An investigation of enhancing theatre mask comfort using electrospun breathable material

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Abstract

The aim of this thesis is to investigate the issue of perspiration and temperature increase when wearing theatre performance masks. Semi-structured interviews and surveys were designed and employed to elicit knowledge on wearer comfort, manufacturing considerations, mask-making material properties and industry context perspectives from purposely selected professional mask makers. The qualitative data was analysed using thematic analysis consisting of deductive and inductive coding approaches. One key observation from the interviews indicated that the mask material breathability issues were unaddressed due to their incompatibility with the requirements for mask durability, shape retention and currently practiced hygiene solutions. Current mask making practices focussed on addressing sweat related mask damage by adding a water-resistant coating to seal the pores of the material, eliminating its potential for breathability. The aim of this research was to explore the capacity of addressing breathability in performance masks without interfering with other necessary mask material attributes. Using Varaform thermoplastic mesh to tension and structure electrospun PU fabric, kept the majority of the PU fabric surface unsealed and therefore breathable.

The research contributes to new knowledge in several ways:

- Following the insights gained from the interviews with the mask makers, research explored application of porous hydrophobic materials in mask-making to allow water vapour to evaporate via the pores and prevent the durability issue caused by moisture damage by using hydrophobic materials.
- Complex electrospun PU 3D form characterised by double curve was formed from 2D electrospun PU sheets by subjecting it to in-plane distortions while simultaneously constricting the distortion. To create a structurally effective electrospun PU fabric 3D form, thermal based method was used by stretching and compressing the electrospun PU fabric and bonding it to a thermoplastic material – Varaform.
- The approach introduced a new way of thinking about technology integration to mask-making as the researcher brought the user's comfort needs to the forefront focusing on alternative technology and materials to find creative solutions.

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1. Introduction

The research demonstrates an exploration of the potential of using new electrospun PU fabric for theatre mask production with the intention of improving mask breathability. This study bridges the gap between the use of new technology and craft thinking and skills in the mask making field by developing and evaluating the application of new material for masks while engaging in both scientific and embodied cognition of its physical properties. The research highlights the use of electrospinning technology which allows to produce a stretchable, breathable fabric possessing high tensile strength and its potential use to elevate comfort needs of theatre performance masks through added breathability. The researcher's previous experience included costume work and an MSc study in advanced textiles which provided a thorough introduction in textile development. The duality of researcher's background was purposively used to approach and to refine the research problem – improving the comfort in a fit for purpose way through the co-development of the technical and scientific properties of textiles, the physical aspects of material handling and artifact construction. Technical understanding of the new material enabled the researcher to introduce a waterproof breathable composite fabric as new material that could be used in mask-making to address mask breathability issues sidestep the durability concerns caused by moisture damage.

The literature review gave an overview of the traditional and modern materials used in mask making as well as the purposes for material selection. The review also examined the effects of mask wearing on the performer considering restrictions such as limited verbal communication, facial expression, or vision. Additional user comfort issues were found to be considerable in prosthetics and special makeup field with difficulties such as lengthy application time, physical strain of wearing heavy prosthetics or discomfort due to lack of material breathability. The researcher conducted semi-structured interviews and surveys ascertain the biggest modern issues related to mask-making and to appreciate the key concerns that need to be take into account when constructing a fit-for-purpose performance mask.

1.1 The research problem

Wearing a performance mask during significantly reduces visibility, challenges performer's balance (Kal *et* al, 2020) and raises bodily temperature. There is a significant lack of research and practice focussed on improving performer's comfort, especially sweating, when wearing a mask with existing methods such as adding foam or felt pads on the inner surface of the mask to lift it off the face being somewhat limited. With the availability of new technologies and materials, this project aims to connect the advantages from craft and technology disciplines to achieve a more user centred mask making idea. Electrospinning is a nonwoven fibre production method capable of producing nano-diameter fibres which allows to achieve Multiple desirable material functionalities, such as isotropic stretchability, material breathability or embedding particles that have antimicrobial properties such as silver (Akduman, 2017). Electrospinning technology has already been used in making PPE equipment. Introducing this technology in theatre mask-making could help to improve performer comfort and other functionalities, such as water resistance.

1.2 Aims and objectives

The aim of the research is to incorporate electrospun PU textile in performance mask-making with an added breathability functionality.

- To document materials and methods currently used in theatre mask making.
- To analyse the design challenges of achieving mask wearer comfort.
- To explore the capacity of 2D PU textile application for 3D complex structures using 3D collectors.
- To elicit knowledge from professional mask makers and gain insight into current materials and methods used for theatre mask-making and determine existing challenges related to mask comfort and functionalities.
- To develop a structured design approach for introducing alternative materials and technology into mask-making with added value of more scientific to craft decision making.

1.3 Overview of chapters

Chapter 2

Chapter 2 describes methodology used by the researcher. In this chapter, the researcher explains why the Bricolage methodology was selected for this particular study.

Chapter 3

Chapter 3 reviews the literature evaluating mask making traditions from social and cultural perspectives and then assessing the evolution of craftsmanship and the materials used. This chapter covers three major themes. The first section of the review considers mask evolution from anthropological perspective reflecting on ritualistic functions of masks, the capacity to alter appearances, protective uses and the effect of the mask on the performer. The second part of the chapter reviews the materials used in mask making and considers their specific properties. The last section of the chapter investigates mask comfort and key considerations when making a theatre mask and offers a comfort model for masks.

Chapter 4

Chapter 4 focusses on the interviews with the professional mask makers. The chapter discusses the process of mask maker selection, the interview questions and subsequent analysis. The chapter details the identified comfort factors for masks and discusses specific solutions that mask makers use to improve the comfort. The chapter discusses the interconnectedness of comfort factors as well as other necessary mask construction considerations.

Chapter 5

Chapter 5 details the process of the prototype mask construction. This chapter discusses the considerations for creating complex 3D structures and the nuances of subjecting materials to in-plane distortions to achieve double curvature. The chapter introduces the electrospinning technology and its capacity to produce porous, stretchable material that could potentially be used for theatre mask making to enhance breathability and therefore improve performers comfort. Subsequently, the process of prototyping is described, depicting different attempts made to create 3D structures using electrospun PU fabric, without compromising the breathability property.

Chapter 6

Chapter 6 is a discussion chapter focussing on summarising the key insights from the whole project. The researcher describes how the decision-making was informed by the process and the outcomes of prototyping. Additionally, the researcher describes the planned validation stage which intended to receive feedback from professional mask performers that could not be executed due to the pandemic.

Chapter 7

Chapter 7 presents the overall conclusions and findings from the project and presents a series of recommendations for future work.

2. Methodology

2.1 Design research methods

The philosophy of this research study was leaning towards a pragmatic strategy, which can be understood as an approach that considers concepts or theories in terms of their capacity for practical application (Hicks 2010). The main aim of this project was to explore the user-centred mask comfort functionality implementation in performance masks, specifically breathability through electro-spinning technology. The fundamental idea of this research project was to bring alternative technology and craft practice together for the benefit of advancing mask-making knowledge and seeking out experientially and scientifically informed ways to improve mask comfort. While scientific explorations primarily seek to understand and explain the natural world so that future events could be more accurately predicted, design scholarship aims to employ existing knowledge to suggest an alternative approach to complex issues. In design research, using methods from different disciplines allows the researcher to compare and contrast multiple points of view which help to ensure research validity (Yee & Bremner, 2011). This research project intended to combine the knowledge from the science discipline with experiential human knowledge, condition and needs.

Mixed methods research can be defined by its capacity to combine qualitative and quantitative research. The benefit of mixing these two different types of research methods is the added element of complexity to the study. Due to its indeterminate nature, design research frequently embraces multiple methodologies as it allows employing established strategies and methods and, if necessary, creating new tools and techniques to address the research issues. The choice of mixed methods research was task driven and built around the research question. One of the methods used to transfer craft knowledge (which includes material and hand-making knowledge) to other industries is through a collaborative process. In this research study, the researcher herself attempted to merge the interdisciplinary knowledge by using her own accumulative experience from past craft-based engagements, experiential knowledge attained from the interviews with mask-making experts as well as technical manufacturing knowledge of the electrospinning technology.

Design thinking is a popular pragmatic set of methods to provide innovative solutions placing the user as a priority. This approach requires openness and curiosity in working to re-frame the problem from a user perspective. Design thinking is centred on empathy, collaboration, solution ideation, experimentation and iteration and bias towards action (Mishra, 2021). The main themes that inform the design process can be identified as user focus, problem framing, visualization, experimentation, and diversity. These common themes direct the practices within the design process (Kloeckner et al. 2017).

The design thinking process relies heavily on user participation throughout the whole project, including interviewing, co-developing the ideas, and continuously testing the prototype. However, the possibility of fully involving real users necessitates extensive resources and time. An additional limitation of this research study was the limited access to professional mask performers (due to the ongoing decrease in masked theatre funding) which was problematic as continuous user engagement in the study is key in design thinking. Furthermore, the research study was particularly interested in exploring the process of the electrospinning technology and craft knowledge integration itself and developing new knowledge from the activity. For this reason, the bricolage approach to the research study was found to be more suitable as it focuses more on the process of interaction with the materials, the practice itself and the technology. The nature of bricolage is about making do with whatever is available, using alternative existing resources and 'learning by doing' which proved to be a necessary method of enquiry for this study as it often leads to the ingenuity and novelty of what is produced (Hammersley, 2004).

2.1.1 Bricolage

Bricolage can be viewed as an extension of mixed methods research and triangulation (Sharp, 2019), it acts as a pieced-together, cohesive set of practices that provide solutions to a problem in a specific situation (Yee and Bremner, 2011). This mode of research construction is in direct contrast to the work of engineers, who follow set procedures and have a list of specific tools to carry out their work (Rogers, 2012). Bricolage research, as conceptualised by Denzin and Lincoln (1999) is considered a critical, multi-perspectival, multi-theoretical and multi-methodological approach to inquiry (Rogers, 2005). This research study followed an exploratory sequential design model where collected and analysed qualitative data helped to inform the prototyping process (Creswell & Creswell, 2018).

To demonstrate the bricolage nature of the investigation, it is important to consider the researcher's position in the study. The researcher's past training included the accumulative experience of fashion garment and costume making as well as practice-based research on tacit knowledge extraction from textile mending specialists. According to Denzin and Lincoln, interpretive bricoleurs undertake reflexive analysis when piecing together their research as they not only examine an object of inquiry but also inspect how their positioning affects their research process. Consequently, the researcher used the accumulated craft knowledge skills to find a common language with the interviewed experts and establish a rapport.

Having technical manufacturing knowledge of the electrospinning technology and the benefit of having access to the electrospinning equipment and necessary materials enabled the researcher to consider new possible technology applications that could further innovation in mask making. Reflecting in action refers to situations such as: thinking on your feet, acting straight away, and thinking about what to do next (Schon, 1991). Data contained within a bricolage may include both existing uncovered data and new data, constructed through the study itself. During one of the interviews, the researcher was given some mask-making material samples, one of which, Varaform, was found to be a suitable material that could provide structural integrity reinforcement for Electrospun PU fabric in a mask. This research project sought solutions to problems in an exploratory way through reflection-in-action, experimentation, tinkering and applying knowledge collected from the experts. Reflection-inaction helped to reshape and support the prototyping activity during the course of its development. This unique positioning allowed the researcher to investigate the process and incorporate new technology into the craft practice and evaluate its outcomes.

