The new face of personal protective equipment design

Dan Jenkins & James May

Following the outbreak of Ebola, the importance of personal protective equipment (PPE) has been in the media spotlight. The Ebola case has reinforced the importance of PPE being not only comfortable to wear, but also being able to be fitted and removed without contaminating the wearer. Given the risks of exposure, it is critical that PPE is designed to be intuitive to use and also resilient to departures from the prescribed ways of use.

Ostensibly, PPE works by creating a barrier between the user and their environment. Dependent on the hazard, this barrier may seek to completely block or reduce access to sound, light, heat, radiation, gases, vapours, particles, or projectiles within the environment.

Ergonomics has always been an important consideration in the design of personal protective equipment. After all, there is an unambiguous link between the way PPE fits and its user's task performance. There is an overlapping relationship between efficacy, comfort and fit. Comfort is critical for more than just user preference. Users need to be unencumbered, with the freedom of movement to conduct their primary task. As such, PPE should be as unobtrusive as possible, and weight should be minimised and carefully balanced. Likewise, impacts on breathing performance, vision, hearing and thermal regulation should all be controlled.

Good PPE design must achieve both comfort and ease of use. Ultimately, more comfortable products are more likely to be worn, and worn correctly. Furthermore, more comfortable products mean more comfortable users and the relationship between comfort and the reduced propensity for error has been clearly demonstrated.

If PPE is to be used effectively it needs to:

- Be simple and quick to select and fit.
- Reduce the amount of user handling and interactions to fit, adjust and remove through the wear cycle.
- Provide clear confirmation of an effective fit, both to the wearer and those around them.
- Be comfortable and non-restrictive in use.

The importance of fit

Where a seal between the PPE and a part of the human body is critical, the obvious challenge comes in the form of the variability between users. This is further compounded by the complexity of this variation. Facial features, such as noses or ears, come in a multitude of different shapes and sizes. Likewise the relationship between these features also changes significantly across the user population.

Historically, this variation between users has been accounted for by either introducing a number of different sized products (small, medium, large) or by building in some form of adjustability. Introducing size ranges increases the supplier's costs, resulting in more expensive products. It also requires higher stock levels of product and spares to be held at all levels in the supply chain, and introduces the risk that users will compromise their protection by making do with the product size that is to hand.

Adjustable PPE introduces its own issues. The more complicated the adjustment process, the more complicated the product becomes to use. As such, the burden of responsibility is placed upon user training and ultimately upon the end user themselves to ensure an effective fit. Furthermore, the increased requirement for handling the PPE, brought about by the need for adjustment, can result in equipment damage or contamination, both of which undermine the value of PPE. Adjustability can also be used to mask inherently poor fit characteristics. Users will attempt to compensate for this lack of fit by over-tightening adjustment straps resulting in unevenly distributed pressure and an uncomfortable product.

Identifying requirements for fitting and removal

While fit is a challenge dominated by physical ergonomics and anthropometry, the task of

ABOUT THE AUTHORS

Dr Dan Jenkins is Research Lead at DCA Design International.

James May is the Industrial & Commercial Sector Manager at DCA Design International.

safely and correctly fitting PPE is as much a cognitive challenge as a physical one.

PPE needs to be designed so that it is both intuitive to put on as well as being easy to train in or use with instructions. There are a number of human factors tools that can be used to ensure these cognitive elements of the task are considered throughout the design process.

› Task analysis can be used to identify and map individual task steps, allowing tasks to be combined or removed.
› Structured error identification tools can be used to identify possible fitting errors leading to designs that either prevent these actions or provide greater feedback.
› Video-recorded observations with a range of users can offer rich insights. When the video records of user interactions with different products are compared, performance metrics, such as time breakdown and touch counts, can be used to optimise designs.

Each of these tools offers the potential to objectively describe the differences in performance between legacy products, competitor products and design concepts, at the same time, identifying opportunities for improvement.

Designing a better fit

The relationship between comfort, fit and protection has long been understood. However, as those who have designed PPE will be aware, it can be very difficult to design new products and be confident of their level of fit. The typical response to this is to start the design process with an existing product and make iterative changes. These changes are themselves then iterated with prototypes and small sample size testing. Once the team believes they have a winning design, this is then usually rolled out for more extensive testing across a large representative sample population.

This highly iterative process can be both protracted and expensive. Furthermore, as a result of the process of refining proven designs, the design of PPE can remain relatively conservative.

One opportunity for streamlining this process lies in the use of digital headforms. The National Institute of Occupational Safety and Health have produced a range of five 'headforms' (small, medium, large, long/narrow and short/wide) based on anthropometric data from nearly 4000 users. These CAD models can be used to assess a design for fit. Being digital, they are also editable, allowing them to be scaled and modified to meet the needs of specific populations. The models can also be sectioned to investigate fit at various intersections.

Incorporating digital fitting using CAD headforms into the design process has a number of potential advantages:

› A greater number of more innovative solutions can be generated and evaluated very early in the design process.
› The development timeline can be shortened as the design converges towards a product that provides a mutual fit.
› The cost and time associated with repeated user testing can be reduced.
› The design can be evaluated against population extremes or populations that may be difficult to recruit for.

There is, of course, no substitute for user testing and we are not advocating a complete move away from this. However, with the use of CAD models it is possible to assess and refine the design to create a better quality of output before the first fitting trial.

A structured, iterative and evidence-based approach is fundamentally important for the design of revolutionary, rather then evolutionary, PPE products.

The use of digital headforms enables designers to make an earlier assessment of the capacity of a design proposal to accommodate global user geometry extremes. In combination with established iterative physical prototyping these headforms can greatly speed up the iterative loops of the design process.

Engaging with human factors specialists to integrate a structured consideration of usability and fitting errors into the design process allows more accurate and robust prototypes to be implemented into real life testing, increasing the quality and innovation of the designs.

Ultimately, sealing PPE is most effective if it fits well, is comfortable to use and easy to don correctly without damage, errors or contamination. The tools and techniques are available to achieve this, but success requires designers and human factors specialists to work together closely and cooperatively. ❖