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Paper title **Out of Isolation: designing reusable PPE gowns based on an understanding of healthcare workers' lived experiences**

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Abstract: The paper reports on an AHRC-funded project aimed at mitigating the personal and environmental impact of PPE isolation gowns, as worn by healthcare workers treating patients with COVID-19. The enquiry was devised in collaboration with NHS and industry partners and is informed by empirical investigations into procured gowns and the lived experiences the health professionals' wearing them. The development of an industry standard 'reusable gown system' requires negotiating various proximities: between safety and disease transmission; sustainability and medical waste; the needs of end users, regulation and cost; public and private stakeholders. The article contextualizes the research problem and methodology, incorporating survey, co-design and material methods employed to gain a better understanding of the issues associated with current gown design, fabrication and use. The study raises questions around how critical clothing items are produced, procured and disposed of, and the need for circular design and supply chain models.

Keywords: reusable PPE, healthcare workers, lived experience, circular design

1. Introduction

The paper reflects on the early stages of an empirical 'research through clothing design' enquiry into developing reusable PPE isolation gowns, as worn by healthcare workers to treat patients with COVID-19. The project was implemented in collaboration with partners from the public health and private manufacturing sectors in the UK, by a team with experience in sustainable fashion design (Townsend et al. 2017) advanced textiles and functional clothing (Hardy et al. 2019), uniform and corporate wear (Šterman, 2014). The design research responds to the identified need for investigations into the (re)design of PPE isolation gowns by

taking the following question as its starting point: “What new materials, design and manufacturing approaches should we start to consider in preparation for pandemics e.g. reusable PPE to replace single use?” (UKRI, 2020).[1]

The outbreak of COVID-19 in 2020 saw the total disruption of global PPE markets, demand outstripping supply and the Department for Health and Social Care centralising PPE procurement due to a lack of stock in the NHS supply chain (DHSC, 2021). New PPE workstreams such as ‘UK Make’ and ‘China Buy’ were implemented to meet need, for example, “the number of gowns increased by approximately 1,600% from 60 to 65 thousand units per month pre COVID-19 to 1 to 2 million units per month during COVID-19” (DHSC, 2020). An outcome of the DHSC’s procurement strategy was the PPE industry’s adoption of a disposable non-circular approach to meet demand, leading to human and environmental impacts (Textile Services Association, 2021). Limited understanding of healthcare workers’ roles and protective clothing needs resulted in a generic "one-size-fits-all" approach, including PPE gowns, highlighted by The Royal College of Nursing as being "problematic" and "restrictive" when worn for up to 12 hours during shifts (RCN cited in Wong, 2020, n.p.).

This research response focuses on developing a fit for purpose, reusable PPE gown from the dual perspectives of sustaining the wearer and the environment by replacing a disposable “closed object” designed for obsolescence, with an “open object” that can be reused, repaired and recycled (Simondon in Jayout, 2019, p30). The project negotiates and addresses various design proximities: environmental sustainability in proximity to medical waste; safety and protection in proximity to COVID-19; garment comfort and fit in proximity to the needs of healthcare workers, and design intervention in proximity to the PPE supply chain.

Through collaboration with National Health Service (NHS) trusts, PPE textile, gown and laundry suppliers in the East Midlands, UK the authors are developing a sustainable design and circular economy (CE) model. The overarching aim is to integrate expertise in clothing design, PPE and clinical practice to develop a new ‘reusable isolation gown system’ comprising multiple sizes, adaptable styles, and incorporating a doffing hook (for the safe removal of gowns) to mitigate infection. An “intentional…backwards approach” has been adopted by considering the philosophy of purpose; from recycling to original design (Niinimäki & Karell 2019, p.12). The following sections contextualize the research methods employed towards balancing the wearers’ needs with “the key factors impacting the design development of isolation gowns [influenced by] regulation, degree of protection, comfort and cost” (Kilinc, 2015, p.185).