2.2 Data collection

2.2.1 Literature review

The purpose of this study was not merely to identify the current developments of mask practice and assess the existing artefacts, their current developments in the practice and assess the existing artefacts and their functionalities but also to design and evaluate the prototype mask and explore it through user comfort requirements. The most common research concerning craft has been craft historical research as well as research in material culture and anthropology. However, this kind of research is not aimed to address the problems that craft practitioners face and does not apply itself to advance their practice. Historical research primarily focuses on contributing to the knowledge of craft history and material culture research to the knowledge base of material culture. Research that is significant to practising craft professionals and addresses the problems and opportunities across professional craft practice should go further than historical and cultural craft domains (Niedderer and Townsend, 2010).

Niedderer and Townsend (2010) suggest that craft knowledge is based on both experiential and propositional knowledge. For example, for their work, craftspeople draw on propositional knowledge, which may include elements of material science or chemistry, such as material structure, and melting point. These are essential aspects of the craft but not sufficient on their own to fully understand the materials and how to manipulate them. Experiential knowledge builds the skill of material manipulation and the ability to make judgments made about working with a specific material. This research project used different methods to collect and combine propositional and experiential knowledge by bringing together the already existing literature, the extracted explicit and tacit knowledge from the interviews with the professional mask makers and the researcher's own experience of producing a prototype mask.

The research was initiated through an extensive literature review using diverse sources including papers, books and industry-relevant publications to get an insight into the mask-making field of study. The literature review explored the traditions of mask making, considering the breadth of the subject in terms of cultural and social anthropology, craftsmanship, the purpose of use and evaluation of different materials used. The review helped to differentiate the contexts and reasons for wearing masks and evaluated traditional and modern mask-making materials, their selection and how their properties can contribute to creating specific features or functionalities. The critical evaluation of the literature helped to determine the extent to which mask-making as a research area revealed any interpretable trends or patterns.

2.2.2 Evaluation of materials used in mask making

Secondary research gathered on mask making materials and their properties demonstrated certain limitations in terms of a lack of academically critical sources on the subject as some information found proved to be ambiguous, dated and incomplete. To underpin the synthesised data patterns from the literature, professional mask makers were approached and interviewed. The objective was to gather primary data from industry professionals who have an in-depth understanding of the materials and their properties as well as the specifics of using them in mask making industry.

Through the literature review, it was noted that traditional makers were primarily using materials found in their immediate environment, often with customs, rituals and taboos influencing their choices. In a more contemporary setting, such as film, advancements in motion picture technology were found to generate a need for more innovative materials like silicone to achieve highly realistic or fantasy-based appearances and the ability of the face covering material to move along with the facial expressions of the actor. The review also examined the effects of mask-wearing on the performer considering restrictions such as limited verbal communication, facial expression or vision. Additional user comfort issues were found to be considerable in the prosthetics and special makeup field with difficulties such as lengthy application time, the physical strain of wearing heavy prosthetics or discomfort due to lack of material breathability.

2.2.3 Semi-structured interviews

To underpin the synthesised data patterns on mask-making material characteristics found in the literature, professional mask makers were approached and interviewed. Interviews are seen as a useful method for collecting rich, detailed data, getting a holistic view of the subject as well as its nuances and understanding the usability requirements (Courage and Baxter, 2005). The objective was to gather primary data from industry professionals who have an in-depth understanding of the materials and their properties as well as the specifics of using them in the mask-making industry.

The data was collected using semi-structured interviews which involved having pre-determined questions yet allowed the flexibility of finetuning the received information as well as enabling the respondents to offer additional information that was not potentially foreseen by the interviewer. For example, in the interview with the mask maker MC, the questions about mask durability were paraphrased and altered to be more specific. Instead of inquiring about "In terms of durability, how long does the mask need to last?" and "Which materials are most durable?" the interviewer specified the question "Could you please talk about the durability in theatre masks and how you would address it." (Appendix A, Part 5). The question was tailored to be more open-ended and revised to delve more deeply into the individual methods of the mask maker. In the interview with the mask maker AK, an additional question "Could you please tell me more about sealing the mask?" (Appendix A, Part 1) was asked, as the respondent mentioned the importance of sealing the mask when discussing the durability and breathability issues. The additional question allowed to uncover more specific considerations that the mask maker takes into account as well as the methods to achieve them.

Structured interviews in qualitative data research are often used for sociodemographic data collection (such as age, gender or ethnicity) (Merriam & Tisdell, 2015). The benefit of structured interviews includes a lower predisposition for interview bias and more straightforward data coding and analysis (Monday, 2020). However, structured interviews were considered unsuitable for this study due to their limited capacity to fully investigate the individual circumstances, experiences and worldviews of the mask makers. Structured interviews can feel impersonal and fairly generic and the lack of flexibility to adapt the questions and the language to individual interviewees can lead to fragmented responses. Additionally, respondents as well as the interviewer may not always share the same vocabulary and could interpret structured interview questions differently depending on their know-how (Monday, 2020).

2.2.3.1 The selection of the participants

Although many actors, directors, and playwrights have acknowledged the power of masks in performance, their use in modern theatre has significantly diminished (Siegel, 2018). The decrease in masking activity in the theatre signifies reduced access to practising professional makers. Additionally, research shows that the majority of mask makers are self-taught with their skills originating in various art disciplines, puppetry, make-up, prop making or costume making (Yaeger, 2020).

According to Niedderer and Townsend (2010), one of the issues in craft research is the tendency to rely on intuition in the understanding of materials and processes. However, the acquisition of intuition is only accessible through extensive experience manually working with these materials and processes. This type of tacit knowledge is very difficult to communicate because we can know more than we can tell (Polanyi, 1967). In this research project, the data collected from professional mask makers included both propositional and experiential knowledge. This data supported and propelled the researcher's prototyping process, judgement and decision-making. Conversely, the prototyping process helped to better extract the tacit knowledge from the mask makers by asking better, more specific questions and later through reflection.

Qualitative research typically employs nonprobability sampling techniques, meaning that the findings of the particular study will apply only to the specific population or phenomenon that is being investigated rather than a generalised representation. Therefore, the sample size may be much smaller as it is not determined by the need to ensure generalisability, but by the intention to carry out an in-depth investigation of patterns and causal mechanisms (Crbich 1999). There are many different typologies of qualitative sampling within the literature, some examples include convenience, purposive, theoretical, selective, and within-case sampling techniques (Higginbottom, 2004). This study sought to gain an in-depth understanding on the mask making materials and their properties as well as the specifics of using them within the industry therefore, the following sampling methods were determined to be the most appropriate:

- Convenience sampling - participants are chosen based on their relative ease of access (Higginbottom, 2004).

- Purposive sampling - participants are chosen who have specific characteristics or knowledge concerning the research topic. This is used primarily when there is a limited number of people that have expertise in the area being researched (Higginbottom, 2004).
- Snowball sampling – the researcher identifies new cases of interest through the respondent who may refer the researcher to their acquaintance (Creswell, 2007).
- Criterion sampling – participants are chosen that meet some criterion; this is useful for quality assurance (Creswell, 2007).

Murphy et al. (1998) state that study samples in qualitative research are not necessarily static or shaped by the original concepts in the research design but are iterative and emergent in nature. Within qualitative research, the study sample is identified both at the start of the study and during the emergent research design therefore it may not be possible to fully specify the number of participants required at the start of the study (Higginbottom, 2004). To identify the potential informants an online search was conducted to find the names of independent professional mask makers as well as producing theatre companies with in-house prop and costume departments.

Table 1 illustrates the participant selection criteria. Participant sample sizes in qualitative research tend to be on a smaller scale to substantiate the vigour of a case analysis (Vasileiou et al., 2018). Considering the ongoing decline in masked theatre access to mask-making specialists has also become limited. The age factor was considered to have a moderate significance in selecting the sample group as higher age can be positively linked to professional experience. However, some specialists have been known to take up a new vocation during midlife, in which cases the higher age bracket would not directly correlate to increased professional experience. Geographical location was considered to be important and the researcher attempted to meet and interview the participants in person, when possible, as it gave chance to create a better rapport with the participants and to view and handle their work examples. However, the use of video calls was heavily relied upon as well, especially during the pandemic lockdowns. Interviewing the participants via video calls helped to expand the sample size and overcome geographical limitations. The ability to communicate in English was a necessity when selecting the participants so that the participants could answer and elaborate on their experiences and the information could flow freely between them and the researcher. To ensure the data credibility, mask makers who engaged in the production on a commercial degree rather than a recreational level were approached. As the researcher sought to expand the knowledge on the properties of mask-making materials, makers with experience in working with a variety of materials were also sought.

Table 1 Mask maker sampling criteria

Mask maker selection criteria	**Low significance**	**Moderate significance**	**High significance**
Age		✓	
Geographical location		✓	
English speaking			✓
Commercial experience			✓
Experience in theatre mask construction			✓
Experience in working with a variety of materials		✓	
Experience in performing with a mask		✓	
Availability			✓

Overall, 10 participants were selected, 8 of which were interviewed and 2 of which responded via the questionnaires. The original intention was to interview all of the participants, however, 2 of them were unable to attend either live or video interviews. As an alternative, the 2 said participants received and filled in the questionnaire based on the interview questions. The data acquired from the questionnaires were significantly lower in quantity and quality compared to the data obtained through the interviews. The responses to questions in the questionnaire contained minimal detail, occasionally consisting of one-word answers, and some answers to questions were completely omitted (Appendix A, Part 10).

The initial contacts were made via email, briefly introducing the aims and objectives of the research project and asking to arrange an interview. Interviews were conducted in person, via skype, phone call and in some cases via email depending on geographical, accessibility and time constraints. The length of each interview lasted between 1 and 1.5 hours. The interviews were audio recorded following the consent of each participant. Taking notes instead of making recordings was not considered to be sufficiently accurate or detailed for this project. One of the primary benefits of recording an interview is to ensure the flow of effective communication as valuable data may become unavailable due to frequent breaks in eye contact and lessened attention due to notetaking (Millar et al., 2017). This diverted attention may lead to a disjointed interview where key information can be overlooked. Additionally, recorded interviews are advantageous in fostering a better relationship and rapport during the interaction between the interviewer and the participant which can help in disclosing more detailed and thorough information. Another benefit of a recorded interview is the capacity to facilitate higher quality and more transparent information as an audio recording minimises misinterpretation by providing an unbiased narration of the interview (Cook, 2017).

2.2.3.2 Interview questions

Propositional knowledge is largely acquired through research and scholarship and it embodies the understanding of the subject. Habgood-Coote (2019) argues that experiential knowledge comprises both, the ability as well as a relation to a set of propositions. To develop questions that would be suitable for experiential knowledge capturing, the researcher identified and separated the most significant different types of knowledge or skill sets applied in mask making. The questions asked were specific and open-ended. The nature and the process of the semi-structured interview allowed the enquirer to engage in reflective listening through paraphrasing, clarifying and summarizing the received information.

Interview questions were framed around the knowledge and knowledge gaps extracted from the literature review with the purpose to retrieve the required data from the specialists. To ensure the consistency of the collected data, the interview questions were aligned with the research question. The interview questions were composed to allow the mask makers to display the expertise of their craft. According to Merriam and Tisdell (2015), effective interview questions are open-ended and produce thorough and descriptive data. The opening set of questions was relatively neutral, devised to gain an initial understanding of the personal practice, experience and individual key considerations when making masks. The questions were open to encourage respondents to engage in detailed descriptions of their practice. The second half of the questions had more direction, intending to gain a more focused perspective on factors that could influence mask comfort. Questions regarding specific mask-making material properties were focussed on extracting propositional knowledge from the specialists.

