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Design and Development of 3D Face Mask Clips for Hijab

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ABSTRACT

The world has suffered from a critical shortage of Personal Protective Equipment (PPE) (Riva et al., 2007) during the pandemic of Covid-19 for medical staffs, the front liners. Like the whole world, Malaysia also imposed the stay-at-home and Movement Control Order (MCO) to break the chain of infections and flatten the curve of cases. The supply of PPE became a challenge during the lock down. There have been joined efforts from various parties stepping up, with different ways to help the production process of these key equipment but mostly focus on PPTs for male. Another challenge was face mask for Muslim lady health workers who wear hijab. This paper is about how to overcome these challenges and designed a novel face mask clip for hijab, using 3D printing. The face mask clip is for wearing a mask over hijab and is designed by generating a 3D digital file using computer-aided design (Hourcade, Bullock-Rest, & Hansen, 2012) software. Then the 3D design was converted to Standard Tessellation Language (STL) format, for the use of 3D printing systems. Then the design was split into layers for precise printing. The clips were tested by the staff in faculty of Cognitive Sciences and Human Development, Universiti Malaysia Sarawak. Feedbacks were collected by an online survey using the modified System Usability Scale. The participants reported that the clips are very comfortable and easy to use.

Keywords: Covid-19; Personal protective equipment; Pandemic; Movement Control Order; 3D Face mask

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INTRODUCTION

Malaysia has now increased its capacity of diagnostic testing (World Health Organization, 2020a). Hospitals on the other hand, are still slammed with flooding patients coming in and out with different health status. Many of those are at risk of getting infected or even infecting others with Covid-19. As the Covid-19 virus is proven to be mainly spread

through droplets and near contact between people (Daim & Radhi, 2020), it is believed that avoidance is Covid-19's best prevention, hence the MCO implemented by the Malaysian Government. Nevertheless, people still need supermarket visits. Some of them still responsible to work in crucial industries such as healthcare, public safety, solid waste, communications, and transportation, consequently putting vulnerability at risk. While the Ministry of Health is still waiting for World Health Organization (WHO) guidelines on the requirement of wearing face masks for the public members, all healthcare workers and frontline personnel have been advised to wear face masks when facing the public (Qishin, 2020). In Malaysia, people are still apprehensive about the possibility of Covid-19 being spread even more widely thus the soaring demand of PPE kits, overpowering nation production capacity.

Equally worrisome is the shortage in the supply chain for crucial personal protection equipment leaving both medical staffs and patients at high possibility of getting infected (Riva et al., 2007). As the health director-general Datuk Dr Noor Hisham Abdullah said in Bernama Report published by malay mail media organization, the use of personal protective equipment had rose by two to 10 times the average amount, and the front-liners continuously need new stock coming every day as it is one of the most important disposable items used (Najib, 2020). Preventing the spread of infection depends on the productive use of PPE such as head covers, face masks, respirators, goggles, gloves, and gowns. Currently, the ministry is receiving donations from non-governmental organizations (NGOs), and mass-purchasing PPE in bulk by procurement at federal or the state level (Qishin, 2020). More and more volunteers including corporate companies and NGOs are stepping up by donating PPE to help in fight against the Covid-19 and ease the burden of the frontline workers and also public in general.

The article highlights the design and development process of producing 3D face mask clip to be given to essential workers and members of the public during the Covid-19 pandemic especially Muslim women who wear hijab. As much as the program is aimed to have clear practical applications, the methods involved can be adjusted to fit in future ventures.

RELATED STUDIES

3D Printing Face Mask Clip

Developed in the 1980s, 3D printing technology has advanced tremendously in the last decade, both in terms of cost and usability (Mardis, 2018). It is now being used widely for the manufacture of all forms of open source designs such as in the food, healthcare, automotive and aerospace sectors (Keles, Blevins, & Bowman, 2017).

As the pandemic Covid-19 taking over the globe and continuing to make a mess with supply chains of crucial medical equipment, the 3D printing community is reaching out to help. Many companies and organizations in possession of a 3D printer have already started to volunteer the use of their printers to aid health centres and even community members. PPE such as face mask is indeed very important to decrease the risk of infecting or getting infected by the Covid-19 but wearing them for a prolonged timespan can be very

uncomfortable and even cause some serious physical pain.

