

ARTICLE

Face mask designs following novel Coronavirus

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Abstract

Doctors need to wear complete protective equipment when large numbers of patients flood into the emergency room. Taiwan has so far managed to prevent a large scale community outbreak, city forces wearing face masks on public transportation, and keep social distancing to stem the virus from spreading. The protective device may be contaminated and must be replaced. In the situation of limited resources, how to take care of the physiological needs of the doctor without increasing the chance of contamination during replacement is a consideration. By reducing the chance of contamination during removal and storage, the previous designs were analyzed and improved. We proposed three improved designs to reduce the contact. Design-A features a mask with a water channel that allows the user to remain hydrated without removing the cover. Design-B has a folding pattern that hides the outer surface. Design-C combines the mask with the brim of a cap which form an extended air-intake area. Through understanding the problem, related product began distribute on the market, Design-D extend the mask usages period with less contact.

Introduction

This paper proposes three mask improvement designs for both general users and hospital staff to reduce the chance of face mask contact transmission. Influenza virus infection occurs through contact transmission between people. Infectious diseases can spread through droplets, respiratory aerosols, or direct and indirect contact with contaminated surfaces. The effectiveness of face masks in disease prevention has been verified through research.¹ MacIntyre *et al.* examined the effect of surgical masks and hand-washing on the prevention of influenza transmission.² Public compliance with infection control measures is crucial. If a large number of people use masks during a severe pandemic, the spread of the epidemic is reduced. Reducing exposure can reduce the spread of disease in public places such as schools. Cauchemez *et al.*³ have shown that holidays lead to a 20-29% reduction in the rate at which influenza is transmitted to children in school. Face mask comfort is a key to public compliance with infection control measures. In a survey by Purdy,⁴ participants were asked to use a Likert scale of 1-6 to assess the N95 filtering facepiece respirator (FFR)

based on fitness, temperature, and respiratory comfort.⁴ In terms of discomfort, warmth, and breathing comfort, fitness was rated the most important, and two-dimensional patterns expanded the mask area to cover the facial contours for individuals.

The use of reusable cloth masks is widespread, particularly when surgical face masks are scarce, but there is no clinical guidance regarding their use. Many people repeatedly use a mask every day, and the masks are repeatedly donned and doffed, placing their users at risk of contact transmission. Masks are often placed in a purse or pocket, further compromising their cleanliness.⁵ People feel using a face mask is uncomfortably humid and inconvenient for inhalation. In a previous evaluation of mask contact diffusion, individuals who donned and doffed a face mask during a simple task polluted an average area of 530 square centimeters.⁶

Novel Coronavirus in Taiwan

A novel coronavirus was eventually identified on 1 January 2020, WHO had set up the IMST (Incident Management Support Team) across the three levels of the organization.⁷ Virus can be transmitted even during the incubation period. As a result, asymptomatic carriers may still pass the disease to other people. Some patients exhibit normal temperatures, and there are many milder cases. Medical practitioners are required to wear complete protective equipment when large numbers of patients flood into the emergency room. If the face mask is removed while going to the restroom or drinking water, this protective suit may be contaminated. In a situation with limited resources, it is essential to take care of one's physiological needs without contamination.

Taiwan has so far managed to prevent a large scale community outbreak, city forces wearing face masks on public transportation, and keep social distancing to stem the virus from spreading. When asked by Fox News reporter, Gates highlighted Taiwan as an exemplary country because it quickly⁸ identified the problem and initiated community-wide testing early on and reduced the disease burden.

Taiwan had learned valuable lessons from the SARS outbreak in 2003. A centralized CECC command center led the actions and resource allocation and the necessity to be highly skeptical of data and information when an explosion begins. The Central Epidemic

Significance for public health

We demonstrated the potential for facemask contact to transmit viruses among staff and people. After an investigation of the existing product and patent database, we redesign the mask that could reduce contact transmission with a low-cost approach. Through understanding the problem, product-related improvements have already begun in the market, these designs also extend the mask usages period during daily work or a hospital visit. In this article we reviewed the process of finding problems and needs. Designers connect needs with product features through creativity. The process of exploring solutions requires a combination of domain knowledge.

Command Center (CECC) announced standards for the suspension of classes. High Schools and below will shut down for 14 days based on following rules: i) if one teacher or student is listed as a confirmed case of COVID-19 by the CECC, their classes will be suspended; ii) if two or more teachers or students are confirmed to have contracted the disease, all courses in the entire school will be suspended; iii) if one-third of schools in a township or city shut down due to infections, all schools will be closed.

