The Journal of Health Design

DESIGN INSIGHT

Development of a PPE visor for female healthcare workers

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To Cite: Jones G, Siena FL, Watkins M, Breedon P. Development of a PPE visor for female healthcare workers. JHD. 2021;6(3):440–447. https://doi.org/10.21853/JHD.2021.145

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SUMMARY
During the COVID-19 pandemic the demand for personal protective equipment (PPE) has increased dramatically. However, the lack of PPE designed specifically for women is leaving many without adequate protection, as current "universal" solutions fail to address female healthcare workers' varied needs. Instead, current solutions present users with a host of problems, including discomfort, hindrance, incompatibility with other wearable items, and adjustment difficulties. This paper explores and reflects upon the design thinking approach used to develop a PPE visor for female healthcare workers while following a user-centred design approach/methodology.

Key Words
COVID-19; Design thinking; Design for women; Healthcare professionals; Personal protective equipment

INTRODUCTION & BACKGROUND

In 2020, the demand for personal protective equipment (PPE) increased drastically due to the COVID-19 pandemic, particularly in the healthcare sector because frontline workers were in close, daily contact with patients who may be infected. Unfortunately, among the many infections and deaths recorded due to COVID-19, a number of infections have occurred in healthcare workers, with infections accounting for 9%–13% of the total confirmed COVID-19 cases in some European countries in the early stages of the pandemic, and with several deaths being recognised as a result of the inadequate provision of PPE.[1]

Despite the vast quantities of PPE totaling over 3.5 billion items[2] sourced by the UK's Department For Health & Social Care (DHSC) and supplied to healthcare services in England during the pandemic, some healthcare workers were still not adequately provided for, which was especially evident in March 2020 at the start of the pandemic in the UK.[3] The maker community tried to help plug the gap by contributing to the production of PPE, especially face shields/visors in the fight against COVID-19[4]. However, leading healthcare ergonomists and behavioral experts have recognized significant human factor issues have arisen due to working in PPE during the COVID-19 pandemic, especially for female healthcare workers.[5] Most PPE is produced in

standard "universal" sizes, however, typically this PPE has been designed based on the measurements of the average male, leaving those with smaller/unique proportions without suitable protection, particularly women.

Healthcare professionals, experts, and unions have noted that poorly fitting equipment is risking lives, especially those of female healthcare workers. A frontline healthcare worker interviewed by The Guardian[6] described how they feel that "PPE is designed for a 6-foot 3-inch bloke built like a rugby player" due to how poor fitting the equipment is. Furthermore, a case report by Vidua et al.[7], reported significant adverse effects caused by PPE such as feeling excessively hot, nausea, headaches, neck spasms, fatigue, nervousness, dizziness, enhanced perspiration, dyspnoea, dehydration, facial redness, amongst others.

Building on this need for an adjustable low-cost face shield/visor for female health professionals, this paper reflects upon the design thinking approach used to develop VI-GUARD, an adjustable face shield (Figure 1), which has been designed using user-centred design activities to address the lack of female-specific PPE.

Figure 1: VI-GUARD adjustable face shield designed to address the lack of female-specific PPE

SUMMARY

Using the Stanford design thinking approach[8] of empathise, define, ideate, prototype, and test, the development of a PPE visor specifically for female healthcare workers required a range of

research and design activities. To begin, we conducted empathic research (Figure 2) using several face shields and visors readily available within the National Health Service to identify key design flaws with existing devices. We conducted detailed product teardowns and documented the assembly (for use) and disassembly (for disposal) processes.

Figure 2: Empathic research using face shield to identify key design flaws and issues*

* *The individual modelling in Figure 2 granted the authors permission to use her images in this paper.*

Next, secondary research methods involved the completion of a literature review, market research, ergonomic and anthropometric research (to define female anatomical data), and materials and manufacturing research. We conducted primary research activities to obtain a full understanding of female healthcare workers' perspectives. We conducted eight interviews with female healthcare workers based around face shields/visors to obtain the perspectives and opinions across different scenarios (Table 1); we also completed a survey of 70 participants to gain insights into PPE usage and problems (Table 2). We formed product evaluation groups, which reaffirmed complaints about pressure from headbands, the distance of the shield from the face, how secure visors felt, and the issues surrounding nose features.

Upon completion of the empathise stage, we defined key design criteria, and produced a product design specification. The ideate stage followed where a significant number of concepts (30 +) were generated, and initial models prototyped resolving the defined problems; our target demographic reviewed and tested many of the initial prototypes and designs. We produced multiple prototypes, combining rapid prototyping techniques and digital manufacturing tools. We tested numerous

prototypes iterations leading to the production of the final VI-GUARD solution (Figure 3). To prepare for implementation, we designed an instruction manual (Figure 4) using an infographic approach and tested it to ensure the developed solution could be easily assembled and disassembled.