2. Context: disposable isolation gowns

Isolation gowns are part of Personal Protective Equipment (PPE), worn by healthcare workers when treating patients with COVID-19, and other contagious diseases, “identified as the second-most-used piece of PPE, following gloves, in the healthcare setting” (Kilinc, 2015, p. 180). Before the pandemic PPE was in plentiful supply with over 80% being manufactured in

[1] UKRI, 31 March, 2020, https://www.ukri.org/opportunity/get-funding-for-ideas-that-address-covid-19/.

and exported from China – a global supply chain that became fractured as the pandemic unfolded (World Health Organization cited in McQuerry et al., 2021). "A severe shortage in the amount of necessary PPE during the COVID-19 pandemic caused concern for health care providers as they feared being infected by the patients they cared for and, in turn, passing the virus on to their own families" (Ibid. p. 563). Additional issues with disposable gowns when worn in AGP (Aerosol Generating Procedure) and high-risk environments were identified by a survey of over 11,000 nursing staff in the UK in relation to: the reuse of single-use gowns, heat inducing properties, limited washing and changing facilities and problems with donning and doffing (Royal College of Nursing, 2020).

Figure 2 Four disposable and one reusable (yellow) gown symbolizing the 80%/20% ratio we found available on the market in early 2021. The gowns are overlaid for comparison of size, shape and fabrication during the Gown Review (discussed in 5.2). Photo David Baird, 2021.

Press reports highlighted issues relating to the availability and performance of PPE including for nursing staff from black and ethnic minorities (Gilroy, 2020) and that the generic sizing of gowns (designed for men over 6 foot tall) was putting the 75% of females who make up healthcare staff at greater risk than their male co-workers (Fidler, in Wong, 2020 n.p.). In a pre-COVID-19 report on 'Personal protective equipment and women', "57% of women stated that their PPE sometimes significantly hampered their work" and only "3 in 10" considered the PPE equipment they used "was designed for the female frame" (TUC, 2017). The widespread procurement of disposable gowns also "highlighted the staggering amount of single-use PPE that medical and healthcare facilities use on a daily basis, and the associated high costs" (Way, 2020, n.p.). And although reusable surgical gowns have been used in the UK for over 20 years, evidence suggests that at the first peak of the COVID-19 pandemic "everything went disposable as a result of some poor and misinformed decision making within various government departments" (Textile Services Association, 2021, p.1).

3. Scoping the project

On 31 March 2020, UK Research and Innovation launched the rapid response call: 'Ideas to Address COVID-19', encompassing 'Engineering and Physical Science approaches for national recovery and transformation' through, for example: "Adaptable and reconfigurable manufacturing, to allow scale-up of COVID-19 related products quickly, efficiently and at volume."[1]

As outlined above, the impacts of one-size-fits all, disposable gowns on healthcare workers experiences of treating patients with coronavirus, informed a research proposal to mitigate some of the negative effects. By scoping the emerging literature and through discussions with clinical leads and a PPE manufacturer we triangulated the problem in relation to three key areas:

1. User experience of wearing gowns
2. Gown procurement and production
3. Gown design and fabrication (based on knowledge of 1 & 2)

3.1 Considering he effects of PPE on user experience

From the outset, the project teams' core research interest was in designing functional, sustainable clothing that is "connected to the end user and their specific requirements" (Šterman, 2014, p.29). This led to prioritizing user experience as a research tool by using nurses' tacit knowledge of wearing existing gowns to inform future improved styles incorporating longevity (Townsend, Sadkowska & Sissons, 2017).

Accruing qualitative information during the coronavirus pandemic about "the effects" PPE gowns had on the wearer in terms of their "material agency" (Woodward, 2019, p.20) had to be mediated remotely through telephone conversations and online meetings with healthcare managers. Findings from informal interviews with three clinical leads working for NHS trusts[2] (May and June 2020) helped inform the research proposal, through confirmation that: one-size disposable gowns were used across all their organizations; staff, including some male nurses, experienced issues with sizing and fit and the need to order in bulk (to provide up to 5 gowns per day depending on the number of procedures undertaken) presented resource issues. There was strong interest in reusable, multiple-sized gowns in breathable textiles to reduce excess volume/ length and heat stress (Davey et al. 2020) particularly for individuals with petit frames, such as nurses from East Asian backgrounds.

In September 2020 the Department for Health and Social Care cited 'Improving user experience' (Section 6) as an identified aim of the UK government's 'PPE strategy' from perspectives of:

- how potential inequalities have been considered
- the demographics of both their workforce and the public their workforce interact with which has proved significant in the use of PPE

[2] Queens Medical Centre and Diaverum, Nottingham University Hospital Trust, Northampton General Hospital Trust.