The coronavirus is spread through coughing or sneezing or by touching an infected person. Commuters are particularly at risk, since they travel with large crowds in enclosed spaces, and subway handrails may spread the virus through contact transmission.^{9,10} There is also a risk of the virus adhering to the car doors and elevator buttons. People cannot avoid the germs that touch their hands and masks, which puts them under substantial psychological and physiological pressure.

Literature of facemask design

Relevant literature on masks is mainly in the product catalog or patent database. Let's summarize them separately from below.

Several variations on the standard surgical face mask are currently offered by companies. Halyard health face masks offer several features and levels of protection. The materials and donning attachments are sonically bonded, and a nose piece assists the mask in conforming to the contours of the face (Figure 1). Most surgical face masks contain an adjustable iron wire which is bent with finger pressure to fix its shape close to the bridge of the nose. This one-dimensional fixation creates a gap when the mask moves. Figure 1a also shows an adjustable nose bridge design that maintains a closer fit to the user's face. Three charging techniques (viz., corona charging, tribocharging, and electrostatic fiber spinning) were used to charge fibers or fabrics of different polymer types.¹¹ Electrostatic charging technology enables regular masks to filter more air particles.

Figure 1b shows an extended surgical mask designed with respiratory comfort concerns in mind. A flat-fold design protects against airborne biological particles and serves as a respirator. The three-panel, low-profile N95 particulate respirator mask features a soft cover and nose clip. The mask is opened by pulling up and down, and closed in the opposite way. However, although it is folded vertically, the front outer surface is still touchable during donning and doffing. Many existing product designs are based on considerations of filtering performance and suitability for individual face shapes. Figure 1c is a design with an elongated elastic restraint. A three-dimensional mask increases the protection of the mask and is convenient to carry.¹³ Figure 1d shows the upper section and the lower sections are respectively lifted away from the middle to form a three-dimensional shape. The sheet is bent along the first fold line and toward the opposite surface to facilitate carrying. The packaging of the Snack face mask is easily opened for fast use (Figure 1e). The packaging is part of the mask, so it does not come into contact with the outside world when it is folded. Although there are different folding methods for each design, there is no product that can avoid outer layer contact completely.

The elongated hexagon-shaped portion of the face mask has a clear surface.¹³ Another patent features a gathered peripheral bottom, which provides an air-tight seal under the face.¹⁴ Greenblat¹⁵ proposed a mask with a unique shape design which decreases in volume when folded with a joint style. Nilsson *et al.*¹⁶ proposed a cone-shaped tent structure with forward-extending support with an additional air valve device used to reduce the difficulty of inhalation. Wang altered the periphery of the breathing area with a compressible gasket and a three-dimensional sealing structure to abut

the user's face.¹⁷ A tight seal is necessary between the face and the mask when worn. If it is not tight enough, contaminants may be inhaled by the user. M563890 is a narrow strip mask with reinforced covering.¹⁸ The M464196 folding three-dimensional mask folds to make a three-dimensional mask with a larger exhalation space.¹⁹ Since the lower edge of the upper mask portion is engaged with the upper edge of the symmetrical mask portion, mutual contact is ensured to improve safety. After the patent database survey, we did not find a model that could completely prevent the outer layer from contacting contaminants after folding.

Design method

"Design thinking" has generated significant attention in the business press and has been heralded as a novel problem-solving methodology well suited to the often-cited challenges designers face in encouraging innovation.²⁰ The solid background of knowledge help starts to "think alternative ways to view the problem." After the team member identifies innovative solutions, the prototype is used to redefine one or further problems.

Li²¹ proposed six rules for innovation, which used in different fields such as advertising, commerce, engineering, and design. The Six rules are reverse, transfer, combination, reduction, change of direction, and extension. The rules were applied to the development of mask redesign. Their contents are:

1. Reverse (R): different appearance from previous objects;
2. Transfer (T): capture features in other objects;
3. Combine (C): capture and combine different characteristics on different objects;
4. Reduce (Rd): presented in a simple way;
5. Change direction (Cd): change direction or position of object features;
6. Extension (E): changes in the amplitude of object features.

During the design process, the designer needs to think about possible situations and parameters repeatedly and pick the appropriate settings to reduce the time spent on attempts. The design flow is, firstly, i) we look for problems and available materials, ii) we observe the medical characteristics through a simplified model, and iii) we try to find appropriate implement way. Secondly, concept drawings provided by the design group and screened based on producibility.