The drafted questions were reviewed by the supervision team of the researcher and after the received feedback, some questions were re-written to avoid composite questions consisting of multiple subject matters. The intention was to prevent confusion and make sure that the respondents could fully focus on a specific topic without having to exert additional effort in trying to remember the additional question levels. Leading questions were also excluded to prevent the interviewer's biases and assumptions that could influence the responses of the mask makers. The interview questions were tested and reviewed after the first interview and then continuously refined throughout the interviewing process.

1. What materials do you work most with when making masks and why?
2. What are the key considerations when making a mask?
3. What is the design process when making a mask?
4. When making a mask, do you consider comfort?
5. How would you address different issues related to comfort?
6. What are the limitations and challenges when considering mask comfort?
7. Which materials in your experience provide skin breathability?
8. Which mask design allows for more mask ventilation (airflow)?
9. In terms of durability, how long does the mask need to last?
10. Which materials are most durable?
11. What is your preferred mask making method and why?
12. What is your preferred mask making material and why?

The use of semi-structured interviews helped the researcher to have some reference points and guide the conversation, without too much interference or preventing the flow. Each interview was adapted to suit the participant since each respondent had different experience and expertise, therefore a tailored approach was necessary to attain deeper information. The sequence of some questions depended on the responses and some questions were eliminated and replaced with more suitable queries. As semi-structured interviews are built around storytelling the researcher encouraged the participants to mentally re-visit the steps of their processes so they could describe and articulate their methods and decision-making during their practice.

The effectiveness of using semi-structured interviews can be limited on occasions when the investigator has a narrow understanding of the topic or insufficient subject terminology. In this particular study, there was a definite risk of stumbling blocks concerning extracting tacit knowledge as craft specialists are prone to relying on non-verbal cues when elucidating their process (Kakilla, 2021). Another issue related to semi-structured interviews is a potential lack of consistency. Due to their flexible nature that allows the conversation to develop naturally, semi-structured interviews are challenging to recreate, which may pose a concern for research replicability and robustness (Knott et al., 2022). Allowing participants the freedom to deep dive into their topics may also allow them to digress into subjects that are specifically important to them but that do not have any relevant links to the question at hand. Participants may veer off to irrelevant topics and thus provide data containing broad yet shallow insights. Therefore, the interviewer must succeed in balancing the direction of the interview and the scope of the questions. The lack of consistency in the collected data may further complicate the data coding and the result comparison processes as there may be differences in wording in each interview (Newton, 2010). While using a highly structured interview could have helped to collect more uniform data, the capacity to probe further during the semi-structured interviews was crucial in assisting the respondents to articulate tacit knowledge.

2.2.4 Interview data analysis

Thematic analysis can be defined as a method for seeking out themes and patterns that occur across qualitative data. It can be used for data illustration, and interpretation as well as the processes of selecting codes and constructing themes (Kiger & Varpio, 2020). This method of qualitative data analysis is useful when seeking to understand a range of experiences, thoughts, behaviours, and their differences and similarities across a data set Thematic analysis is also useful for summarizing key features of a large data set, as it forces the researcher to take a well-structured approach to handle data, helping to produce a clear and organized final report (Nowell et al. 2017).

Sandelowski and Barroso (2003) suggest a framework representing a continuum of qualitative analysis methods which can be classified by the extent to which data is transformed during analysis with grounded theory on one pole and methods such as phenomenology on the other. While the grounded theory is concerned with mainly descriptive inquiry and phenomenology deals with an interpretive exploration, according to Kiger & Varpio, (2020), thematic analysis is positioned near the middle of this continuum. Thematic analysis is valid when assembling themes that can re-examine and/or link data components. The method of analysis chosen for this study was thematic analysis incorporating a mixed coding strategy consisting of deductive and inductive coding approaches. This approach complemented the research question by allowing to employ the deduced themes from the literature research to the process of deductive thematic analysis while at the same time acknowledging the emerging themes in the data through inductive coding (Bingham & Witkowsky, 2022). Themes were identified at the latent level, meaning that the grouping of patterns was based on the interpretation of the meaning and context rather than following purely specific terminology.

This study followed a simple and easy-to-follow six-step analysis process described by Braun and Clarke (2006). It is important to keep in mind that the whole analysis activity is not linear, but should be seen as iterative in nature, according to Fossey (2020): "sampling, data collection, analysis and interpretation are related to each other in a cyclical manner, rather than following one after another in a stepwise approach". The six steps of analysis were as follows:

1. Familiarising with the data

This stage of the analysis requires full immersion into the collected data. The initial qualitative data appraisal often starts during the data collection stage. Afterwards, the activity of transcribing the interviews necessitated close inspection of and familiarisation with data through repeated listening. Following the data collected from 8 interviews and 2 questionnaires, the transcripts were entered into QSR NVivo qualitative analysis software which accommodates a rich and large amount of data in various formats (Dollah et.al., 2017). The transcripts were read and re-read multiple times searching for meanings and patterns.

2. Generating initial codes

Coding helps to organise raw data into the most basic components that have a meaningful connection to the research question (Boyatzis 1998). Codes were formed using both deductive and inductive coding approaches. In-depth semi-structured interviews tend to produce lengthy descriptive responses containing rich and nuanced information. To fully capture data subtleties multiple codes were assigned to the same unit of information, which later helped to inform the connectivity and relationships between the themes.

3. Searching for themes

A theme can be defined as a recurring response or inference obtained from the data that informs the research question (Braun & Clarke, 2006). In this study, the deductive approach was used to identify the main themes. The propositions found in the literature review of this study indicated that the key mask making considerations to achieve the best performance and comfort include mask fit, weight, surface properties, breathability, durability as well as appropriate design. These considerations were used as a template to develop the interview questions, which were also used to inform the main themes. Inductive codes, which were established directly from the data, were added later to create more nuance in the analysis and reduce the risk of research bias. Some of the inductive codes formed additional themes that were initially unforeseen during the deductive coding process.

4. Reviewing themes

During this stage, the codes and the themes were evaluated to make sure that the data allocation was appropriate. The Information within each theme was reviewed to make sure it was congruent and assigned to a correct theme, while the data across separate themes should have a substantial difference to necessitate an additional category.

5. Defining and naming themes

During this phase, the most important aspect of each theme was identified while seeking the connections, relationships and hierarchies between the themes.

6. Producing the report/manuscript

The final step included the overall analysis and the explanation of the findings and their implications in the larger context.

2.2.5 Primary research via prototyping

For the exploration of functionality enhancement in performance masks, specifically, breathability, using electrospinning technology, a specific newly developed and patented fabric was used to commence the study (Goswami et al., 2016). The electrospun material displays certain properties such as high porosity, stretchability and excellent shape recovery which allows the fabric to be breathable, making it a desirable attribute for theatre performance masks and prosthetics.

2.2.5.1 Electrospinning Set-Up

For this project, a laboratory-scale standard electrospinning setup was used (at the Technical Textiles Research Centre at the University of Huddersfield), which consisted of Cole Parmer/200 Dual Syringe pump 78-9200C in conjunction with a counter electrode collector connected to a high voltage supply.

2.2.5.2 Preparation of Polymer Solution for Electrospinning

A 10 wt% solution of Selectophore™ polyurethane was prepared using a 60:40 DMF: THF vol: vol (N,N-Dimethylformamide and Tetrahydrofuran) solvent ratio. Selectophore™ polyurethane (1g) (used without further purification) was added to 10ml of the DMF: THF solvent mixture and left to dissolve overnight by mixing at room temperature. The mixture was filled in a 10ml glass syringe set up with an 18-gauge stainless steel needle. Electrospinning was performed under a series of constant parameters: flow rate 2.0ml/h maintained using a digitally controlled syringe pump; distance between the needle tip and the collector 18cm; supplied positive voltage 18kV; temperature 20°C ± 1; and relative humidity 65% ± 5. All nanofibers were collected on a stationary electrically grounded target. The collected nanofibre web samples were subsequently dried for 8 hours in a vacuum oven with reduced pressure to below 1mbar and an increased temperature of 50°C to remove any residual solvents.

2.2.5.3 Variations of special collectors

The 3D collector shape was designed following the areas that contained the contrasting concave and convex lines following the mask mould. Three different types of collectors were used: a) a 3D collector made from papier-mâché and painted with electroconductive paint; b) a 3D wire mesh collector; c) a flat (2D) wire mesh collector.

2.2.5.4 3D fabric moulding

For this study, thermal-based 3D fabric shaping method was used by creating Varaform and electrospun PU fabric composite. A temperature around 70 °C was used to melt Varaform and mould the composite material to the desired shape.

2.2.5.5 Water vapour permeability testing

Moisture vapour transmission rate (MVTR) is a measure of a material's permeability to air and water vapour. The electrospun PU fabric was subjected to water vapour permeability tests before and after it has been altered into a composite structure with Varaform. The test was carried out following the British Standard BS7209:1990.

2.3 Conclusion

This chapter explained the methodology, research approaches and methods selected for this research study. The following Chapter 3 will provide an in-depth secondary research review evaluating mask-making traditions from social and cultural perspectives and then assessing the evolution of craftsmanship and the materials used. The chapter will review the mask wearer comfort considerations, electrospinning technology and its popular applications and will evaluate the existing gaps in mask-making literature.

3. Literature review on mask making tradition, purposes, and material evaluation and comfort

3.1 Introduction

The literature review examines mask making traditions, considering the breadth of the subject in terms of cultural and social anthropology, craftsmanship, purpose of use and evaluation of different materials used. Multiple reasons for wearing masks were explored and discovered to be context and location dependent as people throughout history have been making them for rituals, entertainment as well as protection. Arguably, the greatest difference between traditional and contemporary mask making was found in its intention as contemporary art aims to tell a story, aid a social movement, be emotive and relevant, rather than fulfil a religious purpose or indicate an individual's position in a society.

The review evaluates traditional and modern mask making materials, their selection and how their properties contribute to create specific features or functionalities. Material culture theory was valuable in learning how man-made objects, such as masks, directly as well as indirectly reveal the circumstances or beliefs of individuals linked to the manufacture and utility of masks within the given society (Prown, 1982). The objects themselves carry an enormous amount of information as well as embedded tacit knowledge which can be accessed through careful evaluation and addressing multiple layers of cultural, contextual and technological implications (Rowsell &Abrams, 2015). Exploring archival sources, speaking to practitioners and studying the objects themselves are fundamental methods for building an understanding around them. Historical analysis of material objects requires engaging in a detailed descriptive analysis which may include measurements, material or distinguishing features, such as patterns (Grassby, 2005). This kind of analysis may provide evidence about manufacturing technology or tools used may indicate its quality. Material objects reflect the design choices made regarding their requirements for use. When considering material properties through the dynamic practices and settings of use, different qualities may emerge depending upon specific interactions or contexts (Woodward, 2015). Understanding the evolution of society and its culture as well as its response to existing needs through available technological means was important for the design and product development process of this project as it encouraged the reconsideration of the evolved needs of the contemporary mask wearer.