- incompatibilities or difficulties observed between any of the PPE used by their workforce

They also suggested that increased UK manufacturing could offer more opportunities for industry to hear directly from the user and involve them in the design and development of products (DHSC, 2020: 6.18)

3.2 Procurement and production: policy, cost and regulation

The business-as-usual NHS procurement model requires companies to respond to product/ service tenders, with successful applicants signing framework agreements as contracted suppliers (Lamb, 2021). In the early part of the pandemic, between March and July 2020, this model was reversed with PPE companies invited to tender via a High Priority Lane set up by the UK government, (DHSC, 2021). However, despite subsequent reports (Ibid.) the selection criteria for how companies were awarded contracts remains unclear to established SME's with experience of producing reusable gowns (Lamb, 2021).

The pricing model for reusable surgical (and PPE) gowns is based on the cost of the gown and the laundry service, with the laundry purchasing the gown from the manufacturer (estimated cost £15.00) and then charging the healthcare organization a set fee per wash (e.g. 80 pence) for upwards of 70 washes (Ibid. 2021; Textile Services Association, 2021). Single-use disposable gowns can be purchased for less than £1.00 for polyurethane (PU) coverings and up to £5.00 for items fabricated from polyester-based composites and textiles. All PPE gowns are required to meet British Standards, BS EN 13795 for 'surgical clothing and drapes'[3] which includes links to EU medical standards for users and suppliers of single-use and multiple-use products with mutually agreed test methods and certification[4].

A review undertaken by the DHSC (2020) with 40 key stakeholders "to understand the challenges and potential barriers to increased innovation and sustainability in PPE in the UK" identified the following challenges:

- a complicated stakeholder landscape
- a need for improved demand signaling and engagement between innovators and frontline staff
- difficulty navigating the regulatory process for new entrants
- financial and procurement frameworks that incentivize single-use PPE with low purchase prices but potentially higher overall life cycle costs

In response, the UK government (DHSC, 2020: 5.18) stated their need to "develop a framework and purchasing environment that enables a shift towards more innovative and sustainable PPE".

[3] Cabinet Office and Department for Health and Social Care (2020) *Technical specifications for personal protective equipment (PPE)*, 30 March [online] https://www.gov.uk/government/publications/technical-specifications-for-personal-protective-equipment-ppe, Accessed 10 July 2020.

[4] The CE marking (an acronym for the French "Conformite Europeenne") certifies that a product has met EU health, safety, and environmental requirements, which ensure consumer safety.

Through our research aim to design and produce 'a reusable gown system' we have identified a locally based, advanced medical textile manufacturer,[5] experienced surgical/ PPE gown supplier[6] and laundry provider[7], all with commitment to recycling. The CE infrastructure represents an example of (Re)distributed Manufacturing (RDM), involving rescaled global production by identifying a complementary fabrication, production and distribution ecosystem for local and global supply-chains (Real et al. 2018).

4. Methodology, aims and objectives

In July 2020 we submitted a project proposal entitled: 'Redesigning PPE: enhancing the comfort and safety of healthcare workers wearing isolation gowns to treat patients with Covid-19, funded by the AHRC in January 2021.[8] The aim was to design reusable gown system in XS-3XL sizes, to accommodate the overlooked PPE needs of healthcare workers, the majority of whom are women, many from BME backgrounds (Gilroy, 2020; Wong, 2020). We use the term 'system' as a reference to the designed product being conceived as part of a systemic, cradle to cradle approach to aspects of the supply chain, including design for extended use and recycling at end of product lifetime (Feltcher and Tham, 2019; Niinimäki & Karell 2019; Real et al. 2018).

A co-design methodology has been adopted, using "probes, toolkits and prototypes" (Sanders and Strappers, 2014) as research tools to garner qualitative feedback from stakeholders on existing and speculative gown designs via questionnaires, surveys and samples. This involves participation from healthcare professionals and collaboration with the PPE supply chain, based on the principles of a 'participatory research through clothing design' model (Townsend and Sadkowska, 2020) devised to engage overlooked groups of wearers and new "landscapes for fashion" (Fletcher and Tham, 2019, p.41). Due to the challenges of engaging with participants face-to-face during the pandemic, the model was adapted as a 'co-design' framework based on the criteria illustrated in Figure 2.

