Co-design of Do-it-yourself Face Shield in Japan Under COVID-19 Pandemic

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ABSTRACT

Along with the spread of open-design environments and various types of digital fabrication tools (e.g., computer numerical control machines, laser cutting devices, and 3D printers), the "maker movement" or "personal fabrication" has been spreading worldwide over the past decade. This case study introduces grassroots activities in Japan that employ personal fabrication tools to manage the COVID-19 crisis, focusing on the co-design of do-it-yourself face shields for healthcare workers. We address the various issues emerging with face shield production: (1) development of face shield designs and materials, (2) examination and information sharing regarding the practicality and safety of open-source designs, and (3) collaboration with local factories. Thus, we demonstrate the significance of maker contributions to COVID-19 and provide suggestions to address future challenges.

Keywords: COVID-19, FabLab, Face Shield, Japan, Maker Community.

1. INTRODUCTION: COVID-19 CRISIS AND MAKER MOVEMENTS

Since the widespread use of personal computers and the Internet, individuals have been able to access vast amounts of information for computation and communication. In addition, open design environments and various types of digital fabrication tools such as computer numerical control machines, laser cutting devices, and 3D printers have been developed, encouraging individuals to experiment and/or fabricate things they require. In this context, a movement known as the "maker movement" or "personal fabrication" has been spreading worldwide over the past decade (Dougherty et al., 2017; van Abel et al., 2014; Gershenfeld, 2007). Maker Faire, a festival of the do-it-yourself (DIY) community, has been held worldwide, including in Japan (e.g., in Tokyo, Kyoto, Ogaki, Yamaguchi, Tsukuba, and Sendai). Furthermore, as hubs of personal fabrication, "FabLabs" have been established in more than 1,800 locations in 120 countries (Fablabs.io, n.d.). The FabLab Japan Network, a voluntary community of FabLab managers and supporters with diverse backgrounds, was established in Japan in 2010; labs are now spreading to more than 18 locations, including those in Hiratsuka and Shinagawa.

The COVID-19 infection, first confirmed in November 2019, spread worldwide in 2020. Owing to the rapid spread of the infection, serious global shortages of personal protective equipment (PPE), including face shields, masks, and gowns, have occurred. To eliminate supply shortages, the aforementioned individual makers and FabLab communities responded quickly by attempting to manufacture PPE equipment in a DIY manner using digital fabrication tools, followed by publishing open-source licenses. Various design ideas have been proposed for the DIY fabrication of face shields. For example, nine different design options were introduced in a PLOS BIOLOGY review article (Chagas et al., 2020), and the Open Source Medical Supplies website shows 28 different design ideas. Examples of equipment and tools for making face shields include 3D printers (e.g., for the "Prusa Face Shield" or "Easy 3D printed Face Shield" on Thingiverse), laser cutters (e.g., for the "Proto Shield" or "Origami Face Shield"), and even scissors and staples. In addition, the open data are licensed under Creative Commons licenses (CC BY-NC: Attribution-NonCommercial, CC BY-SA: Attribution-ShareAlike), many of which are available to the public. By July 10, Prusa Face Shield had 217 remixes by 3D printer users, and the "Easy 3D Printed Face Shield" had been remixed by 82 contributors.

On the global Maker community's website, various initiatives of makers tagged as "Plan C" ("If Plan A is the government and Plan B is industry, then Plan C is for civic action" (Dougherty, 2020)) have been published since March 22, 2020. In Japan, Maker Faire Kyoto 2020 was held as an online event on May 2. During the course of five hours on Twitter, 957 works from 394 makers were presented (Kobayashi, 2020). In addition, two panel discussions were planned on YouTube. One of these was themed "What We Makers Can Contribute to the World since the COVID-19 Pandemic." The discussion was preceded by a Slack workspace "COVID-19 Makers Forum JP" set up to share ideas, with 186 makers. For example, ideas for preventing infections in the medical and welfare fields were considered on an "idea-hackathon"' day. In addition, an online survey was conducted regarding homemade masks openly available on the Internet.