The mask itself can be generally considered as a technique for transforming one's identity, either through the modification of the represented identity, or through its temporary removal (Pollock, 1995). The manifold uses of masks are context and location dependent, throughout history people have been making them for rituals, entertainment as well as protection (Woodward, 2000). To uncover the legacy of material culture contained within the objects three stages of analysis can be applied – description, deduction and speculation. Description of the object should be unbiased, factual and precise in details, specifying the materials and methods of construction. Focussing on the object itself aids in discerning the evolution of shapes and designs. To ensure objective judgement, the description stage is limited to concrete and specific sensory appraisal. The deduction phase involves discovering the relationship between the object and the observer through assumptions or interactive exploration. The final stage - speculation enables the investigators to draw the meaning behind the object considering historical context and societal values (Prown, 1982).

In some of the more traditional societies, masks formed an indispensable part of the creative and spiritual lives as each culture conveyed the unique characteristics of their belief system through the images used as well as the conditions and methods of masking. In ceremonial contexts masks were utilised by shamans to personify spirits, with the aim to mediate with them and seek advice from ancestors or deities on behalf of a community (Woodward, 2000). It is also likely that masks in some cultures were employed as devices for social control with the aim, for example, to frighten people into initiating or rejecting certain actions or reactions (Edson, 2009). In other cases, masks were used for protection, to counterbalance the weight of the helmet as well as inspire terror upon enemies (Artuso, 2015; Monson, 1939).

Even though many masks demonstrate a high level of craftmanship and are visually pleasing, the association of masks with folk culture has to a large extent interfered with them being considered as an art form on their own. However, it is not unusual for Western artists to draw inspiration from ethnographic and tribal masks, with the tendency to do so mainly for aesthetic reasons, reinterpreting the meaning of the object and often disregarding its context or purpose (Foreman, 1999). In modern Western countries the use of masks conveys more contemporary values and means of artistic and cultural expression. These involve a strong emphasis on recreation and leisure, for instance, some masks may be worn simply just for fun, on occasions such as Halloween costume parties, Mardi Gras celebrations or cosplay (Woodward, 2000). Masks used for entertainment purposes can be found in theatre, dance, and drama performances. When it comes to contemporary art, masks can be used as a very impactful medium when dealing with themes like identity, gender or current events (Smith, 2008).

3.2 Critical evaluation of purposes of masks

3.2.1 Ritualistic functions of masks

The oldest surviving masks are 9000 years old and were found in the Judean Hills, near Jerusalem but the custom of mask wearing is arguably even older dating back 25,000 years as seen in cave drawings which depict people wearing animal masks (Williams, 2014). Tests conducted at Hebrew University in Jerusalem have indicated that many of these 9000 years old masks may have been worn on people's faces (Estrin, 2014). This conclusion has been drawn because the full-sized masks have human proportions and follow the contours of a living face. Additionally, they have big eye holes, allowing a clear view, which indicates that it was meant for someone to look through (Gannon, 2014). Many of the masks have holes around the edges, suggesting that straps may have been attached there to tie it around a participant's head. The masks weigh between one and two kilograms, which is not considered heavy when compared to the ones worn in cult rituals by modern participants in traditional societies in Oceania and Africa (Williams, 2014). These masks were made from stone and are believed to have been made to resemble the skulls of dead ancestors for the use of ceremonial purposes. The time period during which these masks were fashioned marks a defining moment in the evolution of civilisation, when humans replaced their hunter-gatherer lifestyle with farming. According to researchers, ritualistic ceremonies emerged as a method to sustain societal and land-dwelling connections (Estrin, 2014).

Figure 1. 9000 years old mask found near Jerusalem (BBC.co.uk, 2014).

Masked rituals within African communities served as a process of meriting assurance within the context of general uncertainty that pertains human experience (California State University Dominguez Hills, 2011). In ceremonial contexts, wearing a mask would allow the priest to become the physical representation of the god. African masks frequently characterise animal or ancestor spirits, mythical heroes, or virtue symbols (historyofmasks.net, 2013). Such masks were used in private and maturity initiations, seasonal, celestial and life cycle rituals (Owens, 2014).

In ancient Egypt, masks were predominantly used for burial and other ritualistic purposes. It was believed that the body of the dead needed to be preserved so that the soul would have a place to dwell after death. The dead body was preserved through the process of mummification, which involved removal of the internal organs, wrapping the body in linen and embalming. Death masks were made in order to help the soul recognise the body. The most famous example of death masks is the mask of Tutankhamen. Ritual masks in Egypt were donned by priests during the ceremonies. They were made out of cartonnage (tightly fitted layers of linen or papyrus glued together) and designed to emulate animal heads, representative of the gods of ancient Egypt (Historyofmasks.net, 2013).

Figure 2. Tutankhamen – Death mask (Historyofmasks.net, 2013).

With ideas about religion evolving, masks tend to lose their sacred and cult significance. In many cultures this created a shift towards dramatic performances that effectively tied in with rituals and ceremonies as a means of keeping alive ancient traditions and teaching their message to the public (Foreman, 1999). Both theatrical and dance displays necessitated the performer to wear an appropriate costume which often included masks depicting totemic or celestial representations. Dance routines were often vigorous and centred around the repetition of gestures and motifs expressing the cyclical nature of the world. In medieval times, death became significant in everyday life due to persistence of famine and plague, consequently, the images of death started appearing in medieval masked dances and balls, giving the origins to the Dance of Death. During the Renaissance period, the upper-class entertainment form called masques appeared at lavish court parties where performers often dressed as mythical and fictional characters would invite audience members to participate in a dance.

By the 18th century, the attitude towards masks in the performance had changed as the aspect of hiding dancer's features and emotions was seen as obstructing and, therefore, masks became discarded (California State University Dominguez Hills, 2011).

3.2.2 Masks used as a way to represent symbolic messages

Traditional African masks largely embody local tribe values. The distinctive symbols, designs and practices of making were passed on through generations during the training acquired through apprenticeships ensuring the future preservation of a tribe's custom characteristics. The composition and display of specific details on the mask demanded precision so that the attributes of the divine beings and symbols were represented correctly (Edson, 2009). In Gabon, for example, large mouths and chins represent strength and authority (umusetsu.org, 2005). Sowei masks are somewhat unusual in that women are the ones to wear them traditionally. The features of these masks indicate the preferred female character and beauty attributes of Mendé people (Figure 3) with the bird on the head symbolising the intuition, the prominent forehead representing the perceptive mind and the small mouth implying the tranquil nature (courses.lumenlearning.com, 2016).

Figure 3. Sowei helmet mask (tribal-art-auktion.de, 2017).

In many cultures, colours are used very intentionally in mask making for the specific symbolism attached to them. The featuring colours often depended of geographical and geological aspects largely depending on pigment availability. In Korea, China and Japan red colour helped to deter wickedness and the use of white and black colours symbolised purity and godliness. The use of colours enables the audience to read the character role at one glance. In Noh performance, white colour depicts immorality and corruption, red is used for honourable characters and black embodies cruelty (Wingert, 2015). In Korean colour symbolism, white implies characters of young age, red denotes middle age and black is used for masks that represent older characters (Historyofmasks.net, 2013).

3.2.3 Masks used as means to alter an appearance

While one of the major purposes of wearing a mask is to alter one's appearance, the intentions and approaches behind it are various. Stimulus for altering facial appearance seems to have its roots in hunting societies as masks resembling animal heads were used when hunting in order to disguise and approach the prey unnoticed (Edson, 2009).

Another example is ancient Greek theatre, where masks were used to enhance the audience visibility, as exaggerated features helped to communicate the characters and their moods (Sandberg, 2015). Greek theatre masks were void of a facial expression, allowing the audience to assign their individual emotional reaction to the blank mask on the stage (Brown.edu, 2010). Additionally, wearing a mask allowed actors to play more roles by allowing them to portray a number of different characters as well as enabling them to play female roles in a play (Greektheatre.gr, 2015).

Due to changes in weaponry, World War One has caused more severe injuries and disfigurements to soldiers fighting in the trenches than in previous wars (Meier, 2016). In order to cover devastating facial disfigurements, tin masks were designed and used to alleviate the visual discomfort of the war veterans. Copper masks were custom made to make up for missing features or simply to conceal the unsightly facial parts. These masks were held in place by ribbons or spectacles (Feo, 2007).

Figure 4. A French soldier wearing a mask made by Anna Coleman Ladd (1918) (Meier, 2016).

3.2.4 Masks used for protection

Samurai warriors were considered to be a powerful military caste in feudal Japan. Their armour was elaborate yet functional, designed to both protect and intimidate the enemy (History.com Editors, 2009). The helmet specifically was designed for three purposes: to protect, to induce fear into the enemy and to be easily recognisable to the allies (Figure 5). The shapes of the masks were inspired by beings in Japanese folklore, such as devils or mountain sprits, the materials used for their manufacture included iron, fur and rhino horns (Sullivan, 2017). One additional function of these masks was to counterbalance the weight of the helmet (Artuso, 2015).

Figure 5. Kabuto - unique helmet worn by the samurai class (Harvey, 2016).

Contemporary masks and helmets can offer a visual portrayal of our technologically oriented society. Modern-day hazards require different protection compared to those encountered by older societies, contemporary headgear and face coverings are used to ensure safety in everyday work, recreational activities, as well as life-threatening situations (MoMA, 1991). In China, for example, nearly 1.6 million untimely deaths are linked to air pollution. Studies suggest that wearing anti-pollution masks reduce risks of developing heart and cardiovascular diseases (Cherrie *et* al, 2018). Some other areas where protective gear is used in contemporary situations include protection against fire, explosives, chemicals, infection control or providing safety during activities such as diving or skiing (Foreman, 1999).

The fundamental design focus for masks or helmets is on proper fit, vision, mobility, and comfort as well as advanced features such as improved ventilation, noise reduction, and surface scratch-resistance. The modes of making tend to rely on increasingly standardized forms, mass-produced from moulds, rather than aiming for traditional individualized styles. Some of these masks and helmets are developed as complete technological networks with integrated respiratory, illumination and built-in radio communication devices. The use of cutting-edge synthetic and compound materials, such as expanded polystyrene foam, reinforced plastics, and Kevlar, has helped to achieve higher comfort and performance of the protective headgear. Kevlar, for example, gives properties such as ability to be bullet proof, withstand extreme temperatures, as well as flame and fragmentation resistance. Employing appropriate design can help to achieve other desired features such as enhancing speed by manipulating forms to be aerodynamic or using silver-coloured helmets with gold coated screens to reflect heat and ultraviolet rays (MoMa, 1991).

Surgical masks were first recommended and designed by Henrot and Sold in 1868 with the aim to protect both the surgeon and the patient from the transmission of various microorganisms (Song, 2011). The Covid-19 pandemic generated significant debate regarding the sufficiency of different PPE forms (Stewart et.al., 2020). Currently, the most widespread protection equipment available on the market are face masks and respirators. Surgical face masks are used to prevent the spread of exhaled germs, they are tie on masks made out of a non-woven hypoallergenic 3-ply construction with a filter in between. In the United States, surgical masks are rated by ASTM F2100-19 as level 1, 2, or 3 depending on their permeability to synthetic blood, bacteria, particles, and flammability. Level 1 masks must have >95% filtration efficiency to bacteria and air particles 0.1 to 5.0 µm. For levels 2 and 3, this increases to >98% (Stewart et.al., 2020). However, these face masks are not designed or made to provide full respiratory protection for the most part due to lack of sealing between the face and the mask as microorganisms can pass through the gaps (Saha, 2020).

