Face Masks as Awareness and Engagement Platforms

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Abstract. The COVID-19 pandemic required the adoption of several health-safety practices that have been demonstrated to be crucial for limiting the spread of the virus, including the use of personal protection equipment (PPE). Particularly, face masks have become a ubiquitous component of our daily lives. However, despite their effectiveness, they have several drawbacks. In addition to being uncomfortable for many users, they entirely cover the mouth, which, in turn, poses limitations to non-verbal communication and interpersonal interaction. In this paper, we present the user-centered design process of a solution that augments face masks with additional features that support interaction, awareness, and engagement.

Keywords: pandemics, COVID-19, Personal protection equipment, Human-Computer Interaction,

1 Introduction

Adopting proper individual health-safety measures is crucial for limiting the spread of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) pandemic. Specifically, in combination with non-pharmaceutical practices such as social distancing, the use of Personal Protection Equipment (PPE), and particularly, face masks, is among the most effective practices for reducing contagion from the coronavirus disease 2019 (COVID-19). Research studies demonstrated that especially when most individuals comply with their adoption, PPEs could reduce mortality by 24-65% [1].

Currently, several types of face masks are recommended depending on the context of use, and they offer different levels of protection. They range from cloth masks, which provide the user with the least insulation from infectious agents transmissible by droplet or air routes, to more effective pieces of equipment such as surgical and filtering facepiece (FFP) masks, which are recommended in hospital settings and in situations where there is an increased risk of contagion [2]. Although their effectiveness has been demonstrated by several studies, there are still discrepancies related to the consistency of public safety guidelines: most countries have introduced them as a requirement in indoor public spaces and, in case of gatherings, in outdoor areas, whereas other nations recommend their use without making them mandatory. Similarly, the World Health Organization (WHO) and the Center for Disease Control (CDC)

have different approaches to PPEs: the former does not recommend healthy individuals to wear a mask routinely, whereas the letter suggests face covering among the best practices, because it helps prevent asymptomatic and presymptomatic virus transmission [3].

Although there are different regulations and individuals' adherence to prescribed measures varies greatly depending on many factors, face masks have become a ubiquitous component of social interactions [4]. Unfortunately, despite their usefulness in terms of safety, they have several drawbacks. Many users perceive them as uncomfortable, especially when they must wear them for several hours, as in the case of health workers and employees who work in contact with customers [5].

Moreover, as most models entirely cover the mouth, they considerably affect verbal and non-verbal communication. For instance, they render lip-reading impossible, which significantly impacts people who are deaf and results in increased frustration and loss of interpersonal communication. Furthermore, they make it difficult to detect facial expressions and hearing the voice well, which is even more significant considering the overall pandemic scenario (e.g., shelter-in-place and lockdown orders) and the diminished opportunities for social contact and interaction. In addition to issues related to communication and interaction, users are often concerned with the effectiveness of PPEs worn by others. As the efficacy of masks decreases after a few hours of use [2], individuals feel unsafe, especially when interacting with workers in stores, because of the absence of any indication of the safety level of the mask (e.g., cloth, surgical, or FFP masks) and to the time it has been used for. In this regard, the COVID-19 emergency highlighted that the consequences of pandemic go beyond morbidity. Several studies showed that restrictive nationwide orders, including shelter-in-place and lockdown and, especially, their prolonged time, have several consequences on individuals' mental health. Similar results are found worldwide, in countries that were hit earlier and experienced more restrictive lockdown policies (e.g., China), as well as countries such as the United Kingdom, where measures against the spread of the virus were introduced later [6].

In this paper, we propose a novel approach focused on improving the user experience of face masks. Specifically, our work aims at augmenting traditional face protection devices, so they can be utilized as social awareness and engagement platforms. To this end, our design strategy consists in incorporating features that can result in enhanced interpersonal communication, increased compliance with safety measures, and improved engagement with social spaces. We detail two example implementations in which our solution integrates with traditional and non-conventional face masks for increasing health-safety awareness while restoring some of the components of non-verbal communication that are impaired by the current design of most facial protections. Furthermore, we present the results of a research study on human factors and adoption dynamics that demonstrates that our approach is viable for both personal and work-related uses.