The model facilitates co-design through a "collaborative encounter" whereby the exchange between the participants' experiences (of wearing, manufacturing and servicing PPE) and the researchers' design expertise will "result in benefits for each contributing group" (Manzini, 2015, p.93).

> "Here lies the definition of a field of possibility for those who design, between the two poles of *diffuse design* and *expert design*, where *diffuse design* is put into play by "non-experts", with their natural designing capacity, while design experts are people trained to operate professionally as designers…" (Manzini, 2015, p.37).

[5] Toray Textiles Europe Ltd (TTEL) UK, http://www.ttel.co.uk/
[6] Anze Ltd, UK, https://anze.co.uk/
[7] Synergie LMS, UK, https://www.synergylms.co.uk/
[8] Official AHRC/ UKRI project information link: https://gtr.ukri.org/projects?ref=AH%2FV015842%2F1

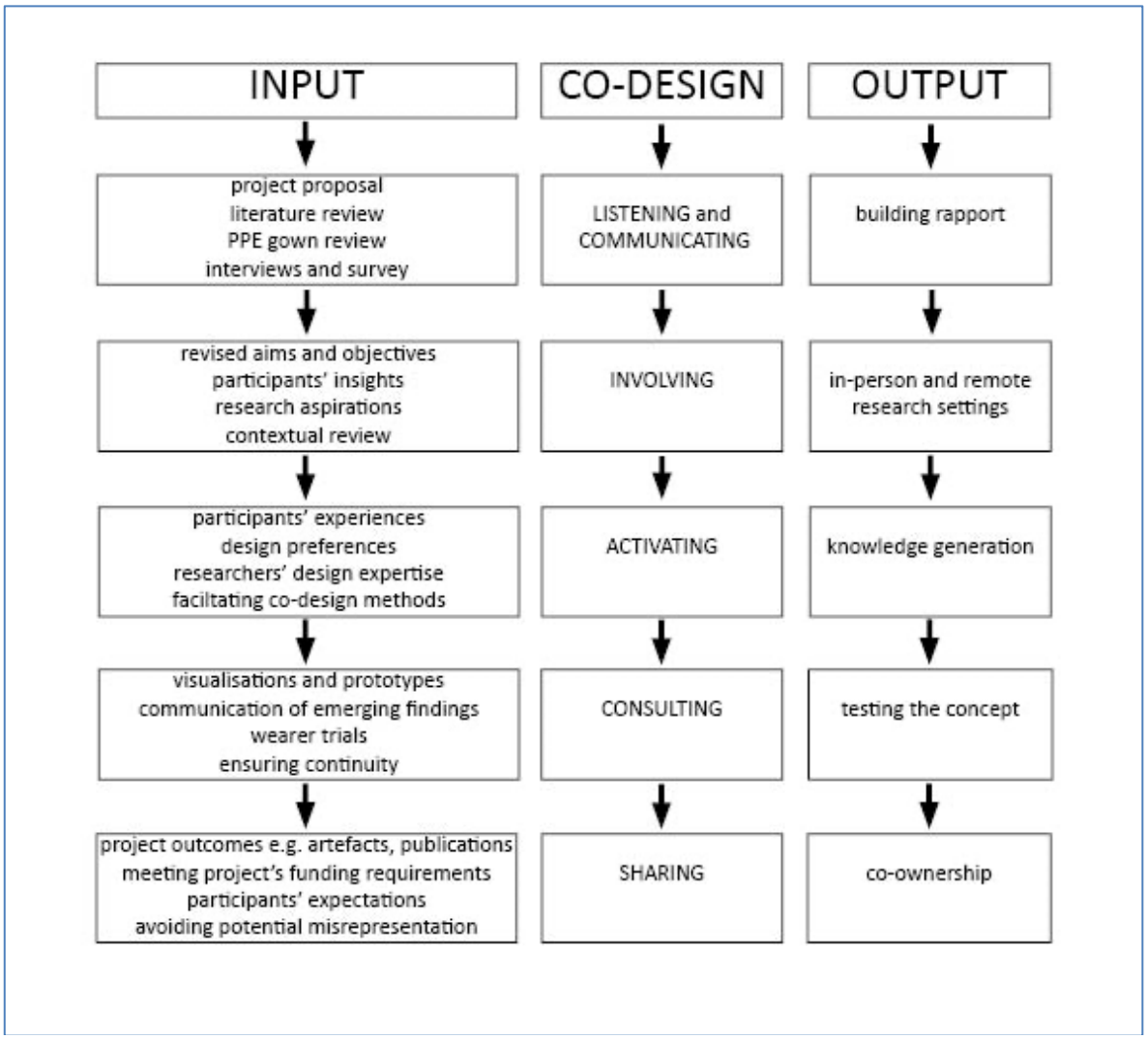

Figure 2 Co-Design Model underpinning the methodological approach to Redesigning PPE Reusable Gowns, based on a 'Participatory research through clothing design model' © Sadkowska and Townsend, 2019.

As with many participatory projects, the roles of the experts and non-experts have become interchangeable throughout the collaboration with the research teams' aim to make PPE gowns more effective, reliant on the participants' experiential knowledge of their "material properties", what they are made of and how they are designed as well as the specific contexts of their use (Woodward, 2020, p.19). Throughout all stages of the methodology (Figure 2): devising the proposal and prototypes (INPUT); listening, involving and consulting (CO-DESIGN); to knowledge generation and testing the concept (OUTPUT), we sought to place the user and their involvement at the heart of the project. The co-designing is an acknowledgement This was strategically important for the development of durable, user-friendly styles "offering personalization" and potential garment longevity (Jayout, 2019, p.29).

The methodology facilitates a systematic review of current PPE gown design and provision in the UK but with consideration of relevant global advances and critiques. An illustrated online survey has been circulated amongst nursing teams from the partnering NHS Trusts (5.3).