Respirators are specialized masks to prevent inhalation of airborne particles. They are usually made from a material that has filter properties. The most commonly used materials include silicone, neoprene, and rubber due to the properties such as firmness, robustness, comfort and capacity for being sterilised. Respirators vary in shapes and sizes in order to achieve a suitable fit to seal the gaps between the face and the respirator. Sealing to the face ensures the passing of the inhaled air through the respirator's filter material rather than the gaps around it. Attributes such as having facial hair can interfere with achieving a proper seal. However, the capacity for filtering needs to be balanced with breathability as the harder it is to breathe through, the more unfiltered air will ingress from around the respirator's edges (Bort, 2020).

3.2.5 Masks used to create anonymity and conceal

In Venice, citizens wore masks not only during the occasion of the Carnival, but also to attend the theatre, and for evening outings. Wearing masks provided a liberating experience during this conservative and morally strict historical period of Middle Ages. Not only did masks provide a reputation security, they also had a levelling effect on the society. Instead of displaying the status of the wearer, ordinary colours and designs of the masks were used to create neutrality and thus achieve anonymity (Roy, 2015). Some masks, such as Bauta (Figure 6) featured a square design that gave it a wide chin and lacked a mouth, but its shape permitted the wearer to eat or drink without the necessity to unmask (Siano, 2015). In the seventeenth century masks increasingly became seen as a way to facilitate the pursuit of

Figure 6. Bauta was one of the more popular traditional masks of the Venetian carnival (Siano, 2015).

clandestine activities and indulge in socially deviant behaviour, consequently, the act of masking grew to be associated with some form of disreputable activity (Edson, 2009).

A battoulah (Figure 7) is a traditional face covering worn by Bedouin women from the Persian Gulf region, which includes Oman, the United Arab Emirates, Bahrain, Kuwait, Iran and Saudi

Figure 7. Battoulah (Ghanem, 2017; aminoapps.com, 2017).

Arabia. The women of elder generations tend to wear the battoulah daily while, the younger girls use them more on special occasions (Jaffery, 2018). Originally a battoulah was worn to shield from the extreme weather conditions in the desert, protecting from the hot sand and dust. The shape of the covering, specifically the nose and the mouth areas were meant to mimic the features of a falcon's beak. Battoulah can also be referred to as a burqa as it is used as a modesty attire and is worn by young unmarried women signalling the period of coming into age. At first glance, due to its shiny texture battoulahs appears to be made out of metal but in fact many women would make them using goat leather and metallic embellishments. The mask has a strip of fabric that conceals the eyebrows and runs down the centre of the nose covering the mouth as well, it is fastened with hooks (Ghanem, 2017).

3.2.6 Masks used to reveal

Another reason for wearing masks can be found in female masking, which is an alternative scene that began in Europe in the 1980s. The scene consists of mainly heterosexual men who express themselves through transforming themselves into living female dolls. The transformation is achieved through men putting on silicone and latex suits, prosthetic breasts, masks, and appropriate costumes in order to reconstruct the female form. The community is predominantly active online with exceptions such as an exclusive masking forum exhibiting their transformations, however, the participants tend to keep their identity and the practice secret. Opposite to transgender community, 'maskers' as they are also known, do not suffer from feeling born in the wrong body, their motivation for dressing up as a member of the opposite sex is fuelled by experimentation and personal gender identity exploration (vice.com, 2016).

Designer Siba Sahabi designed a series of blue masks made out of wood (Figure 8) with an intention to examine self-representation and the nature of individualism in a digital age. Sahabi's masks encompass the aspects that an individual may want to show to others to make a positive impression and at the same time obscure their true nature. The collection was inspired mostly by social media, where many users are able to display polished and edited version of themselves. The masks are shaped intentionally to conceal certain facial elements yet allowing some openings with visible face parts. According to the designer, these masks encourage engagement while at the same time creating borders (Howarth, 2018).

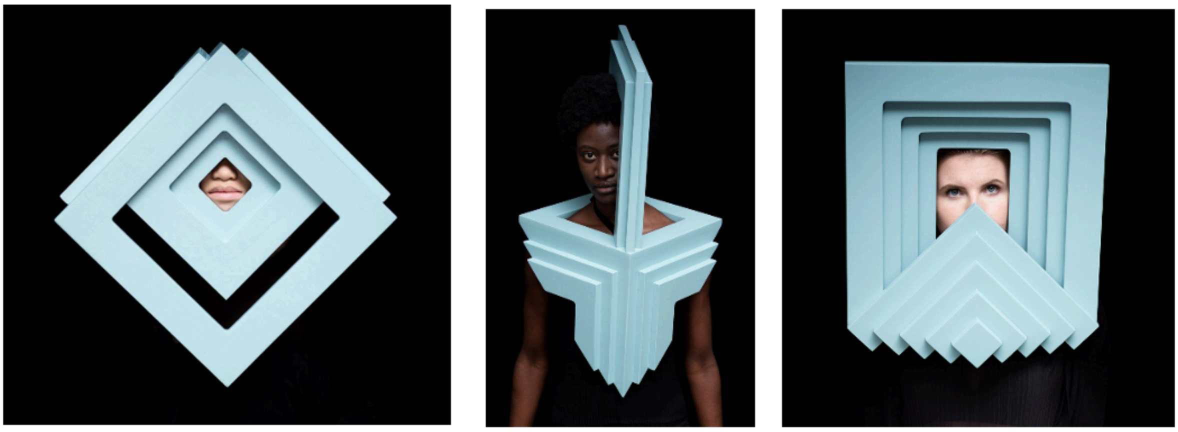


Figure 8. Sahabi's architectural masks question culture of digital self-representation (Howarth, 2018).

On June 2016, singer-songwriter Björk performed on the first virtual reality/360-degree live stream on YouTube wearing a 3D printed mask (from series Rottlace – 'skinless') (Figure 9) custom designed by the Mediated Matter group at the MIT Media Lab in collaboration with 3D-printer manufacturer Stratasys (MIT Media Lab, 2016). Conversely to the usual intention to conceal when wearing a mask, Rottlace assisted in creating an effect of 'revealing' Björk's musculoskeletal system (the muscles, tendons, ligaments) during her performance which appeared to emerge from underneath her skin. The mask was designed to express 'the face without a skin' augmenting the expressions that appear on the mask with each facial movement and allowing for new identity that originated from the artist's facial structure (Lau, 2016).

Figure 9. Björk wearing Rottlace, 3D-printed mask based on her musculoskeletal system (Tucker, 2016).

3.2.7 Effect of masking on the performer

Masks, when used in theatre plays, may prevent performers from speaking, instead requiring them to employ specific body language, gestures and symbols to express themselves, allowing freedom for the audience's imagination and interpretation. With the absence of verbal communication, the audience is compelled to interpret the show through symbols, engaging in the performance on a more instinctual level and relating to it through a personal experience (Selde, 2012).

Wearing a mask has a huge impact on the performer. For example, an Ancient Greek mask would greatly limit the visibility of the performer, as the eyeholes were very small, matching the size of an actual eye of a living person. This would have compelled the performer to maximise his listening senses in order to react to other actors. This is believed to have altered the state of awareness of the actor with his presence being based not so much on visibility but on auditory sense (Kontomichos et. al., 2014). Additionally, it would have required the performer to continually face the audience. In Indonesia, during the Topeng dance performances, it is believed that when actor puts his mask on, he is connected to the spirit realm and enters a state of trance (Historyofmasks.net, 2013).

Traditional Japanese theatre performers believe that the Noh masks encompasses a particular command and power making the experience of wearing the mask a much more spiritual event compared to using ordinary stage props (Figure 10) (the-noh.com, 2008). Since the mask shows a static expression, the audience is unable to read emotions in the same way as it would normally, therefore the actor has to convey everything through their body and voice. Noh masks are remarkable in that they have a capacity to convey numerous different facial expressions depending on different angles of head and body orientation. When a mask is moved by the actor's hand or gesture, its expression appears to change (Wingert, 2015). This feature is made possible by both the mask maker and the performer. While the general appearance of the mask may imply a 'neutral' expression, the maker aims to instil an assortment of emotions in the mask by making some of the features slightly asymmetrical, which serves to heighten the impression that the mask changes expression as it moves (Pulvers, 1978). It is then left to the performer to uncover the emotions of the mask by using minute movements (the-noh.com, 2008).

In the 20th century, dancers and visual artists initiated a re-introduction of masked performance in order to develop non-realistic styles in movement. Martha Graham in the United States, and Mary Wigman in Germany, considered masked dance performance as a liberating experience and helped to pave way the evolution of modern dance. Masks found

Figure 10. Noh mask showing different emotions when tiled upwards and downwards

their place in specific ballet and opera parts as well as in experimental dance companies, like the Bauhaus, Alwin Nikolai, and Erick Hawkins, as they were considered to enable the performer to surpass their own ego and exhibitionism and become an artist (California State University Dominguez Hills, 2011).

3.2.8 Modifying the acoustics

In addition to altering the visual appearance of the performers, Ancient Greek theatre masks also served to amplify and modify the acoustic characteristics of their voices (Brown.edu, 2010). Research that investigated the effect of the ancient Greek mask on sound properties, discovered that the masks were able to amplify the spectral region up to 1000 Hz. Furthermore, these masks would have altered the actor's voice by enhancing the low mid vocal frequencies (Kontomichos et. al., 2014). The masks were made to enclose the head of the actor fully, which in effect, produced a resonance chamber, reflecting the acoustic waves from the interior surfaces of the mask. Reflected sound waves can sometimes create an acoustic phenomenon called consonance which infuses stability and harmonious qualities to the tone. Evidently, ancient Greek theatre masks were used for technological purposes to alter the sound through volume and tone (Vovolis & Zamboulakis, 2008).

Similarly, Zanni mask used in commedia dell'arte, also aided the actors by improving the sound properties. This mask portrayed one of the initial and most popular characters in commedia, this character could be described as a long nosed, acrobatic, storytelling clown. His mask covered half of the face and did not hinder the speech of the performer, quite the opposite, the large nasal cavity of the mask helped to create a resonance as the actor spoke, amplifying his voice (Thurston, 1990). With regards to more recent developments in term of sound alteration using masks, one source describes a patented face mask that can modify the wearer's voice. The face mask is made out of rubber, latex or plastic, inside, it has an integrated microphone connected to a sound signal modifying device. The device can amplify or muffle the volume, shift, alter and conceal specific frequencies or produce computerised sounds (Goldberg, 1987).

3.3 Mask Making

3.3.1 Traditional mask making

Traditional mask making was regarded as a multifaceted task that combined a variety of skills and techniques of manipulating materials into visually powerful objects capable of stirring up strong emotional responses in the onlookers. The purpose of masks was to embody the obscurity of the cosmos and present a tangible component that allowed humans to physically interact with the mysterious world. Early mask makers had to follow a meticulous training process and guidance governed by the obligations to the group. There was a need to respect the rules of traditional methods of decoration and to transfer the symbols of the community to future generations. The way the mask makers were able to express themselves and their craft was through the interpretation of those cultural representations. Produced masks displayed the beliefs, customs and behaviours within communities with regards to nature, afterlife and magic (Edson, 2009).