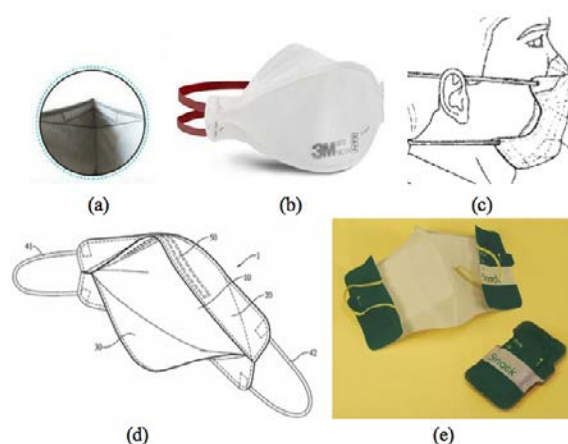


Figure 1. Current mask products: a) adjustable 3D nose bridge design; b) flat-fold design with respiratory comfort concern; c) elastic restraint;¹² d) three-piece three-dimensional design;¹³ e) extra packaging of the snack face mask.

In a medical design, the designer needs to extend his knowledge through international regulations such as ISO, MDR and FDA. The MDR sets high standards for ensuring reliable data are generated from clinical investigations.²² Recently, FDA recommendation on device reuse, so that developing cost-effective reusable face masks for the public is essential. The 510(k) submission of surgical mask evaluates medical devices for marketing to ensure they are safe and effective. Ultraviolet germicidal irradiation, microwave-generated steaming, and dry heating were tested in reducing or inactivating viral and bacterial pathogens.²³ A cost-effective full-face mask was developed to support safety of staff.²⁴ In this urgent need of the epidemic, it also urged the creation of improved mask design. Designers can develop concepts firmly and realize ideas through cross-domain cooperation.

Results

Through thinking about the real-life environment situation, brainstorming between medical consultants and designers, we selected ideas and presented three realistic and feasible ideas below.

Design-A

Caregivers must wear N95 masks before entering closed spaces. Because the mask isolates the virus from the user via the surface layer, touching the mask with hands is dangerous. After a sneeze, droplets soak through the mask, and other individuals have the chance to be infected. In addition, when caregivers remove their masks to drink water, they put themselves at risk of infection. Design-A aims to reduce mask removal and infection chance during drinking. The creative rules applied are: Reverse-drink water without taking off your mask; Transfer-transfer the Pet cap to the mask; Extension-drink water with an extension straw. Medical staff can drink water safely and conveniently without removing their masks. A water bag will engage the inlet on the front of the cover (Figure 2). The flange of the water bag can be extended to the user's lips, and the water outlet does not touch the outer surface of the mask while drinking which avoids the risk of contact transmission.

Design-B

After taking off their masks, most subjects carry them in purses or pockets. The hands touch the contaminated areas on the mask and the outer edge of the mask also touch the interior of the purse or pocket. Therefore, it is crucial to minimize the chances of contacting the outer edge of the mask. Design-B can be folded in a W shape so that the outer part of the mask faces inward and reduces contact transmission (Figure 3a). When the mask is unfolded, a three-dimensional convex surface is formed over the nose (Figure 3 b,c) which increases the available area for inhalation. The creative rules applied are: Reverse- change of direction, Outer surface facing inward; Transfer-techniques of origami; Reduction- reduce the chance of hand contact.

Design-C

Because people often do not wear masks when going out, Design-C (Figure 4) combines the mask with the brim of a cap, a design usually acts as a hat, and when needed, the user pulls down the headband, which is made of a flexible material. At this

time, the mask and the brim form a sizeable three-dimensional space, and it is easy for the user to breathe with a large area of air intake. When the mask is doffed and folded, the user holds the headband of the cap to avoid contact transmission. The creative rules applied are: Reverse- cap front edge elastic can be pulled down; Combine- mask combines with hat; Change direction- pull down; Extension- increase front end size.

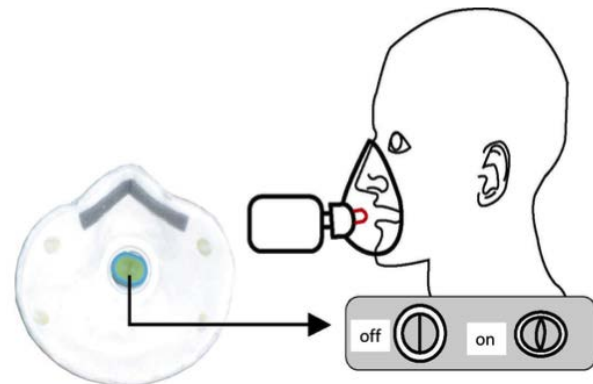


Figure 2. Design A allows for easy drinking (design by Po-Ming Shi).