Online feedback questionnaires and in-person "object interviews and elicitations" (Woodward, 2020, p.34) have also been developed for nurses undertaking future wearer trials of prototypes, incorporating multiple choice options and text boxes to allow for reflective comments. Survey and feedback questions have been devised to gain insights into design specifications but with special emphasis on individuals' phenomenological, or "lived experiences" of wearing gowns, in line with an "interpretative, phenomenological approach (IPA)" (Eatough and Smith 2017).

The analyzed survey and interview findings are being synthesized with measurements derived from participants' dress sizes and the PPE Gown Review cross-referenced with international sizing charts. A recognized problem with garment sizing is the lack of standardization in the fashion and clothing industry because the human body does not come in a standard size, as illustrated by the UK Fashion and Textile Association's International chart.[9] This rationale seems to have been completely ignored by the PPE industry with many isolation gowns designed to fit the proportions of a 6' 4" man (Fidler in Wong, 2020), as reiterated by our empirical Gown Review (5.2).

The collated qualitative and quantitative data has informed the design of two contrasting Styles (1 and 2) of gown prototypes which will be tested through wearer trials to inform a third, resolved Style 3. Further wearer trials of Style 3 will constitute the final specifications of a 'reusable PPE gown system' comprising a eight individually sized (XS-3XL) garments manufactured and marketed in the UK. A doffing accessory for removing the gowns safely has been designed in the Product Design Lab at the University of Maribor to be tested with focus groups.

4.1 Aims and objectives

The project encompasses six key aims and related objectives, originally timetabled to be completed by July 2022, but extended until January 2023 due to the impact of the pandemic on the project partners ability to collaborate as planned.

<u>February – July 2021</u>

Aim 1: Understand the issues experienced by healthcare workers wearing isolation gowns

- Undertake literature review into gown design, provision and use
- Source and review disposable and reusable gowns and textiles
- Undertake interviews with NHS team leads and develop online survey
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Aim 2: Design two contrasting styles of reusable gowns

- Study sourced isolation gowns (dimensions, fabrication, fastenings)
- Analyse interviews and survey responses to identify key design issues
- Develop pattern blocks and gown designs based on above

[9] https://s3-eu-west-1.amazonaws.com/ukft/wp-content/uploads/2018/05/17111332/UKFT-International-Sizing-Chart.pdf