3.3.2 Traditional materials used in mask making

Traditionally, the materials used in mask making were found in nature. The most universally used material in African mask making was wood due to the abundance of supply as well as the customary belief that an innate spiritual presence exists within the tree (Artyfactory.com, 2018). Most wooden masks available today are less than 100 years old, because wood tends to deteriorate fairly rapidly in tropical climates. The selected timber would usually come from resident forests and would be shaped using a traditional tool called an adze. To commence the tree cutting, a small ceremony would be performed to honour nature's sacrifice. It was common for mask makers to also double as farmers and blacksmiths who would transfer their already existing skills of manual dexterity into mask making. Commonly, the skill of woodcarving was taught from a parent to a child or during an apprenticeship with a recognised craftsman (Owens, 2014). Tools were also considered to have special powers and, therefore, were respected and passed on through generations. Other commonly used materials in mask making were natural fibres, beads, ivory, feathers, shells, horns and paint (Owens, 2014).

Often customs, rituals and taboos exist regarding the choice of the material. In the case of wooden masks, the essential drying processes would have to be followed before the wood is ready for carving. In Bali, ceremonies accompany the removal of the wood from the tree for the most sacred masks. The wood is fully dried before carving. The holy ceremonial masks are carved and later stored in shrines, for they are believed to contain the spirits within (Foreman, 1999). Some cultures have changed their choice of materials to meet certain requirements for comfort and durability. For example, the most traditional Cajun Mardi Gras disguise consists of a wire screen mask, originally this was constructed using an aluminium wire screen but due to it not being sturdy enough it was replaced by a galvanised wire screen. What's more, local women found that sharp edges of wires on galvanized steel masks hurt their skin during the performances. Consequently, Suson Launey invented needlepoint masks, that would be stitched onto a plastic mesh instead (Roshto, 1992).

3.3.3 Early Prosthesis

The artificial tin masks produced after World War One helped to disguise disfigured faces of the soldiers. These early prostheses were made out of 1/32-inch-thick copper or tin sheet and were coated in silver and painted using a cream-coloured spirit coating to resemble the Caucasian skin tone (Friend, 2014). While they would appear momentarily realistic at first glance, the masks also had a disturbing effect due to the absence of an animated expression. Moreover, at the time of the making, the masks would have been modelled after the faces from the photos taken before the war, which created an age mismatch. These characteristics made these early prosthetics used primarily for the worst-case scenarios to hide the major disfigurements of the face. Another design weakness was the considerably short longevity of the mask. The tin sheets that were used for their manufacture were thin and lightweight and thus would noticeably break down over several years of time due to daily use and weather (Feo, 2007).

3.3.4 Modern materials used in mask making

A wide variety of materials can be found in contemporary mask making. Some artists and makers still work with what is most accessible to them, including natural materials or recycled objects, others employ newly developed materials. It could be considered that the biggest distinction between traditional and modern mask making is the intended use. In a contemporary context, masks may be utilised as a storytelling prop or a therapy aid, dealing with modern world issues. Religious and mystical functions of masks in current societies have been replaced by the demand for self-analysis and the dissemination of individualism (art-south-africa.co.za, 2018).

Modern film and theatre masks use an eclectic range of materials from wood or leather to industrial materials such as latex, plastic, fiberglass, resin, cloth, silicone, foam rubber and polystyrene (Foreman, 1999). Simple techniques involving papier-mâché are also still employed in theatre and film as they are versatile enough for the mask maker to make their structure look as though they have been created from a different medium such as stone or bronze (Foreman, 1999). When wet, papier-mâché can be moulded like clay and when dry, it demonstrates many properties of wood as it can be rasped, sanded and carved (Burkett, 2006). Unlike clay, however, it does not require firing or baking. The advantages of masks made using papier-mâché include good durability, lightness and low production costs (Thurston, 1990).

Masks for commedia dell'arte can be made from leather, papier-mâché or neoprene, however, leather is still a preferred material as it has superior performance quality, feel, look, breathability, durability and comfort. Additionally, leather tends to mould to fit one's face over time. Neoprene masks are favoured when the budget for the production is tight. Neoprene rubber is an invention that was designed many years ago as a substitute for latex rubber. Neoprene castings are very tough and durable and are easy to work with, which is useful when there is a need for many copies from the same mask mould. This material is a suitable choice for Halloween or masquerade mask production. On the other hand, neoprene is not particularly flexible, especially when the walls become more than 1/8 inch thick (Maskarts.com, 2008).

One researcher generated a new practice-based study on the connection between the contemporary theatre mask design, its use as a tool during the performance and the introduction of crocheting as a novel process of mask making. The researcher recognised a need for a user-friendly, porous and opaque theatrical mask that could visually enhance the performance. In addition to presenting an alternative to customary mask making materials such as leather, plastic, wood or papier-mâché, the study aims to make a connection between the functionality of a mask as well as it being an artistic object in its own right (Oksanen, 2017).

Present day film industry tends to heavily rely on prosthetics and special effects make-up to alter the appearances of the cast to enhance the plot with visual cues like wounds or ageing. Prosthetics are also used to build life-like dummies to portray corpses or monsters for screen productions (iveracademy.co.uk, 2018). The latest high-resolution cameras used in film are increasingly more sensitive to detail and colour, which means that materials used for prosthetics need to be further refined to achieve a realistic look. Since the prosthetics need to imitate real skin, silicone-based materials have gained a lot of popularity in recent years. Sculpt Gel is a very popular silicone-based material that can facilitate the capacity of pre-preparing effects such as wounds and sticking them directly onto moving parts of the body. It allows the appearance of an actor to altered without restricting their movement. For larger special effect pieces, as well as masks, foam latex or silicone rubber is often used (iveracademy.co.uk, 2018).

3.3.4.1 Gelatine

Aside from foam latex and silicone, gelatine is one of the leading materials in the field of prosthetics. Gelatine is particularly suitable for prosthetic makeup due to its good elastic and textural properties that allows a flesh-like resemblance to be achieved. What's more, gelatine is hypoallergenic, therefore, it can be used on most people. Another positive feature is that gelatine can be re-melted and re-cast several times, which allows for design as well as time flexibility to achieve a desired result. On the other hand, gelatine is not a porous material, thus sweat or air molecules are not allowed to pass through the material. Sweat may accumulate on the skin, forcing the prosthetic to lose contact with the skin. Consequently, gelatine may not be suitable on sets in warm climates where heat conditions cannot be controlled. Still, gelatine is a very popular choice among the professionals in prosthetics for its capability to match the skin in texture and the ease of use (Pirolini, 2014).

3.3.4.2 Foam latex

Foam latex originated through an accidental discovery of vulcanization at the turn of the 20th century, but the foam latex that is known today was formulated in 1936 by a multi-talented makeup artist Charles Gemora (Bray & Debreceni, 2016). The discovery of latex facilitated a surge of innovation and development in prosthetic makeup effects. John Chambers was the forerunner of using foam latex in prosthetics, some of his most famous creations include Spock's ears for Star Trek as well as makeup designs for Planet of the Apes. The major limitation was that the masks remained inflexible, disallowing the apes to change expression. Dick Smith later revolutionised prosthetic make up process by combining separate latex pieces to transform different face parts rather than one single piece, this allowed the performers to achieve more realistic facial expressions (Konow, 2013).

Table 2. Advantages and disadvantages of using foam latex.

Advantages	**Disadvantages**
Durable yet flexible	Lies close to the performer's face, allowing pools of perspiration to collect
Flexible	Difficult material to work with
Low breathability	A natural organic product, so its properties vary depending on environmental conditions. These factors cause fluctuations in the quality of rubber.
Lightweight	Is naturally opaque, which makes it harder to achieve the look of real skin
Economical	Latex is more fragile than silicone, for example, it often gets damaged after removing it from the face
Pleasant feel and smooth texture	It gives off toxic fumes during the heat curing process
	Shrinks over time
	May cause an allergic reaction

3.3.4.3 Silicone rubber

Silicone has been an exemplary material for prosthetics because of its outstanding ability to closely transmute facial expressions (Bray & Debreceni, 2016). Silicone is lightweight, transparent and has excellent flexibility properties which contribute to its capacity of achieving detailed mask work (Hague, 2018). Silicone rubber is not porous, therefore masks made from this material should be worn in a cool environment and even though most masks have openings at the mouth, nose and ears, long term wearing is not recommended for an average user (Celesmask.com, n.a.). Silicone prosthetics are considerably more expensive than the ones made from latex. One of the more important features regarding the prosthetic piece is its edge, which is the part that meets the body of the performer. Generally, the thinner the edge, the easier it is to blend the prosthetic with the body, making the prosthetic look more realistic, however this causes the prosthetic piece to be more fragile. Silicone prosthetics can hardly ever be reused as it is applied leaving an incredibly thin edge, which greatly adds to the expenses of the production (Hague, 2018).

3.3.4.4 3D printing technology

3D printing is widely used in cosplay, particularly for armoury and masks. Once the original scan has been generated, 3D-printed plastic is very suitable for multiple mask production as it requires very little active work time. 3D printing has also been increasingly used to construct the moulds for silicone mask making. Instead of sculpting and constructing moulds from clay, which is a time consuming and expensive process, moulds can be created using 3D modelling software and then 3D printed using filaments such as nGen and PolyLite PLA to create negative moulds. The moulds are reusable and create extremely realistic masks (O'Connor, 2017). This technology has proved to be extremely useful when creating prosthetic pieces for film as make-up and prosthetics artists can pre-prepare the prosthetic pieces beforehand greatly reducing the make-up application time for the actor (Grunewald, 2015). Additionally, using 3D printed moulds is particularly advantageous when creating hyper-detailed sculptures of someone wearing a more intense expression, such as screaming, which can be very difficult to live cast (Lalwani, 2015).

The 3D printing technology has the unique capacity to materialise extraordinarily outlandish concepts to a remarkably precise level of detail and 3D expression. The previously mentioned Rottlace mask, worn by Björk (**Error! Reference source not found.**) was printed by 3D printer manufacturer Stratasys using a flexible, acrylic-based polymer. This process facilitated the exploitation of several different materials with assorted mechanical properties varying in rigidity, opacity, and colour permitting the property distribution within a single object (Tucker, 2016). Rottlace was made up from rigid materials, nano enhanced, elastomeric structures as well as soft and flexible materials that created intricate fibrous tissue, which allowed for facial movement transmutation. The system was arranged in a way that permitted an uninterrupted modulation of properties, exposing stiff bone-like structures, semi-flexible ligament-like structures as well as flexible fibre-based connective tissue structures. The resulting system produced the effect that worked on centimetre, millimetre and micron levels creating a structure with parts that had flexible movement as well as uninterrupted material variation within the object (MIT Media Lab, 2016).

3.3.5 The challenges of the prosthetics

Prosthetic make up and its application in film regularly pose some challenges for the performers. Bulky and weighty prosthetic pieces restrict actor's facial movements, necessitating them to find different methods of expression through body language (Greenwood, 2017). Additionally, the application usually requires many hours of sitting in place, before the actor is ready to perform, which is time consuming and exhausting for the actor and also expensive for the production (Grunewald, 2015).

Table 3. The evaluation of materials used in mask making and prosthetics.