However, the global FabLab network uses hashtag #FabDoesNotWait as its motto. The aforementioned initiatives were conducted after discussions with industry experts and researchers in the field of respiratory health. They have led to the development of PPE for frontline healthcare and essential workers, and helmets for continuous positive airway pressure treatments (i.e., sending air into the nasal airway). In Japan, several FabLabs are promoting efforts to create face shields using 3D printers. For example, Doyo from FabLab Hiratsuka and Kanagawa University designed a 3D model for the frame of a face shield; the model, called the "DOYO model," is being shared widely (Doyo, n.d.). The model is available as open-source data on the author's GitHub page; therefore, anyone requiring the face shield could print out the frame with a 3D printer at a decentralized lab or home, and modify it as needed.

In this study, we focus on a community of individual makers and FabLabs in Japan. This community has been working to develop and deliver face shields to healthcare facilities, while simultaneously increasing quality and quantity.

2. METHODS

To examine the development and delivery of face shields by personal makers and FabLabs, we focus on two public Facebook groups that have contributed to the grassroots construction of face shields in Japan. Both groups are organized with the aim of sharing open-source face shield designs and supplying them to healthcare workers lacking PPE. The first group is COVID-19: The Community of People Who Make and Distribute Face Shields (established April 10; 258 members). This group is mainly organized by personal makers and FabLabs; there are at least 40 members of FabLabs in Japan. The second group is the 3D PRINT FACE SHIELD (established April 13), a broad community comprising more than 1,000

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members. This community makes face shields based on open-source 3D print data, i.e., the "HANDAI Frame" developed by Nakajima, a professor of Osaka University Hospital. As an open community, various actors—medical workers, designers, engineers, makers, office workers, and high school students— participate in these Facebook groups, and the community members in these groups partially overlap, sharing information and communication among them.

This study mainly concerns the former group, as it is easier to follow the detailed processes of making, modifying, and discussing face shield designs, materials, and methods for maintaining safety, in addition to addressing mass production between personal makers and FabLabs. We created a list of all posts of the Facebook group COVID-19: The Community of People Who Make and Distribute Face Shields through June 30th by sorting the posts by date, poster, design and material of the face shields, input time by 3D printer, and the personal makers' comments on these designs or materials. Meanwhile, we also organized the chronological development process of the "DOYO model" (detailed in section 1) from Doyo's posts on Facebook and his GitHub page (Doyo, n.d.). Using this approach, we analyzed the processes involved in the development of face shields in Japan.

3. RESULTS AND DISCUSSION

The structure of a face shield includes two major parts: a transparent shield and a frame to hold it on the head. The engineering requirements for the frame are as follows: (a) securely fastened around the head and (b) fitted closely to the forehead. The frame must be comfortable to wear for long periods of time. For this reason, there are possible variations in the structure. It must be non-latex if using elastic materials, but the types of materials is not significant. In contrast, the requirements for the shield concern transparency, firmness (e.g., not easy to bend), coverage of the entire face, and type and availability of materials. Therefore, in the following sections, we will focus mainly on the design of the shape for the parts of the frame and on the types of materials for the shield parts.

3.1. Designs of frame parts

In the public Facebook group The Community of People Who Make and Distribute Face Shields, members have posted several examples of designs and fabrication approaches for face shield frames with various shapes. Most of the frames were made using a 3D printer, but others were made using a laser cutter and commercial foam tape. For the structure of the frames, one method for integrating the frame and shield parts involves making three or four small holes in the shield part using a hole punch or other tool, and inserting corresponding protrusions of the frame part into the holes to assemble it in place. Another method involves inserting a shield without holes between the frame parts. To fix the frame to the head, a hook structure is attached around the back of the head and is adjusted with a rubber band. Few posts mentioned the material of the frames; it appears that biodegradable polylactic acid has been used.