Considering this condition, the Cognitive Sciences department of Universiti Malaysia Sarawak, Malaysia, with the same team that assisted in the production of face shields, has once again reached out to help giving back to the community. This time, several units of face mask clip were designed and developed to be given to the public. The faculty staffs were the first to wear the 3D printed face mask clips. The response given by the public were exquisite saying that the clip is very easy to wear and make their experiences with face masks become more pleasant, especially to those who are wearing the face masks all day. This has proven that the participation of the CS Team in the distribution of self-3D printed face mask clips has indeed helped to lighten the load some people were carrying.

Continuing the spirit of reaching out to the community, many units were also distributed to the staffs of the Akademi Percukaian Kuching Malaysia (Malaysian Tax Academy, Kuching branch) located in Jalan Tabuan, from the CS Team. They hope to encourage potential volunteers or anyone that take pride in their society and always find ways to contribute to them, to join in the fight against the Covid-19 pandemic.

Who would have thought that the 3D printer bought by the Cognitive Sciences Department to aid in teaching and learning process in class has become a crucial machine to also aid in facing the Covid-19 widespread?

3D Printing in Other Countries

International concern about providing adequate Personal Protective Equipment (Riva et al.) to the front-line workers is increasing and has become a main controversial issue globally. To satisfy growing global demand, the WHO reckons that PPE production needs to increase by 40 percent (World Health Organization, 2020b). Other countries have started to execute courses to help enlarge production volume. In terms of outbreaks, Spain as the third worst-affected country till the first week of May 2020, has reported at least 12,000 cases of healthcare workers getting infected by the virus due to a critical shortage of PPE. Some staff at Madrid's La Paz hospital have no other options but to reuse gowns when giving treatment to multiple patients, and even making use of double flimsy masks when no advanced respirator masks available (Togoh, 2020).

Centres for Disease Control and Prevention in the US has provided comprehensive guidance on maximizing and contingency plans for hospitals and healthcare staff in the event of a lack of PPE's, including how to process reusable tools. But reprocessing PPE is not as easy as it seems. Several measures should be considered such as content quality, after treatment functionality, along with suitable disinfection. In the US, most of the PPE supply is produced in Asia, specifically in China. This might be not an issue during normal times, but since the Covid-19 first appearance in Wuhan, the country required masks at home first (Megan, Valerie, & Ashish, 2020). The US government recently revoked the FDA requirements, declaring that N95s approved by the National Institute for Occupational Safety and Health could be used by health care workers. As a result, few state hospital systems have been able to close the

gap in the supply chain for PPE (Megan et al., 2020).

This critical issue of PPE shortage has opened up new horizons for not only the government of each countries, but also many of the top companies and independent agencies to come together hand in hand to approach various ways of producing PPE supply. This includes professional designer and creator in 3D printing community. Big printing companies like 3D Platform based in Roscoe, US for instance offered to print no less than 500 face shields every day. 3D Platform not only prints PPE kits for the front-line workers but also tools to make their jobs more comfortable such as little face mask clips to hold face mask straps off the ears to avoid physical pain. As 3D printing communities around the world are now focusing their attention to produce more PPE and additional key tools, free design files have also been shared to allow anyone in possession of 3D printer at home to print and help to benefit their own societies (Cassandra, 2020). Besides that, tech companies like HP Inc. collaborates with partners across the globe to increase production of the most crucial needs. More than 1000 printed face mask clips and other important PPE have already been distributed to hospitals around Barcelona (McCue, 2020).

Other Educational Institution

There are multiple efforts by the upper education sector all around the world, which involve 3D printing techniques to help tackling the shortage of PPE issue during recent outbreak. Engineers at West Virginia University's Benjamin M. Statler College of Engineering and Mineral Resources are using their skills and equipment in a campus-wide project to build PPE and other additional tools to meet the needs of the community especially health care professionals in combating the Covid-19 pandemic. Along with Innovation Hub Prototyping Center and health care professionals at WVU Health Sciences Center, the team joined forces to design face shields and surgical masks to be used by those working in the frontlines. Besides that, many requests have been made to produce mask extensors as the surgical mask can cause irritation to ears. Answering the request made, more than 3000 units mask extensors that can fit comfortably over faces and heads of various shapes, have been allocated to local hospitals and civil servants. The guide to create 3D face shields and ear guards has been shared publicly by The Innovation Hub (The Intelligencer, 2020).