Materials	Advantages	Disadvantages
Stiffened linen with animal glue and plaster	• When shaped in a specific way can help to amplify the sound	• Limited durability
Wood	• Easily accessible material	• Heavy • Limited durability
Japanese cypress	• Lightweight	• Hot to wear
Papier-mâché	• Lightweight • Cheap • Easy to work with • Can be very comfortable if backed with felt or thin strips of foam rubber	• Not very durable
Leather	• Lightweight • Flexible surface • Smooth surface • Comfortable	• Time consuming to produce • Expensive to produce

	• Perspiration is absorbed into the surface of the leather • Durable • Hydrophillic	
Tin	• Lightweight	• Static expression • Limited durability
Silicone	• Tight fit, can move with one's face • Can be hyper realistic	• Expensive • Hot to wear, can be fatiguing • Not breathable • Prone to tearing • Most eye cuts on silicone masks are cut small to keep exposed flesh to a minimum and when a performer starts sweating, the eye lids will start rubbing against the eyeball, which can be incredibly painful • Difficult to get rich colours on a silicone mask • Heavier than latex masks
Foam latex	• Moves with one's face, mostly the mouth • Durable • Flexible • Economical • Lightweight	• Not as flexible to move with one's face as silicone masks • Hot • Prone to tearing • Uncomfortable to wear • Sweat trapped in the latex pores will smell and it will start rotting process • The colours will become dull with time

		• Difficult to work with • Some people are allergic to it
Neoprene rubber	• Tough • Durable • Easy medium to work with • Affordable	• Not particularly flexible • If the walls of the cast are thick, the mask can become heavy and cumbersome
Wonderflex (Thermoplastic)	• Can be moulded to form a shape • Can be re-heated, reworked • Has inner mesh, so has good durability • Lightweight • Easy to use • Cost effective • Little to no waste of material during the production	• Limited flexibility • Mesh side is rough in texture • Not breathable
Varaform (Thermoplastic mesh)	• Heat moulded to form a shape • Will stick to itself in its warm state • Re-mouldable when exposed to a certain temperature • Easy to work with • Biodegradable • Water resistant • Lightweight • Strong • Non-toxic	• Need to use a hot airgun or hairdryer at a high temperature to soften the mesh, with burns becoming a safety risk • When exposed to heat again, Varaform mask may lose its shape • Inflammable
Fosshape ™	• Heat moulded and can be sewn • Lightweight • Easy to use • Cost effective • Breathable	• Shrinks when heat activated

	• Not affected by water • Shrinks when heat activated • Once activated Fosshape cannot be reshaped	
Worbla/TerraFlex (Thermoplastic)	• Heat moulded using heat gun, boiling water • Made from renewable natural raw materials • Durable • Easy to use • Lightweight • Thin	• Pretty rough surface texture • Can crack or split due to thinness
Plasterzote (High density foam)	• Tough • Flexible • Lightweight • Waterproof • Non-toxic	• Not breathable
Buckram	• Can be moulded by wetting and stretching • Lightweight • Non-toxic	• Not durable when exposed to water, the shape falls apart with body sweat or in humid/rainy conditions
Felt	• Can be moulded over a shape by soaking and stretching • Breathable	• Slow making process • Not suitable for nuanced and detailed work
Styrene	• Lightweight	• Not durable • Requires special machinery for forming
3D printed plastic	• Great option for multiples with very little active work time • Quite durable	• Limited flexibility • Not breathable

	• Easy to paint	
3D printed flexible, acrylic-based polymer	• Porous • Allows for flexible movement • Good structural integrity • Extremely accurate fit	• A trade-off between the printing resolution and printing speed

3.4 Exploring the use of electrospinning in mask making

Electrospinning is a fibre production method achieved by drawing fibres from a polymer solution or melt through a needle (spinneret) using electric charge (Beachley & Wen, 2009). The benefit of the electrospinning is its capacity to produce nanometre-scale fibres that have large surface area and good mechanical flexibility which facilitates varied functionalisation for numerous applications including protective clothing, drug release or air filter materials (Akduman, 2017). Electrospinning can be used to produce a variety of different types of fibres with specific properties depending on polymer solution selection. Thermoplastic polyurethane (PU) has an excellent elasticity property, which, when used to spin nonwoven fibres, produces very flexible and stretchable fibres (Ding *et* al., 2017).

3.4.1 Polyurethane (PU)

Polyurethane (PU) was first developed in 1937 (Ardebili *et* al. 2019) and is known to be a versatile polymer that is capable of changing its properties from hard to soft when heated without losing its structural integrity even after multiple cases of reprocessing (Huntsman, 2010). The key purpose for choosing PU in electrospinning is attributable to its wide-ranging properties like durability, elasticity and fatigue resistance (Akduman, 2017). However, electrospun nanofibers display weak mechanical properties which is attributable to the relaxation processes that takes place directly after fibre formation when a certain degree of molecular orientation is lost (Akduman, 2017). One research study reviewed the properties of electrospun polyurethane Selectophore™ membranes where it demonstrated that the hydrophobic property of the membranes increased further with higher fibre diameter and porosity. The electrospun PU membranes with average fibre diameters of 347nm, 738nm and 1102nm had contact angles of 104.3°, 116.1° and 122.5° respectively, with 90° contact angle being indicative of a relatively hydrophobic surface (Wang *et* al., 2013).

3.4.2 Solvents

A wide variety of solvents can be used for polymer solution preparation. Solvent properties determine polymers' capacity for spinning and regulate fibre morphology (Feltz *et* al., 2017). Solvent selection for the electrospinning of a particular polymer is generally centred on its solubility parameters (Li *et* al., 2014). N,N-dimethylformamide (DMF), dimethylsulfoxide (DMSO), N-Methylpyrrolidone and tetrahydrofuran (THF) are generally used to make PU solutions. Previous research has shown that PU dissolved in pure DMF was found to be easily electrospinnable however, adding THF to PU/DMF solution demonstrated the ability to achieve thicker fibres compared to the PU/DMF solutions. The increasing THF volume fraction was found to restrict electrospinning due to higher viscosity and lower conductivity (Akduman, 2017). The solvent is expected to evaporate during the electrospinning process; however, not all polymers are immune to residual solvent retention. As most of the organic solvents that are usually used for PU polymer electrospinning are toxic, it is crucial to remove the residual solvent which can be done by freeze-drying the sample or drying it under vacuum (Xie *et* al., 2009).

3.4.3 The process

During the electrospinning process, a polymer is dissolved in an appropriate solvent (see section 3.4.2) and slowly fed through a spinneret forming a droplet at the tip. A grounded target is placed at a specified distance from the tip of the needle (Feltz *et* al., 2017) high voltage is directed to the needle, which causes an electrostatic charge to mount at the tip of the droplet, which gets uniformly distributed over the surface. This sequence of actions causes the drop to experience the electrostatic repulsion between the surface charges and the Coulombic force (the force of attraction between positive and negative charges) exerted by the external electric field. From these electrostatic interactions, the liquid drop forms a cone shape known as a Taylor cone (Li & Xia, 2004).

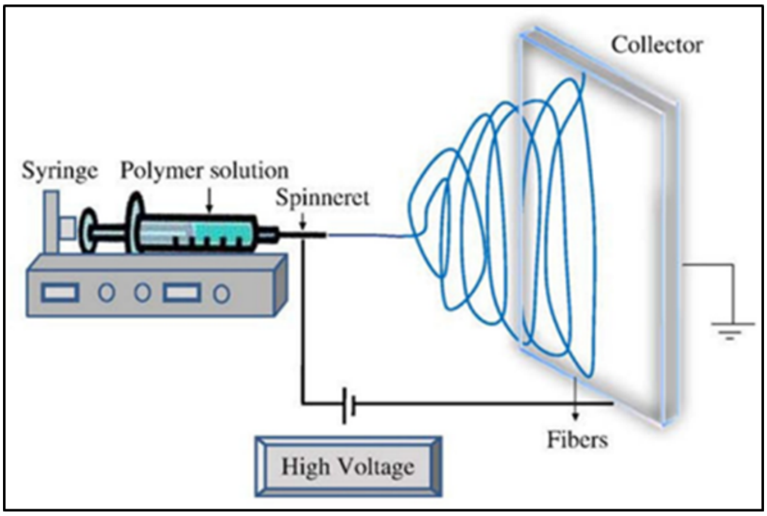


Figure 11. Electrospinning process (Laboratory of Polymers and Biomaterials, 2014).

At the point when the voltage exceeds the threshold value, the electric force overpowers the surface tension of the droplet and a single (or multiple) charged jet of the solution is ejected from the tip of the droplet. Before reaching the collector screen, the liquid jet extends, the solvent evaporates while travelling from the tip of the needle to the collector, which results in materialisation of a randomly oriented, nonwoven fabric on the collector. As the solution travels from the tip of the needle towards the collector, the trajectory of the jet is linear, but at a specific distance away from the needle the jet begins to whip chaotically. This unstable whipping motion of the jet is referred to as the bending instability (Garg and Bowlin, 2011), which causes fibres to be randomly oriented and nonaligned (Asmatulu and Khan, 2019). The geometry of the collected web is usually unreproducible, and it consists of fibres that have a wide range of diameters (Russell, 2007). Most commonly, the collector used during the electrospinning process is made out of a conductive material (Akduman, 2017). The fibres collected follow the geometry of the grounded collector, however excess fibres deposit on every surface in the vicinity of the collector as well (Feltz *et* al., 2017).

3.4.4 Existing methods of 3D electrospun structure formation

The standard method of electrospinning is capable of fabricating two-dimensional (2D) membranes, the growth of the thickness and the depth of the scaffold structure is limited as the fibres tend to spread and distribute on the surface of the membrane (Joshi *et* al., 2020).

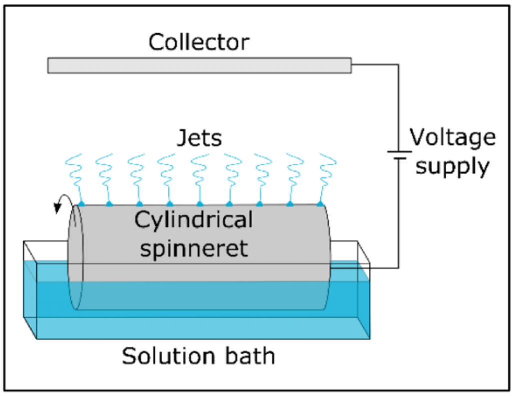
There have been some attempts to investigate the possibility of the 3D electrospun structures, with most applications being explored in the field of tissue engineering (Yousefzadeh *et* al., 2012). The research describes several recommended approaches of producing 3D nanofibrous structures. One method is to collect electrospun nanofibers on a low surface tension solvent such as methanol which would provide conditions for the foremost collected fibres to sink as the succeeding fibres get deposited. Over time, this would generate a moderately distinct layer of accumulated fibres. Another suggested method is to select a frozen collector which would allow ice crystals to form on the collector and over the accumulating nanofibres (Yousefzadeh *et* al., 2012). Both aforementioned techniques of the manufacture of 3D nanofibre structures are principally based on fibre accumulation upon a flat surface, which suggests that building more distinctive 3D structures would be a slow and time-consuming process (Yousefzadeh *et* al., 2012). Additionally, due to the large amount of electrostatic charges carried by nanofibres, there is a significant Coulombic repulsion force between these fibres which affects the nanofibre deposition area on the collector, making it usually large and with the low fibre collection efficiency (Niu *et* al., 2019).

Zhang *et* al. originated the fabrication of nanofibrous tubes using rotating 3D collectors with various protrusions. An additional method to create cylindrical structures could be to roll electrospun meshes using a stress-induced rolling membrane technique (Zhang, 2008). More recently, Rampichová *et* al. used a two-step process combining 3D printing and electrospinning technologies and gluing separate nanofibrous scaffolds to achieve depth (Abel *et* al., 2020). The composite scaffold of 3D printed microfibres and electrospun nanofibers exhibited excellent cell infiltration, high architectural complexity and mechanical reinforcement, on the other hand, the process of fabrication was complex, and processing speed was slow (Abel *et* al., 2020).