In addition, several open-source face shields have been shared by Facebook. The DOYO model has been introduced as a recommended prototype, as it is well regarded by hospitals and other organizations. As a case study, we consider the situations surrounding this "DOYO model." The repository of the DOYO model was created on GitHub on March 31, and in early April, there were multiple commits, and the data had been updated. The DOYO model

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employs the method of assembling parts with holes and protrusions, and uses a hook structure for the frame. This hook structure is based on an open-source design by 3DVerkstan in Sweden with a CC BY-SA license; therefore, the DOYO model is also licensed under CC BY-SA. There are multiple versions of the DOYO model. Following the initial version, a prototype was developed that could make five pieces together, and a week later, a version was released that could provide output in half the time (31 min) of the initial version (60 min), using a 3D printer. Subsequently, in collaboration with the medical community, a version that could make up to 30 pieces simultaneously was released. Following the release of the open-source 3D data, FabLab members and makers in Japan have used this data to make frames using their 3D printers. They have created from a few dozen to a few hundred face shields and donated them to local medical institutions and other organizations. In addition, local companies have provided thousands of face shields to local medical institutions and municipalities free of charge, and domestic 3D printer manufacturers (e.g., MIMAKI and MUTO) have been providing face shields at a rate of 500 units per day to 500 units per month, using the manufacturers' own 3D printers.

3.2. Materials of transparent shield

In addition to the design, the material(s) of the face shield also appears to be an issue in creating face shields. Is the material sufficiently transparent as a face shield? Is it durable (can it be used several times)? Can it be bought easily? In the following, we chronologically show the personal makers' and FabLabs' attempts to seek and examine appropriate shield materials by tracking personal making reports and mutual communication among Facebook groups.

One issue was the use of an A4 clear plastic folder/file. In earlier stages, when people began crafting face shields on their own, a clear plastic folder was regarded as the most potent shield material, owing to its commonness and low cost. Osaka University's model, which gained broad attention to design when published, as the idea of using a common clear plastic folder for the material of a face shield was novel. Yoshioka, a Japanese designer who works globally, published a face shield design ("Easy-to-make FACE SHIELD") comprising a clear plastic sheet that is cut and attached to glasses (Yoshioka, 2020). The social design activist NOSIGNER's DIY face shield (called "PANDAID") also uses a clear plastic folder (PANDAID, n.d.). However, from the viewpoints of people who tried to make and wear them, several problems with clear plastic folders were noted. Although clear plastic folders seemed easy to obtain and could be utilized for the urgent demands for face shields, the transparency of the clear plastic folder was insufficient, particularly for medical uses that require detailed work. Moreover, clear plastic folders suffered shortages of supply on online shopping sites; thus, the price suddenly rose. This was a serious problem for making face shields in emergencies. The idea of using a clear plastic folder, therefore, had already become regarded as unrealistic by the end of April 2020.

Accordingly, the participants in The Community of People Who Make and Distribute Face Shields started working on prototypes using various types of materials, as alternatives to clear plastic folders. Although it is impossible to show them all owing to space limitations, the material types that they targeted were broad: laminated films, vinyl sheets, polyethylene terephthalate (PET) sheets, polycarbonate plates, polyvinyl chloride plates, polypropylene (PP) films, oriented PP films, cast PP films, and so on. The features of each material and its suitability for face shields became apparent within the processes of creation and evaluation

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of the aforementioned face shield prototypes. For example, a PP film is better for durability, as it is hard to break; laminated film is good for lightness and transparency; overhead projector sheets are less transparent, despite their high prices compared with other materials. Not only the functionalities of the materials were examined, but also the adequacy of alcohol sterilization for reuse, that is, which material surfaces do not fog up when wiped with alcohol.

To determine the appropriate material, the makers conducted lively discussions. In the public Facebook group, members commented on each post, exchanged ideas regarding the materials, offered advice based on their experiences, and asked for details from multiple viewpoints – price, transparency, where to obtain materials, safety, and durability. They also held an opinion hearing for healthcare workers close to them as prospective users, allowing for the handling of some prototypes, and asking for opinions regarding wear, visibility, and stability. Such mutual feedback led them to change and improve, or to promptly try new materials.