In Malaysia there is still very little to noneducational institution that produce 3D face mask clips. As the focus is more towards providing essential PPE such as face shields and protective goggles to the healthcare staffs, which is currently in shortage, additional tool like face mask clips which purpose is to lighten the burden of front-line workers especially Muslim women who wear hijab might still in part of their plan. This explains the absence of relevant article to support this specific topic.

METHODOLOGY

The 3D Printing process involves a number of stages such as design face mask clips or customizing existing designs, using a slicing software for instance Matter Control or the Ultimate Cura software and do configuration before printing. Figure 1 shows the flowchart

Figure 1: 3D printing face mask clips process

for 3D Printing process to produce face mask clips.

3D Printing Process

Cognitive Science team uses two different brands of 3D printer in the printing process, namely Flash Forge 3D Adventurer 3, which is an industry grade, and a local brand called Proteus. The printing process for all objects is basically the same with whatever technique a 3D printer uses. There are 8 steps in total.

The first step is the designing before printing, which is to generate a 3D file format of the object we want to print. The 3D digital file can be design by using computer-aided design (Hourcade et al., 2012) software. The software could possibly give some clues about the structural integrity that we can anticipate in the final product. A variety of good 3D modelling software can be used such as Autodesk Maya, AutoCAD, Photoshop Blender, Scluptris, Vue and FreeCAD. Besides that, 3D digital file can also be generated through 3D scanning using the 3D printer itself. This includes scanning an actual 3D object and then modify it to generate a digital replica instantaneously. Another way to produce a digital model is by modifying existing models. Many websites such as CrabCad, Massivit3D, Thingivers and Copper3D provide free 3D face mask clip design specially during the outbreak for volunteers who want to print them at house. The existing models still need to modify the size and other settings according to our preferences.

Next is the conversion of the CAD drawing to Standard Tessellation Language (STL) format, which is developed in 1987 for the use of 3D systems by its stereolithography

instrument (SLA) machines (Rapid Today, 2020). Other file formats that can be converted into are OBJ and 3MF. But such file formats do not contain any information about colors. File formats like DAE, PLY and X3D must be used for 3D printing with color information.

The third step is the slicing process, which is the transferal to STL File Manipulation and AM Machine. Fundamentally, slicing means splitting the 3D model into layers to give command to the machine precisely what to do, in layers. The STL file is copied to the computer that controls the 3D printer where user can choose the orientation and size for printing. This is corresponding to how we would set up a 2D printout for two-sided or landscape or portrait orientation printing. Using a specific software, files are converted into printer instructions and a new file format called G-code with the extension (*.gcode*) is created. G-code is a very popular language for programming numerical code used in computer-aided manufacturing to control automated machine tools like 3D printers. It is important to estimate the printing speed based on how fast the printer can get without losing too much print quality, while the estimated printing temperature requires both trial and error to achieve the perfect temperature which matches the material used. This project used Slic3r to slice the 3D model. The printing speed is fixed to 60mm/s, whereas the printing nozzle temperature is set to 220 Celsius and build plate temperature to 60 Celsius.

After the slicing process finished, we set up the machine used based on the requirements to prepare for a new print job. This involves refilling the polymers, binders, and other items that the printer may use. A tray is also added to act as a foundation or additional material to make short-term water- soluble supports.

The fifth step is the actual printing process where the machine automatically builds the object. But first, it is important to select appropriate material that can fully satisfy the unique properties your object needs. Example of materials used in 3D are metals, plastics, ceramics, glass and even food. As long as there are no software errors or the raw material be used up, the computer will obey the instructions in the G-code. Typically, each layer is around 0.1 mm thick, but it may be much thinner or thicker. The size for each clip is XX = 148.91mm, Y = 28.82mm and Z = 1.83mm accordingly, while the weight is 4g. The printing process took 13 minutes to finish building one clip and almost an hour to print five pieces of the same clip, with continuous attention to identify and correct instantly a variety of problems that may occur during the printing process. It is also important to sanitize all tools and equipment before use.