2 Related Work

Individual protective devices, and especially face masks, were introduced in the very early stages of the emergency and have increasingly been adopted since the inception

of the pandemic. Several studies demonstrated the effectiveness of different types of PPEs in limiting the spread of the virus. Among them, face masks have been demonstrated to be the most effective, either by protecting the individual wearing the mask from outside risks or by avoiding transmission of pathogens and other infectious agents to the others nearby [1]. Thus, most research dealing with the multifaceted health-safety aspects related to the COVID-19 emergency focused on face masks. Specifically, several groups developed hardware and software infrastructure-based solutions for enhancing individuals' safety by detecting the use of PPEs as well as compliance with social distancing requirements in buildings and public places (e.g., offices, businesses, and airports) [7]. In addition to the use of cameras for temperature monitoring and mass surveillance [8], and Internet of Things devices [9], [10], novel machine learning algorithms have specifically been trained to detect and recognize the distance between individuals and whether they wear a face mask [11]. On the contrary, although there are a plethora of PPE options available (e.g., masks, gowns, face shields, etc.), there have been fewer attempts at improving this type of personal protection equipment and overcoming their current drawbacks and limitations. New models of face masks have been introduced to render them more comfortable to the user. Specifically, new designs include transparent materials or different mounts (e.g., on the chin). However, they introduce additional concerns (e.g., increased moisture) and involve more expensive materials. Also, some of the new models were demonstrated to have a lower protection coefficient [12]. In contrast, the objective of our research is to evaluate different strategies for augmenting face masks with features that overcome their drawbacks while enhancing their potential as awareness, interaction, and engagement platforms.

3 System Design

The objective of our work is to design technology that helps individuals adhere to recommended health-safety practices while simultaneously reducing the psychological discomfort, anxiety, and short- and long-term side-effects associated with them. To this end, we utilized a goal-driven methodology detailed in [13]. We At the beginning of our work, we evaluated individuals' perception in regard to the most common health-safety measures adopted against COVID-19. surveyed 514 individuals having different age groups, genders, and demographic characteristics of interest for our work (i.e., living in a country having health-safety recommendations in place). Specifically, we asked participants to rank the most common preventive measures according to their perceived level of safety. As shown in Figure 1, respondents indicated that using and changing face masks with the correct frequency is the most effective practice, as it accounts for 25% of the perceived level of health-safety. Other relevant measures are social distancing (24%) and sanitization (20%), whereas temperature monitoring (14%), getting vaccinated (12%), and contact tracing (4%) were considered as less relevant [14]. Furthermore, despite our data showed high compliance with the adoption of face masks, respondents' comments indicated that personal protection equipment especially is a source of concern, compared to other interventions. In particular, consistently with data from the scientific literature, we discovered three types of issues, two of which are related to interpersonal communication, whereas the other

involves aspects of perceived health-safety. As far as the former factor is concerned, most respondents indicated that (1) the impossibility of seeing the wearer's mouth affects communication and makes it significantly harder for individuals to understand words, especially when interacting in situations of social distancing, presence of shields, and background noise (e.g., grocery stores); (2) the inability to see facial expressions impacts the affective component of communication and makes it more difficult to understand emotions and adjust the tone of the conversation accordingly. Furthermore, in most comments, subjects mentioned their distrust in others' hygiene practices in wearing PPEs, with specific regard to the time the mask has been worn for, which determines its effectiveness.

Face masks have the unique advantage that they are continuously worn by the user in situations in which they could be in contact with others. Furthermore, this type of PPEs is worn in a location that is visible, which that makes it perfect for being easily recognized and read by others who are nearby. As a result, we designed a solution that primarily aims at addressing the main concerns expressed by users, that is, restoring non-verbal communication and providing additional information about the health-safety features of face masks. Furthermore, our approach focused on considering PPEs as devices for social interaction to improve their adoption and increase the overall compliance with preventive measures. The proposed solution, represented in Figure 2, consists in a hardware and software architecture that enables integrating commercially-available and custom flexible LED displays in face masks. Furthermore, we incorporated Bluetooth Low Energy (BLE) transmitter that supports connecting them to a smartphone application. The purpose of the LED display is to show different types of information based on the information received from the application. The main difference of our approach compared to the devices that already are on the market is that the software component of the system is organized as a platform that enables installing, activating, and utilizing multiple plug-ins, each dedicated to augmenting the face mask with a specific feature. To this end, we developed a simple architecture that supports third-party components and exposes the output features of the display so that each plug-in can utilize it entirely or be visualized as a widget on the mask. By doing so, we can support different applications that augment face masks as described in the use cases defined during our participatory design process, which are described below.

One of the plug-ins of our solution is designed to display emojis on the mask. This feature was requested by users in several participatory design workshops as a way to counteract the lack of affective communication caused by the inability to see facial expressions. The plug-in enables users to set an icon to be visualized continuously on the LED, or use shortcuts to activate emojis during conversations. A second plug-in that was incorporated in the prototype based on end-users' input enables visualizing a short text on the display, which can serve as a salutation or a thank you message. Users asked the possibility of saving text to a favorites list for ease of access to common words as well as a default list pre-programmed for commonly texted acronyms and slang. A third plug-in enables activating a timer that has the purpose of measuring the time the mask has been worn by the user and alerting them when it expires. By doing this, the LED display can visualize the expected effectiveness of the mask and show it to others using a simple system based on a green, yellow or red light. The purpose of

this function is to help the user observe good mask hygiene as well as increasing awareness and trust in other people.