August 2021 – January 2022
Aim 3: Manufacture and trial Styles 1 and 2 gowns
- S1 and S2 manufactured and tested by PPE manufacturer
- Wearer trials undertaken across two NHS centres
- Feedback accrued using proformas and selected interviews

Aim 4: Design Style 3 reusable gown and doffing hook
- Analyse feedback forms, interviews, evidence from returned gowns
- Use insights into best features of S1 and S2 to design Style 3
- Doffing hook designed and tested by University of Maribor

February – July 2022
Aim 5: Manufacture and trial Style 3 (S3) gown and doffing hook
- S3 manufactured and tested by PPE manufacturer
- Wearer trials undertaken across three NHS trusts
- Feedback accrued using proformas and selected interviews

August – January 2023
Aim 6: Design and disseminate Reusable Gown System
- Communicate prototype developments
- Publish findings via conferences and journals
- Collaborate with NHS and industry partners to influence policy

The following section primarily focuses the first six-month phase of the project and methods applied to complete the objectives related to Aims 1 and 2.

5. Understanding the issues

To develop a gown system that functions in a similar way to a uniform, we needed to understand the performance and comfort requirements, as "determined by the environment in which the user operates, and the activities that he or she performs" (Gupta cited in Sterman, 2014, p.29). We also needed to gain understanding of existing products, models and barriers to sustainable innovation.

In design terms, a PPE isolation gown is very similar in style to a traditional surgeon's gown; full or three-quarter length (below the knee to prevent contact with the operating table), high neck, long sleeves, back fastening (Lamb, 2021). Surgeons' gowns have traditionally been sterilized in hospital laundries but are now generally laundered off site by service providers including members of the Textile Services Association who have presented this model as the basis of a circular 'reusable gown system' (TSA, 2020) which our research builds upon. Revolution Zero[10] are undertaking research into reusable PPE by employing "circular economy, zero waste, zero carbon and responsible provision", by working with academia, the NHS and the PPE supply chain. There are a growing number of CE approaches being pro-

[10] Revolution- ZERO: https://www.revolution-zero.com/, Accessed 20 March, 2022.

posed by intentional designers, "who call for transparency across the supply chain and information on recycling technologies to successfully create recyclable garments" (Niinimäki and Karell, 2019, p.27). L. Bircham's recycled gown featured in *Ever and Again* (Earley, 2007) and reusable models by David Nieper (Butler, 2020)[11] and Fashion-Enter Ltd (2021)[12] exemplify CE approaches.

As discussed in section 3.2 the take-up of reusable gowns has been limited due to barriers to sustainable innovation, partly caused by the UK governments' procurement policy which prioritized disposable products in the early part of the pandemic. Another reason is the pace of textile and product advances.

> "The need for isolation gowns and coveralls to prevent the spread of highly infectious diseases has led to the parallel development of advanced fabric properties (e.g. pore size and distribution, tear, seam, and puncture resistance) and product compliance, that while protecting the wearer from fluids have often compromised design, size and fit" (Kilinc, 2015, p.185).

Figure 3 A researcher trying on a reusable polyurethane (PU) coated PPE gown in the Gown Review undertaken to test the physiological, ergonomic and biomechanical aspects of comfort, fit and functionality. Photo David Baird, 2021.

5.1 Gown review

Our research continued by reviewing 50 gowns via online searches, 80% (40) of which were disposable and manufactured offshore. We purchased 12 items (8 disposable/ 4 reusable) to analyze and compare fabric quality, design construction, details, size, comfort, fit and cost,

[11] Butler, S. (2020) Women's fashion manufacturer to make reusable gowns for NHS, 28 April, https://www.theguardian.com/society/2020/apr/28/womens-fashion-manufacturer-to-make-reusable-gowns-for-nhs, Accessed 30 June, 2020.

[12] FASHIONCAPITAL: https://www.fashioncapital.co.uk/services/industry-practitioners/pioneering-ppe-reusable-isolation-gowns/, Accessed 30 April, 2021.

which we documented in a proforma. Figure 1 (section 2) illustrates a selection of four disposable and one reusable gown layered flat to visually compare shape and volume.