Table 1: Summary of key quotes from interviews with female healthcare workers about face shields/visors

Key Theme	Key Quote	Reflections
Fit, Comfort, Materials	"They're too big, they're too wide and they're rough against your forehead." – Respiratory Nurse	Highlights improper sizing and the need for a suitable headband shape and material.
Adjustment Mechanism	"Adjusting it is really annoying." – Healthcare Assistant	Identifies the need for easy-to-use adjustment method.
Comfort, Adjustment Mechanism	"Too much going on around the back of your head." – Respiratory Nurse	Improvements in headband and adjustment methods are required.
Adjustment Mechanism	"The straps break all the time" – Midwife	More robust, repairable, or modular strap design needed.
Vision	"It's not as clear (to see)." – Sexual Health Nurse	Identification of the most suitable visor material is required.
Vision, Temperature	"Steams up quite regularly." – Healthcare Support Worker	Identification of most suitable visor material is required. Concepts should avoid steaming up.
Temperature, Hygiene	"They make your forehead sweaty." – Midwife	Solution should avoid steaming up. Potential need for washable/wipeable headband identified.
Fit	"it's quite long on me" – Occupational Therapist "(the visors) don't come down very far." – Deputy Lead Nurse	Highlights potential need for adjustable shield height.
Comfort, Materials	"Biggest bugbear for me was the foam." – Deputy Lead Nurse	Highlights need for detachable/optional foam (if incorporated).

The manufactured final solution (Figure 3) used two small additively manufactured components (2 x hooks) in combination with an elastic strap, a laser cut headband of 0.25mm clear polyethylene terephthalate (PET), foam spacers x 2, a PET main visor, and a selection of adhesive strips. An optional foam pad to be attached to the head band is also provided. The combined dimensions of the designed adjustable solution resolves many of the issues identified during the empathise stage of the process, including the elastic slipping, mask/nose security issues, freedom of movement, and the distance between the shield and glasses (if worn). In addition, the PPE visor is designed to be self-assembled; accompanying instructions have been designed and tested within the demographic to allow for easy assembly and disassembly of individual components to allow for recycling of individual components.

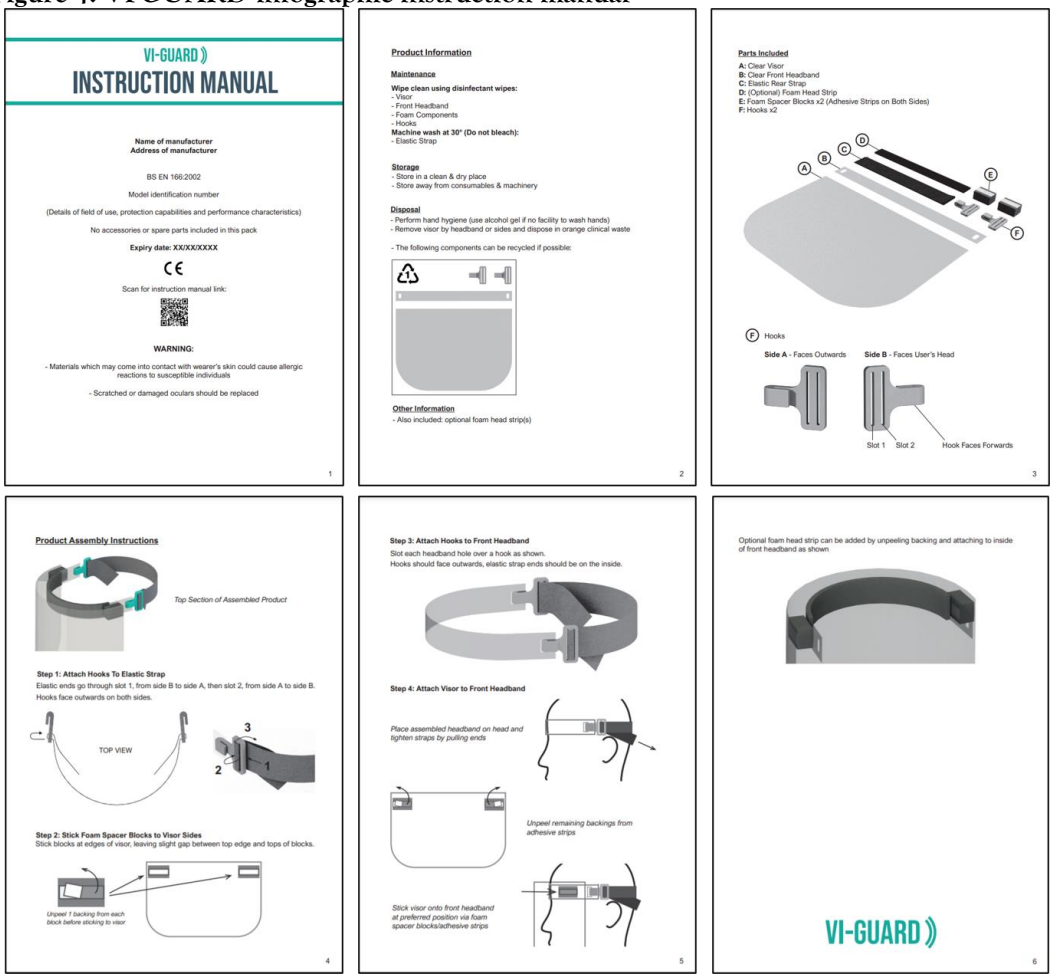
Table 2: Summary of key findings from a seventy-person survey on visor usage