Step six is the removal process. The printed object is removed from the machine. Then, the printed object is cleaned by brushing off any lingering powder or washing it to get rid of water-soluble supports. This step needs special skills and materials as the newly printed object may be fragile because certain materials need time to heal so special care will be required. Finally, the eighth step which is the application process where the object is used for its general purpose. Figure 2 and Figure 3 display the customization of the face mask clip model before being

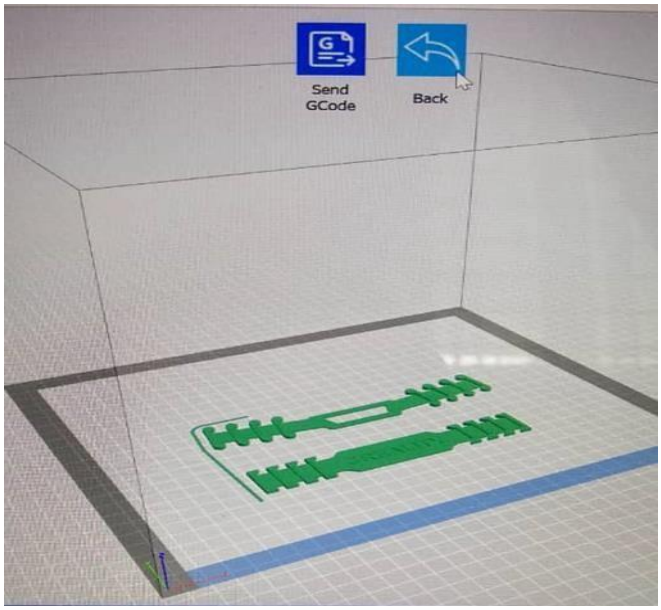

Figure 2: 3D view of the face mask clip

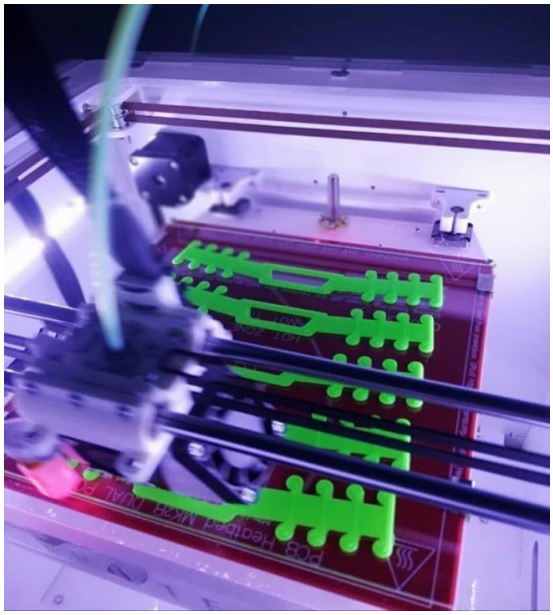

Figure 3: Building 3D object

printed at the final stage in the 3D printing process.

RESULTS

3D Face Mask Clip Evaluation

Following the distribution of the face mask clips to the staffs of FCSHD in UNIMAS and the employees of Malaysian Tax Academy Kuching, a feedback is collected. This is to improve the product based on their experiences and adjusting actions to their needs. Due to the Covid-19 situation it is very

Table 1: System usability scale

Item	Usability scale
1	I think that I would like to use this face mask clip frequently.
2	I found this face mask clip unnecessarily complex.
3	I think this face mask clip is easy to use.
4	I think that I would need assistance to be able to use this face mask clip.
5	I found the layout of this face mask clip is well designed.
6	I think the design of this face mask clip is too much inconsistent.
7	I would imagine that most people would learn to use this face mask clip very quickly.
8	I found this face mask clip very cumbersome/awkward to use.
9	I felt very confident in using this face mask clip.
10	I needed to learn a lot of things before I could get using this face mask clip.

difficult to collect feedback but still we collected some responses from the participants (Macefield, 2009).