The disposable gowns were fabricated in 100% spun-bound polyester or polyurethane (PU) and came in one-size, L or XL. These included a one-size gown provided by Diaverum, enabling us to cross reference the product when members of the same organization undertook the survey (5.3). Confirmation of one-size disposable gown procurement was provided by our other NHS partners. Two of the reusable gowns were made from 99%/1% polyester/carbon, came in one-size, and were PU coated. The other two were constructed in fluorocarbon coated 99.3% polyester/0.7% carbon and available in XS-3XL and S-5XL, respectively.

Most gowns fastened at the back neck with Velcro®, or polyester ties; waist ties were integrated centre-front, centre-back or to the left-back; garment and sleeve lengths varied but were generally overlong if in one-size; cuffs were mainly ribbed, elasticated or cut with a thumbhole (Fig. 4), requiring varying manipulation to accommodate gloves.

Each gown was tried on by the NTU research team, who were a 10, 12 and 14 (S, M, L) UK dress size. By trying the gowns on it was possible to add a qualitative comment regarding comfort and fit. The gown reviews were undertaken in March and May 2021. The warm weather conditions added an element of authenticity to the exercise, as even wearing some of the heavier, fluid repellent gowns for a few minutes (over a single layer of underclothes) caused the researchers to experience symptoms associated with thermally stressful ensembles (Davey et al. 2020).

Figure 3, above, shows one of the PU coated reusable yellow gowns being tried on, which was particularly heat inducing. We later discovered this was one of 2.9M gowns purchased by NHS England and Improvement during the first wave of the pandemic and piloted with 20 providers 'to increase the proportion of reusable gowns in the system and reduce the waste caused by single use gowns' (DHSC 2020). The results of these trials are still unpublished, but findings from our online survey and other sources[13] indicate that the feedback was negative in terms of the impact on the environment, due to microplastic pollution, and the wearer. "The plastic gowns are unbearable when it's hot, I sweat so much in them and then become dehydrated. They are also terrible for the planet." (Anon, Online Survey 2021)

Our main findings from the review were that the sizing, fit and design details of the reusable gowns were superior to the disposable models, were 100% fluid resistant and according to manufacturers' specifications could be washed between 70-80 times at 71°C. However, while durable, the two PU coated models were uncomfortable despite claims of 'providing a lightweight and breathable barrier against bacteria filtration and fluid resistance.'[14]

5.2 Emerging findings from online survey

While our literature and gown reviews provided evidence of the technical and protective standards of the gowns, as researchers it was crucial for us to gain in-depth knowledge of

[13] The NHS and industry sources we consulted with wish to remain anonymous.
[14] Sales literature accompanying reusable PU coated gown.

functional "physiological, biomechanical, ergonomic and psychological requirements" (Gupta cited in Sterman, p.29) and "emotional" aspects of gown performance from the wearer's perspective (Townsend et al 2017). We developed a research tool in the form of a detailed, anonymous online survey to collect this information. Ideally, we would have preferred to undertake "object interviews" with participants wearing their gowns to experience how the wearer interacted in "material, sensorial and embodied ways" (Woodward, 2019: 34). Townsend et al. (2017) employed a similar approach in the project Emotional Fit, a participatory clothing enquiry with older women, whereby different individual's experiences of making, wearing and styling dress objects informed textile designs and minimal waste, adaptable garments. However, in the PPE project the inability to discuss the phenomenon and access the paradigm of wearing isolation gowns in person, led the research team to spend considerable time and care to illustrate key design features and open questions, to elicit as much qualitative information from the survey as possible.

The PPE Gown Survey (2021)[15] incorporated 25 questions, developed from an initial questionnaire devised for the clinical leads, who provided feedback on the content at two draft stages. Analyses of the first 123 respondents confirmed that 75% wore disposable and 25% reusable gowns at the point of writing (March 2021) and that the key attributes of necklines, sleeves, cuffs, overall fit and fabrication were the main contributors to comfort and protection (McQuerry et al. 2021). Insights into how the survey was designed and how analysis of the emerging data influenced the design of the gown prototypes are discussed in detail in a sister paper (Šterman et al. 2022). The following observations are notable for supporting the research hypothesis.