Surprisingly, however, we did not determine the flow of standardization for a material, at least in the last three months. The possible reason for this is that the selection of a material largely depends on the material's availability as well as its functionality as a shield. Because of the heavy dependency on availabilities, destinations, and purposes, it was necessary for the personal makers to discuss the adequacy of the materials from multiple viewpoints. For them, it could be said that the best material was relative. On the one hand, the indeterminacy of the best material might be the limitation of personal production. On the other hand, it was a natural and strong point of FabLab’s characteristics, that is, small production and distributed manufacturing. These efforts could be seen as demonstrating the flexibility of small production (one of the characteristics of FabLab’s work), and helped to contribute to the urgent demands of the COVID-19 problem. At least until shields ready for mass production were completed, the flexible production by personal makers and FabLabs enabled makers to deliver slightly better quality face shields to people who need them immediately.

3.3. Practicality and safety of open-source designs

In this section, we discuss the agendas that makers and suppliers of face shields confronted in the uses and embodiments of open-source PPE designs, and describe their approaches to such problems, mainly focusing on the cooperative works of the personal makers and FabLabs.

The first agenda concerns the flood of open-source designs. Many open-source designs for PPE were shared via the Internet, leading to a saturation of designs. Innumerable open-source designs require manufacturers and suppliers to inspect and select them. The FabLab community dealt with this problem of saturation using various approaches. For example, FabLab Shinagawa, Tokyo, began checking various open-source designs for face shields in early March. They made at least 10 types of face shields by printing based on open-source 3D face shield data, wore them, evaluated each design’s advantages and disadvantages (such as manufacturability, fitting, and visibility), and noted points for reform. Every report was published on their webpage (FabLab Shinagawa, March 20, 2020). By conducting verifications individually, they confirmed whether the face shield designs were practical. As FabLab Shinagawa was the group that originally attempted to create 3D-printed self-help devices by mixing digital fabrication and occupational therapy, their previous experiences enabled them to create 3D printer face shield prototypes promptly. However, there was another challenge, namely, safety in providing the PPE. Sending PPE might cause a risk of exposing the healthcare workers who use them to COVID-19 if SARS-CoV-2 is attached to the PPE. Therefore, makers must seriously consider ways to avoid infection as well as to make the PPE. To this end, it was necessary to create platforms for learning correct knowledge regarding infectious disease prevention.

In April 2020, the project "Fab Safe Hub" was started by the FabNurse project 1, Fab Lab Hiratsuka, and Social Fabrication Laboratory. This online platform aims to explore and share the ways in which makers who create 3D-printed face shields can provide PPE to healthcare workers safely. Fab Safe Hub provides information for both makers and users. For makers, Fab Safe Hub shares face shield designs, checklists for materials and inspections, and guidelines for materials and procedures for sterilization, as appropriate for 3D-printed products. In the guidelines for sterilization, for instance, it is suggested that makers must soak the face shield's frame in sanitizers while wearing masks and rubber gloves. For users, Fab Safe Hub released a sample PDF instruction manual for the face shield, including information on the precautions, assembly method, and management method. Until May 2020, there were not sufficient face shields for single use, and thus Fab Safe Hub also advised users to sterilize the shields for reuse. The information shared via Fab Safe Hub has been widely used as a reference for makers when sending face shields they have produced.

From the efforts of the personal makers and FabLabs communities for providing practicality and safety in making and providing face shields as described previously, we determined their contributions based on their utilization of their skills and know-how in digital fabrication, and on the new tasks they confronted. For example, the FabLab community could mobilize their facilities and experiences in 3D printing to respond to the serious lack of PPE. However, it was revealed that there was a limit to what they could contribute to (or based on) their existing knowledge. Based on the concepts of "Do It Yourself" and "Share It with Others" (Gershenfeld, 2012), FabLabs have generally created small devices for themselves, or, even when giving these products to someone else, have been limited to face-to-face situations. Therefore, in completely unpredicted and new situations requiring them to supply their products to unknown people, they learned that further skills and responsibilities were necessary to make and supply them safely, for example, with regards to the sterilization, explanation, and provision of the products.