We used the following modified System Usability Scale (SUS) to get feedback from the participants shown in Table 1. SUS is composed of ten statements, each having a five-point scale that ranges from Strongly Disagree to Strongly Agree. There are five positive statements (1,3,5,7,9) and five negative statements (2,4,6,8,10).

The final score of the usability test is 73.571 as shown in Table 2. Which shows that overall, the mask clip is easy to use. 71.4% of the participants say that they want to use it frequently. The overall mean of about 73.6 has remained constant. It is slightly lower than the median score of 75, which reflects the negative skew to the set of study mean scores. The low value of standard deviation shows that the data is closely clustered around the mean. Almost 100% of the participants are agree that it is very easy to use.

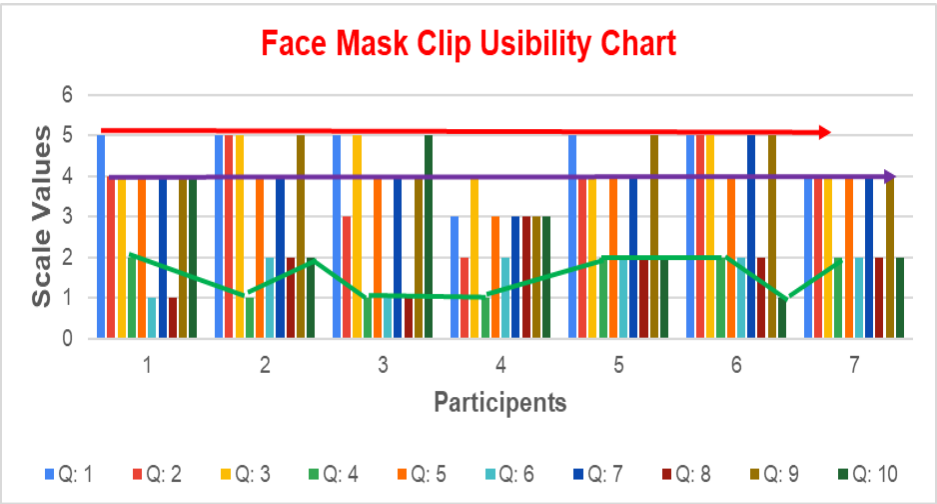

Figure 4: Face mask usability chart

Table 2: Usability Test Data

Participants	SUS Raw Score	SUS Final Score
1	29	72.5
2	31	77.5
3	31	77.5
4	25	62.5
5	30	75
6	32	80
7	28	70
Mean	**29.428**	**73.571**
Median	**30**	**75**
Standard Deviation	**2.370**	**5.926**

The green line in Figure 4 show that majority of the negative questions have small values.

It means that the participants are not agree. While the red and purple lines show the positive responses. It means that majority of them like the clips.

The outcome of the feedback shows that the clip is very comfortable to wear. This "ear guard" gives more of a custom fit as the elastic straps from the face mask will be hold by the small bars on either side of the plastic clip, which then lessen the pressure on their back of the ears. The public said that it is especially useful to those who wear hijab as it is hard for them to wear the face mask normally as other people. Even when wearing the mask for long hours, the clip secures the elastic straps stay in place without making their ears sore. Figure 5 exhibits the final product of the face mask clip.

Figure 5: Final product of the face mask clip

RECOMMENDATIONS

With all positive responses from users, it is recommended to create different shapes and sizes of face mask clip as an additional element. Some people would be more comfortable with smaller clip size while the others might be just fine with the bigger ones.

CS Future Program

In the future, Cognitive Sciences Department, UNIMAS will continuously forging ahead to emphasize the significant benefits 3D printing technology and how we can use 3D printers to help supporting and providing relief, not only to the healthcare industries but also our communities in emergency times like the Covid-19 pandemic. Apart from producing 3D face mask clips, it can also be used to print other essential pandemic toolkit such as hand sanitizer holder, hands-free door handle extension, tubes for ventilator and oxygen valves. There is a plan to raise public awareness and knowledge about how to use the 3D printer to print other things that may be useful in everyday life. In addition to this, there is a desire that CS students, and members of public in general will benefit from this program and that they will be motivated to help with future printing these products or other accessories.

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