Fabrication: The heat inducing properties of disposable and reusable gowns were noted, supported by recommendations for improvements and the desire to be sustainable:

> "A breathable material is very important. Since the pandemic started we have been using reusable washable fabric gowns rather than disposable plastic gowns and I much prefer the environment consequences of this." (Anon, Online Survey 2021).

Gown size and length: A total of 62% wore either Large or One-size gowns, which were at odds with their documented UK dress sizes. A total of 47% stated their gowns fitted well, with 14% suggesting gowns were too small and 60% that they were on the large side, creating problems for nurses of smaller stature who stated gowns were "usually too long" and that "if small gowns are not available I risk tripping up whilst wearing large gowns."(ibid.)

Sleeves, fastenings and cuffs: As identified in the Gown Review, sleeves were usually deemed too long, certainly by female nurses who made up 81.8% of the sample. Ties at the back neck were considered fiddly with suggestions for replacement with Velco® or: "Could have bigger ties as being big and tall makes it hard to tie." Elasticated cuffs were universally

[15] Available online: https://ntusurvey.onlinesurveys.ac.uk/grading-gowns-redesigning-one-size-ppe-to-fit-and-protect, Accessed 05 April 2022.

uncomfortable, with a preference for rib, although and the quality of construction was criticized: "The cuffs are sometimes not sewn on correctly and split apart from the gown."(Ibid.)

Figure 4 A selection of four ribbed and one raw cut cuff (with thumbhole) on the various length sleeves of two disposable and three reusable gowns. Photo David Baird, 2021.

6. Discussion

The healthcare workers comments tell us directly about the 'feeling of wearing' the gowns and provide clear direction for balancing 'applicable and protective' qualities in future designs (Šterman et al., 2014, p.12). Functional clothing has physiological and psychological requirements which must all be considered in the process of design (Ibid. 2014; Townsend et al 2017) The literature review touched upon all these factors, particularly the ergonomic, physiological and emotional strain put on nursing staff by having to wear poor fitting and fabricated PPE. The gown review helped us understand the biomechanical features of gowns by documenting their design specifications and trying them on to attune ourselves to the active and emotional role these items play in the world and the people who wear them (Woodward, 2020; Townsend et al, 2017). The contextual, technical and experiential insights helped us to develop a co-design research tool in the form of an anonymous online PPE Gown Survey enabling us to access key workers in COVID-19 healthcare settings. For now, the survey remains open, foregrounding wearer trials underway as we write.

Reflecting on the first year of this study, analysis of the gathered primary and secondary research has enabled us to gain a deeper understanding of the issues associated with and between the personal and political proximities of gown procurement, production and use. This has required interdependency on our partners and stakeholders and the development of "specific skills of collaboration, listening, dialogue and linking" to co-design solutions that seek to work with "earth logically" (Fletcher and Tham, 2019, p.34). And while the methods

employed are focused on a particular "lived body" experience (Eatough and Smith, 2017, p.4) the research takes a holistic approach, and is not only concerned with "the impact of chemical clothing" on healthcare workers' performance (Rissanen et al, in Davey, 2020, p. 187). The intentional design of the research and product, seek to connect the practices of making and use by collaborating with all stakeholders and with consideration of the impact on the human and non-human actors from the outset (Fletcher and Tham, 2019; Real et al. 2018).

In the parallel stages of co-designing Styles 1 and 2 of the reusable gown prototypes (discussed in Šterman et al. 2022), we have found ourselves negotiating between the proximities of the expressed needs of the wearer, the PPE supply chain (including recycling options) and NHS procurement policy as it moves towards Net Zero targets. As designers, we hope to use this project as a stepping-stone to elevate the isolation gown beyond its current liminal status, as neither garment nor uniform, in a similar way to how UK Defence has improved uniforms for women in the armed forces to have a more ergonomic and high performance fit.[16] We would like to incorporate features into PPE that facilitate a gentle form of 'garment hacking' enabling wearers to modify their gown throughout the wearing cycle. The link to computer software language brings the gown into the realm of technical objects, how people and things coexist (Simondon cited in Jayout, 2019, p.30) suggesting that to transition gown design to the circular economy (CE) requires a expertise in object design *and* fashion. And while it is necessary to build scheduled obsolescence into isolation gowns to ensure performance and protection, we hope this research has opened-up how these critical clothing items are perceived.

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