3.4. Collaboration with local factories

We have described efforts to ensure the practicality and safety of DIY face shields, that is, to ensure quality. We have also discussed the advantages of utilizing a 3D printer in the decentralized production of face shields. However, one of the disadvantages of using a 3D printer is the issue of quantity. There have been attempts to print multiple pieces at a time, and 3D printer companies have collaborated to provide several hundred face shields. However, when needing more shields, a single 3D printer is often unable to handle the need for more pieces. In response, activities for increasing production with small factories have begun. As the DOYO model was an open source, it allowed users to not only download and use the 3D data, but also to modify some of the data depending on their needs. Ten days after the data was released, Doyo was contacted by a cooperative society of small- and medium-sized factories in Aichi Prefecture, Japan. Less than a week later, a mold was created based

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on the 3D print data and was partially modified for mass production. In addition, recycled plastic bottle caps were used as the materials for the frames. PET sheets that were donated by other chemical manufacturers were adopted as the shield material. A production system of 40,000 units per week was prepared (AnjoHearts, April 24, 2020), and more than 17,000 face shields were distributed free of charge to medical professionals across the country in Japan within approximately one month (from mid-April to mid-May) (AnjoHearts, May 19, 2020).

4. CONCLUSION

Confronted with the unpredictable crisis of the spread of COVID-19 worldwide and the corresponding shortages of PPE, FabLabs in Japan have addressed these problems by using their skills and devices. Several issues emerged from the activities of face shield production: (1) development of face shield designs and materials, (2) examination and information sharing regarding the practicality and safety of open-source designs, and (3) collaboration with local factories. This case study clarified how grassroots face shield production helped improve the supply of face shields, at least until the mass production of PPE became ready. Although the cases of the co-design and development of face shields addressed in this article are a subset of the overall activities, these activities mixed previous experiences and immediate measures, and revealed the novel potential of personal makers and FabLabs to contribute to emergencies. The strengths of individual makers and FabLabs' works for COVID-19 are based on their skills in making and local fabrication as well as on their community networks. Instead of mass industrial production, FabLabs and personal makers have continued the prompt development of face shields, along with discussions with users and medical professionals on the safety, usefulness, and accessibility of face shields. This improvisation and flexibility in making products, which are important characteristics of FabLab's small and local fabrication, have contributed to responding to the urgent needs of the COVID-19 crisis. Furthermore, these efforts to produce face shields are based on community networks between personal makers and FabLabs, allowing members to try new designs and materials of face shields, and to modify them. In particular, existing FabLabs, such as the FabLab Hiratsuka and the FabNurse project in Japan, have engaged in healthcare activities, shared their professional medical knowledge, and helped bridge between grassroots face shield production and supply to healthcare workers.

Finally, we conclude this paper with a few suggestions on some remaining challenges. Although the supply of PPE has stabilized to some degree during the writing of this article in Japan, it is not clear that the makers' role is complete. We believe that we are in the next stage, and should consider what makers can provide for the future. The first suggestion concerns inclusive design. The urgent priority in the COVID-19 pandemic was to supply PPE (including masks and face shields) to many people. However, we believe that the development of inclusive designs for various groups of people is also necessary. For example, daily measures such as social distancing and not touching things, as encouraged by governments to prevent infection, could exclude disabled people, such as visually impaired persons (Canadian Council of the Blind, 2020). It is possible that personal makers and FabLabs could flexibly create products for those who have particular needs, by taking advantage of their small production and local fabrication. Another suggestion concerns proactive measures for future crises. In addition to the current situation, it is also important to determine how to prepare for similar infections or other issues that may arise in the

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future. Although personal makers and FabLabs' struggles against COVID-19 in Japan were mainly associated with the creation PPE, their contributions are not limited to this. Considering that the recent sphere of activity in FabLabs is broader than material processing (including electronics design, mechanical design, and biotechnology), we believe that FabLabs and personal makers could diversify the extent of measures taken against crises in the future, as challenges will continue.

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ENDNOTES

[1] FabNurse Projects was launched in 2015 as an interdisciplinary project based in Keio University SFC. The project aims "to employ the power of digital fabrication (FAB) to offer customized and detailed solutions for the healthcare context" by "promoting synergy between FAB and nursing as well as working both in a university context and at actual care sites" through digital fabrication. For example, they create products such as gargle basins and arm holder covers for patients and elderly people using 3D printing (FabNurse 2015).

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