The LED matrix can be attached to the PPE so the mask can be easily changed or washed. Furthermore, the proposed system is designed to work with a variety of displays, including 8-bit and single LEDs. To this end, the resolution of the display can be set in the software so that the application can enable or disable the plug-ins based on the resolution of the display or produce an output that matches the resolution of the display. Each plug-in conveniently appears with a dedicated icon on the home screen of the application so that the user can easily access it. Also, in addition to the settings and to other functionalities, the software provides the user with the possibility of checking the current content of the display.

Moreover, the system incorporates a battery monitor that notifies the user when the LED display needs to be recharged.

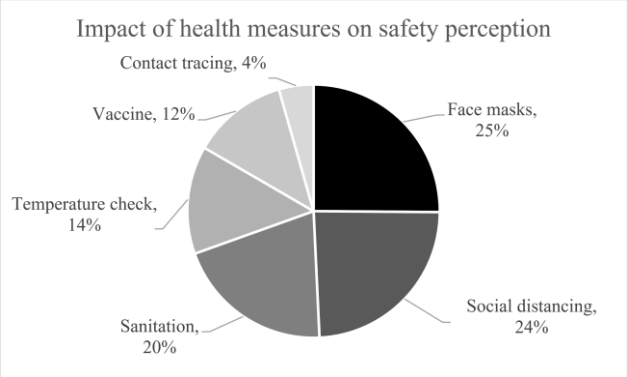

Fig. 1. The results of our preliminary study about the perceived importance of the most common health-safety measures. Respondents indicated face masks as their first priority against COVID-19.

Fig. 2. Home screen and concept of our solution. The smartphone application supports a plug-in architecture that enables incorporating additional features that can occupy the entire display or be visualized as widgets.

4 User Evaluation

A commercially-available LED mask was utilized to preliminarily evaluate the concept and test it with a focus group of users. This enabled obtaining initial feedback and incorporating the necessary changes. Then, we utilized web-based prototyping tools to co-design the system with a group of target users. Moreover, this enabled us to share the prototype with a larger audience of people who showed their interest in contributing to our solution with their feedback and comments. Subsequently, we designed a user evaluation study aimed at analyzing our proposed system from usability and acceptability standpoints. For health-safety reasons, and considering the early stage of the project, we preferred to realize the study remotely. Therefore, in our prototypes, we simulated the hardware component of the system using a digital twin of the IoT device, according to an approach similar to the one documented in [15][16]. This enabled us to minimize any sharing of physical objects. Simultaneously, by sharing a simulation of the hardware system, we were able to reach more users.

During our co-design and user evaluation sessions, participants mentioned that the possibility of visualizing emojis would help them display feelings that would normally be conveyed nonverbally with facial gestures centered on the mouth. Moreover, during our user evaluation study, several participants commented that sending a text to the display can facilitate effective communication when the user's voice is muffled by a face covering, and their audience cannot see their mouth for the usual cues. In this way, the LED display can also assist, in a limited fashion, those with hearing disabilities who rely on lip-reading and facial expressions to understand the people around them. As the features can be combined, much like the adoption of emojis in electronic text communication, the solution will offer a fun alternative for communication when tone cannot be easily inferred.

After conducting preliminary focus groups and reviewing the responses of individuals who used the prototype, the consensus is that a mask or other item incorporating a wearable LED display would be considered a useful tool for communication. This extends to multiple venues for public interaction and would be useful for personal and business use. Moreover, the preliminary feedback collected from users suggests, in line with behavioral models of hygiene from other contexts [17], that increasing engagement with face masks could result in a more positive attitude towards PPEs, as well as in a more informed use. Although the enhanced communication features were received positively from the users, the people who participated in our preliminary focus groups expressed several concerns regarding the awareness component of our solution. Specifically, they indicated that they would not be willing to display the time they have been wearing the mask, though they are interested in seeing it visualized on other people's masks. Although this requires further investigation, the timer feature could be especially useful when utilized by employees who are in contact with customers as a way to display good hygiene and compliance with health-safety practices and, therefore, improve trust.

5 Conclusion and Future Work

In this paper, we proposed a novel approach to face masks that considers them as platforms in which interactive features can help restore the lost components of verbal and non-verbal communication and create user engagement with health-safety measures thanks to increased awareness about their effectiveness. We described the system resulting from a participatory design process in which users contributed to defining and developing the hardware and software features of the proposed solution. In our approach, the face mask can be considered as a support for a series of applications that could help users alleviate the consequences of both a diminished level of social interaction and increased anxiety with respect to others' hygiene and health-safety practices. Thus, we detailed our implementation, which consists of three plug-ins, each supporting one of the several potential uses of our system. Although further analysis is required to assess the adoption of our solution with a more robust approach, our preliminary user evaluation showed that augmenting face masks with additional communication, awareness, and engagement features could also result in overall better compliance with PPEs.

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