constant flow of air. The majority of the subjects agreed with positions close to this description.

Wearability - correspondence to the profile of the face - the shape corresponds to the face, the stiffness of the material can be compensated for by inserting a strip of rubbery material suitable for contact with the skin. The majority of the subjects agreed with positions close to this description.

Face attachment system - double string, above and below the ears, made of synthetic tissue, with circular section, non-elastic strings, allow a pleasant contact on the skin and let the user feel not too much tied by the strings. The majority of the subjects agreed with positions close to this description.

Sanitation - It can be washed easily with soap and water, it can be treated with sanification gels without having any risk of deterioration. The majority of the subjects agreed with positions close to this description.

Customization of the design - The proposed design is one of the many that can be made the proposed shell represents the surface limit to avoid coming in contact with the face but beyond that surface, it is possible to intervene with any shape. The majority of the subjects agreed with positions close to this description.

Speed of realization - The modelling is carried out on a mesh extracted from a simple video lasting a few seconds, for the basic modelling of the lower shell it is sufficient to extract only the guidelines of attachment to the face and profile carefully to extract at least 4 meridian lines, printing time is about 6 hours. The majority of the subjects agreed with positions close to this description. (Figures 16-17-18)

In the end, the very positive reporting from the generic tests in the 'sandbox' of the DiDALabs environment, underline two parallel effects: one is coming from the active participation to this kind of research with an approach that is a lenitive and relaxing activity, it makes people proud about their small contribution in the fight against the pandemic event. It does not matter the minimal effort asked the participants or the minimal effect on a global scale, but the positive feelings are clear and hopefully may help in surpassing the pandemic crisis, bringing a better awareness about the safety mechanisms. At the same time, the clearance about risks and issues linked to mistakes in wearing the mask is for sure a constructive factor. But a laboratory from a non-medicine area, which opens to activities in a dramatic moment like the pandemic event is probably a positive piece of the puzzle in solving the dramatic period that humanity is facing. A small contribution, but in the right direction in bringing things to an end. In facts, it is important to reflect on the general social mechanic of the pandemic. From the past, it is demonstrated how the events have two main ways of ending: the first is the effective ending of the virus spreading, because of the finding of a cure or because of the end of its diffusion, and the second that has an earlier 'social' ending of the pandemic, while people stop or reduce their feeling of fear and go back to some sort of normal life living with the menace and accepting the level of risk as a part of the daily activities (Kolata, 2020). The following real ending of the event, then put the final word on the Pandemic. The value of the operation of 'making your own mask' is a valuable experience in terms of 'social surpassing' the crisis, but it cannot be considered as an effective solution for the safety of professional operators, it may mitigate the effects, support a reduction of the impact of infected people towards the others, but the missing (and impossible) standardization of the final results based on the 'Do It Yourself' procedures gives no option for counting it in the group of the real tools capable to bring the Pandemic event towards the solution number one. A significant study operated in 2020 synthesis precisely on the problems of 3d printing technology in front of the production of DIY safety/medical items. Starting from the absence of clear regulation on the rules related to the production and marketing of these objects. Perhaps the current emergency has highlighted this void and highlighted the need to create a specific path for the distribution of 3d models for 'home' production, a path of legal and scientific validation: 'beyond media and social media volatile information, and will help the development of guidelines and projects that may be centralized and stay as a resource during future pandemics.' (Longhitano et al., 2020). On the other side, the apotropaic value of the operation is extremely interesting, it enters in the range of the 'reactions' against a difficult and hard situation, pushing a personal solution to be a part of the second scenario, with the 'social' overcoming of the Pandemic. The personal use of the masks, even if not perfect, nor acceptable in a bureaucratic protocol or in a structured series of 'scientific' and 'safety' rules, is a specific and creative integration of a positive reaction against the risk and the bad luck, it trusts on technologies to find intelligent and creative solutions, opening the way to possible, genial, unpredicted and surprising inventions, not necessarily structured in the regular set of safety rules, but potentially capable to bring some steps forward in the general way of thinking and designing the safety masks.

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CAPTIONS

Figure 1: Raemaekers, Louis, ‘The gas Fiend’, Raemaekers’ Cartoons. Doubleday, (1917:57) https://doi.org/10.5479/sil.417696.39088007053556

Figure 2: Barrère, M. Adrien, Fifteen French doctors wearing aprons and holding various instruments ca. 1903. Colour lithograph. sheet approximately 50.8 x 92.2 cm. Credit: Wellcome Collection. Attribution 4.0 International (CC BY 4.0). Members of the Paris Medical Faculty (1904), caricature by Adrien Barrère: André Chantemesse (1851–1919) Georges Pouchet (1833–1894) Paul Poirier (1853–1907) Paul Georges Dieulafoy (1839–1911) Georges Maurice Debove (1845–1920) Paul Brouardel (1837–1906) Samuel Jean de Pozzi (1846–1918) Paul Jules Tillaux (1834–1904) Georges Hayem (1841–1933) Victor André Cornil (1837–1908) Paul Berger (1845–1908) Jean Casimir Félix Guyon (1831–1920) Pierre-Emile Launois (1856–1914) Adolphe Pinard (1844–1934) Pierre-Constant Budin (1846–1907).

Figure 3: Cecconi, Eleonora, ‘The surgical face masks protect from inside to outside’. 2020

Figure 4: Cecconi, Eleonora, ‘The respirators with exhalation valves protect from outside to inside’. 2020

Figure 5: Cecconi, Eleonora, ‘The respirators exhalation without valve protection allow protection both from inside to outside and from outside to inside’. 2020

Figure 6: Xiaomei, Chen, ‘Professor Alvin Lai (left), Dr Joe Fan and Dr Iris Li have invented an easy and cheap method for making home-made masks’, https://www.scmp.com/news/hong-kong/health-environment/article/3050689/how-make-your-own-mask-hong-kong-scientists. 2020

Figure 7: Vacca, Vitantonio, ‘Open source mask’. 2020

Figure 8: Algostino, Francesco, ‘Josep, ‘Prusa’s face shield’ Sample printed in LaboratorioModelli per l’Architettura. 2020

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Figure 11: Cecconi, Eleonora, Profile line of (Michelangelo’s) David's face, and construction of the section for the sweep2. Licence CC0. 2020

Figure 12: Cecconi, Eleonora (mash-up by), The cover mask designed by LMA worn by David, Remix of a scanned digital model of a cast of the original David by Michelangelo Buonarroti, a masterpiece of Renaissance art, the original cropped bust was crafted in 1899 (Beckett number 756), https://www.myminifactory.com/users/SMK%20-%20Statens%20Museum%20for%20Kunst. Licence CC0. SMK - Statens Museum for Kunst. 2020

Figure 13: Cecconi, Eleonora, First prototypes printed in PLA with Ultimaker printers, photo by Filippo Giansanti and Paolo Formaglini, LaboratorioFotografico di Architettura. 2020

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