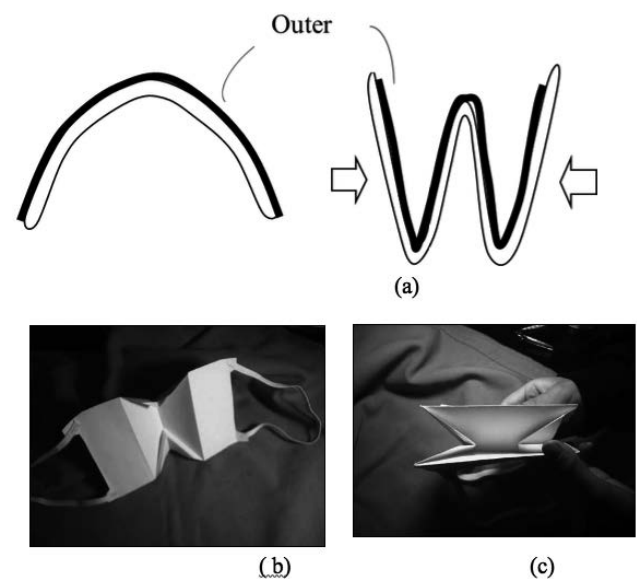


Figure 3. Design-B masks are easy to breathe through without spreading pathogens: a) schematic diagram of folding method; b) during use; c) remove for storage.

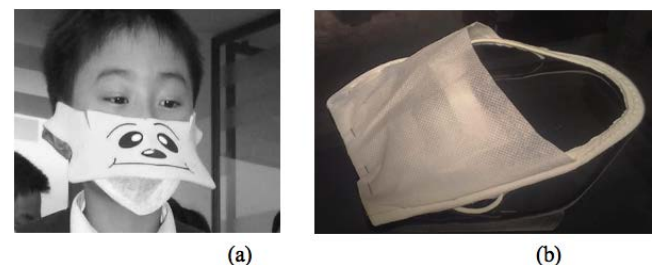


Figure 4. Design-C: a) outdoor hat which is pulled down to reveal a hidden mask; b) hat mode with extended space provided by mask and the brim.

Design-D

A major epidemic makes people aware of the importance of avoiding contact and related improvements have distributed in local market. The Design-D (Figure 5a) added a breathable thin cloth cover outside the mask, the outer surface of the cover is in contact with the virus, and the inner surface is in contact with the mouth foam; after using for a period of time, remove the cover to wash and dry to increase the use time of the mask. Figure 5b shows a foldable box. After removing the mask, the outer surface folds inwards; place the mask in the protective shell with an elastic band to close the protective shell and put it in the pocket. This avoids the opportunity for the outside of the mask to contact the body and clothing. The creative rules applied are: Reverse- mask with another mask; Combination- mask combines with package; Change direction- the outer surface facing inward to reduce contact.

Discussion

The current coronavirus epidemic has increased the need for face masks and respirators that can be used without increasing the chances of contact transmission. Residents who live in affected areas are at risk of infection from close contact with other residents, especially during their daily commute. In addition, it is nearly impossible to avoid contact with pathogens on face masks and hands. Current face mask patent designs do not protect the outer layer of the mask from outside pathogens after they have been folded.

As a result, we propose three improved mask designs to reduce the chances of infection from direct contact. Design-A features a mask with a water channel which allows the user to remain hydrated without removing the mask. Design-B has a folding pattern which hides the outer mask surface and reduces contact transmission. Design-C combines the mask with the brim of a cap. The mask and the brim form an extended air-intake area for easier breathing. The Design-D shows related improvements distributed in local market which reduce the chance of mask contact with users' body and clothing. An epidemic makes us aware of the detail living behaviors which strengthen public health.

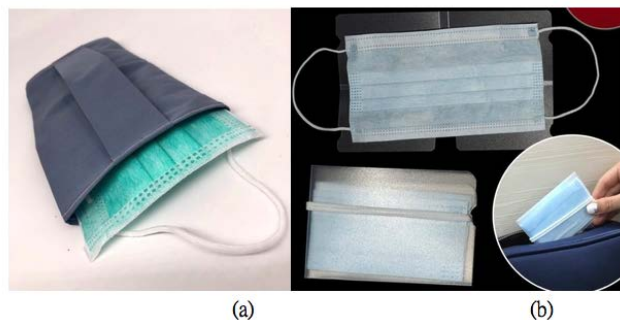


Figure 5. Improved product distributed in local market;²⁵ a) added a breathable thin cloth cover outside the mask; b) a foldable package to reduce contact.

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