Question Theme	Key Points	Reflections
Other items worn alongside a visor?	• A mask • Face mask, gloves • Surgical mask, apron, gloves	The majority of answers highlighted or discussed issues with masks and their compatibility to face visors.
Problems with a visor?	• Rubbing • It is too long • Steaming up • Headache • Flimsy & Loose	Numerous issues were identified, many of which related specifically to the comfort, fit, security and steaming up of existing face shields/visors.
Positive aspects of a visor?	• Not really • Fairly unobtrusive • Feeling safe • Comfortable	There were some positives to highlight from the use of PPE with issues not effecting some users of the equipment. Adaptability however was highlighted as especially important.
Length of time a visor is worn for?	• 10–15-minute spells • In hour bursts • 8 hours • 13 hours	It is clear that the length of time a face shield is used varies considerably. Some users donning/doffing repeatedly, others wearing for extended periods.
Suggested improvements to visors?	• More robust • Fog proof • Easier to adjust • Increase security • Removable sponge	Many answers reaffirmed the interview findings regarding durability, temperature, correct fit and hygiene, amongst other key issues.

Figure 3: Final prototype of the VI-GUARD adjustable face shield*

** The individual modelling in Figure 3 granted the authors permission to use her images in this paper.*

Figure 4: VI-GUARD infographic instruction manual



LESSONS LEARNED

Critically, through the use of design thinking and user-centred design activities incorporating ergonomic and anthropometric data specific to the female demographic, an adjustable PPE solution has been produced that is fit for purpose. Selected feedback from stakeholders included:

- *"Having the adjustability factor allows the shield to be fully personal and provides comfort." (P1)*
- *"The strap of the visor was much more comfortable than what I have used before. It was easily adjustable, so it didn't slip down" (P2)*
- *"The strap across your forehead didn't dig in, which is what I've found with a lot of other visors. It didn't mist up, so it was really easy to see, and you didn't have to keep wiping it down." (P3)*
- *The visor was really easy to put together. I thought the instructions were clear and simple enough that it did not take too long. I thought it was really handy, and it seemed easy to clean as well." (P4)*
- *"I like that fact that the different parts of the visor were easily replaceable if they were to break, or they were to get dirty." (P5)*

Designing for multiple stakeholders working in a variety of different healthcare settings has been challenging. Many of the female healthcare workers wanted different outputs based on their specific role within the healthcare setting. Achieving a one-size-fits-all solution was therefore very

difficult, but through the production of the build-your-own-visor approach using multiple components that can be individually replaced, the user can choose which components to attach to the visor, but also cut or resize components to their desired needs. Significantly, as the designed product can be easily disassembled, individual components can be replaced or easily disposed of.

In conclusion, we cannot overstate the importance of using a multidisciplinary research and design process and an interdisciplinary design team. Working alongside a variety of healthcare professionals has enabled an optimal modular solution to be produced. Finally, working in multidisciplinary design teams consisting of product designers, design engineers, materials/textile experts, and healthcare professionals has enabled a desirable solution to be produced. We strongly recommend using multidisciplinary design teams in the development of future medical devices.

DESIGN INSIGHT

This paper presents an excellent example of incorporating the design thinking process to solve a previously unrecognised problem! As a practicing industrial designer and educator who teaches design thinking, I am excited to see this implementation of design process.

Empathic research allows people to see from perspectives different than their own, gain deeper understandings of their users, explore the space, and use divergent thinking to find and identify problems. Incorporating observations of and conversations with a small group of users is a powerful tool to help unpack and discover the issues the female healthcare workers encountered in their extensive use of PPE during the pandemic. The additional online survey of users and secondary research provided this team with a good foundation to define and develop a new type of product that was mass-produced and also make it customisable to fit a wide variety of women. Prototyping and testing their design with real users allowed them to create a product that met their unique needs and was well accepted by female healthcare workers.

Design thinking is not just for designers, but for the entire multidisciplinary team, including the users. It provides a framework that helps their collaboration become more powerful and adds greater value to the product outcome for their user group.

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ACKNOWLEDGEMENTS

The authors would like to thank and acknowledge the support of the Product Design Department and the School Of Architecture Design and the Built Environment technical teams throughout the duration of this project.

PEER REVIEW

Not commissioned. Externally peer reviewed.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING

None

ETHICS COMMITTEE APPROVAL

Ethics approval for this project was received from Nottingham Trent University via the School of Architecture Design & the Built Environments School Ethics Committee online checklist and quiz resource on October 14, 2020.