The methods mentioned above for fabricating 3D nanofiber structures have their advantages and disadvantages. The main shortcomings of the current production methods that limit their applications: difficulty to scale up the process, lack of structural stability and integrity, capacity only for selective polymers and conditions, limited suitability for applications where a specific shape is needed as well as mechanical weakness of the 3D structure (Lubasova and Netravali, 2020). These electrospun 3D structures are primarily developed to form thick fibrous scaffold layers creating solid 3D structures. When considering these types of structures for mask-making application, the mask shape could be achieved by removing the material which could roughly be compared to wood carving, however considering the nano-scale production of the material, this would be a highly wasteful and inefficient use of the technology. These disadvantages are pertinent to this study as the production of a full-face mask requires easy scalability and access to fabric resources for creative experimentation and artistic freedom. It is essential that produced theatre masks possess reliable durability for the duration of the show run and are able to withstand rough treatment behind the scenes.

3.4.5 Industrial-scale electrospinning

Laboratory scale electrospinning demonstrates a relatively low production rate, which has restricted the industrial applications of this technology so far. However, numerous attempts for scaling up the technology have been made to increase the speed of manufacture in order to make industrial applications viable (Mehta *et* al., 2017). The industrial-scale adaptations of electrospinning techniques can be separated into nozzle and free surface methods (Salehhudin, *et* al., 2018) The nozzle-based electrospinning systems feature the solution being fed directly into the electrically charged needles or multiple-hole spinnerets. The free surface electrospinning methods allow liquid jets to leave from the open surface of the solution. The free surface electrospinning methods have the advantage in that significantly more Taylor cones can be formed during the process in comparison to the nozzle-based electrospinning systems meaning faster production. One significant free surface electrospinning method has been commercialised by Elmarco as Nanospider™ technology (Vass *et* al., 2020). In this case, Taylor cones are formed on the surface of a rotating roller which is submersed in a polymer solution. The Taylor jets are formed across the whole length of the roller giving an advantage of higher productivity (El-Newehy *et* al., 2011).



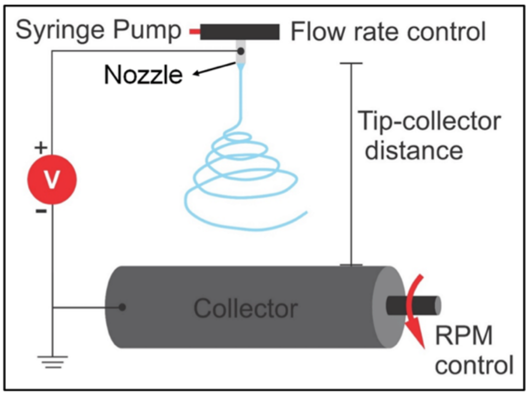


Figure 12. Free surface (left) (Salehhudin et al. 2017) and nozzle-based electrospinning (right) (Samerender and Smitha, 2019) setups.

3.5 Investigating mask comfort

Comfort can be described as a satisfying, relaxing human sensation responding to the specific environment. A comfort model that is regularly quoted in product comfort research is the comfort model for sitting described by De Looze et al (2003)). The model illustrates the correlation between the comfort and discomfort as well as the relationship between the human, environment and the product itself. Personal as well as external factors induce comfort or discomfort responses in humans. Factors such as physical and psychological state count as personal, external factors include influences from the environment and the product,

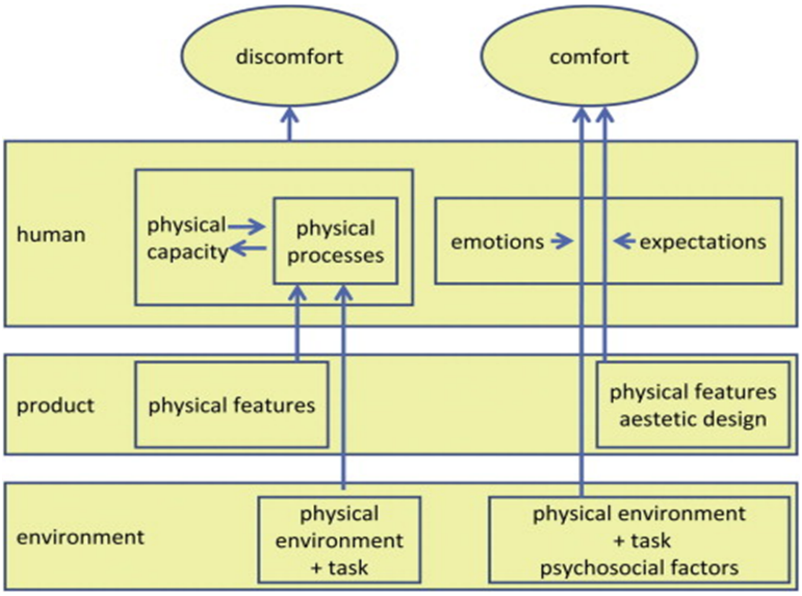


Figure 13. The comfort model for sitting described by De Looze et al. (2003) (Vink and Hallbeck, 2011).

for example, temperature, smell, visual stimulation (Zemp et al. 2015). The absence of discomfort does not necessarily establish a state of comfort, as the need to experience more than anticipated is essential when experiencing the feeling of comfort (Vink and Hallbeck, 2011).

Research on clothing comfort indicates that the main specific factors include thermal, tactile and fit comfort with regards to the specific activity that the clothing is used for. Therefore, clothing comfort can be viewed as a complex arrangement of different physical, psychological, and sensory experiences. The degree of moisture and heat capacity to pass through a textile has a significant impact on thermal comfort. There are four main methods of heat transfer from the human body which include conduction, convection, radiation, and evaporation.

Psychological conditions also have a substantial sway with regards to clothing comfort. Studies indicate that attributes such as economical, historical, cultural, social, and societal aspects have a considerable effect with regards to comfort. Sensorial considerations are critical when determining the textile comfort level. The sensations in response to contact with the fabric as well as its specific features can be classified into softness, smoothness, elasticity, warm or cool feeling, thickness, wrinkle behaviour, bending rigidity and hand fullness of a fabric. Some distinguished factors relating to sensorial discomfort include fabric hairiness, prickliness, or wetness (Fibre2fashion, 2014).

The coronavirus outbreak that commenced in 2019 has led to an increased demand for face masks, which has also brought about significant interest in research on mask effectiveness for protection and wearability comfort. One research study focussed on investigating factors influencing wearer comfort suggested that breathability, thermal conductivity and the fit accuracy were distinctive when discussing mask comfort (Lee *et* al., 2020). Mask breathability has a significant importance as lack of air and water vapour transfer through the mask material have a capacity to change the micro-climate inside of the mask causing a rise in humidity. Although fabric thickness is commonly perceived to be a major factor for breathability, Lee's study suggests that fabric structure and density are significant when it comes to material breathability. For example, because knitted fabrics have the capacity to stretch, and in this way enlarge the pore size they are usually found to be more breathable than woven fabrics provided that the measurement takes place on dynamic objects measuring the yarn of the same density.

A well-fitted mask directly improves the wearer's comfort by minimising the shifting of the mask with the head movements or having the eyeholes and the nose in the correct position so as not to obstruct the vision and the breathing. However, the goodness of fit can also inversely affect mask ventilation as it controls the gap size between the face and the mask allowing airflow and cooling the skin surface. Having the mask too close to the face increases the temperature of the microclimate existing between the face and the mask. Additionally, an extra tight fit may aggravate the skin leaving marks or dents from rubbing. Thermal comfort of wearing a mask would be largely governed by the type of mask fibres. Characteristically, conductive materials have a capacity for rapid heat transfer, therefore adding conductive materials to structures can increase their thermal conductivity (Lee *et* al., 2020).

3.5.1 Key considerations when making a mask for theatrical performance

Certain factors should be considered when making a mask to achieve the best performance and comfort. Key points to consider when choosing a material for mask design include:

3.5.1.1 Fit

A mask should be comfortable and fit well and should not move with the head movements of the performer. Masks made from flexible materials, such as latex rubber, leather or fabric are the easiest to fit, as they can be bent to conform to many face shapes. Vacuum-formed styrene and papier-mâché masks are less flexible but can fit several faces if the bone structure is similar. Sheet metal, neoprene, Celastic and thermoplastic materials are firm and unyielding (Thurston, 1990). Additionally, it is important to make sure that the eyeholes are set in exactly the right place for the actor. To achieve the best peripheral vision, the eyeholes, should be as close to the eyes as possible (Bicat, 2012). For example, many commercially available anti air pollution face masks may not actually achieve their full functionality due to ineffective face fit as the inhaled air arrives through the gaps between the face and the mask rather than through the filtration material (Cherrie *et* al, 2018).

3.5.1.2 Weight

In modern performances, it is imperative for a mask to be light weight. Vacuum formed styrene is one of the lightest materials, but papier-mâché, latex and leather are also very lightweight. Some traditional societies may disregard this consideration. For example, in African mask making, easy-to-carve, soft and lightweight woods are less commonly chosen for masks, and they are less durable in comparison to heavier woods. Endurance displays largely dominate African ritual experiences with dancers occasionally having to perform in masks that are bigger than their own body (DeLuca, 2011).

3.5.1.3 Surface properties

It is very important that the part of mask touching the wearer's face should not have rough edges, as it could chafe with continued use. Vacuum formed styrene has a very smooth surface while materials such as papier-mâché, Celastic and Hexcelite have rough, uneven surfaces, requiring padding on the interior of the mask (Thurston, 1990).

3.5.1.4 Breathability

To ensure user comfort, it is important to choose an easily ventilated material for the mask. Material breathability can be characterised as the capacity of the material to allow the perspiration to pass through it via moisture vapour transmission (Fan *et* al., 2009). Water vapour transmission rate (WVTR) is a measure of a material's ability to allow air and water vapour to move through it, allowing the accumulated sweat to evaporate through the fabric (Das et al. 2007). If a product has a high WVTR value, it means that the moisture permeates through the barrier material quickly (Ozol, 2019). The capacity water vapor to pass through a material is subject to its porosity (Fan & Hunter, 2009). Leather is by far the most breathable mask making material, however it is also highly absorbent due to its hydrophilic nature.

The term absorbency is used to define material ability to take in moisture which is governed by wetting and wicking properties of the material. Wettability can be understood as the capacity of the material surface to interact with liquid and is affected by the material surface properties (Yanilmaz & Kalaoglu 2012). Wicking is defined as spontaneous transfer of liquid through a capillary structure, is instigated through wetting and affected by material porosity (Patnaik *et* al., 2008). Porosity is one of the main material factors that have a huge effect on thermo-physiological comfort properties (Yanilmaz & Kalaoglu 2012). High wicking rate allows to remove the condensation of moisture from the skin surface through the fabric, which can improve the sensation of comfort (Fan & Hunter, 2009). A mask made from papier-mâché or Celastic can be backed with felt or foam rubber to achieve absorbency (Thurston, 1990). One study found that having a face mask on for a prolonged period of time may contribute to the rise in temperature inside the oral cavity as the convection and evaporation of heat is greatly minimised (Yip *et* al., 2005).

3.5.1.5 Durability

A mask must be durable to be able to survive the long run of the performances. Leather, Celastic, latex, foam latex and neoprene possess good durability properties. While vacuum-formed styrene and papier-mâché were found to be less sturdy in comparison (Thurston, 1990).

3.5.1.6 Appropriate design

It is crucial that the design of the mask should not interfere with an actor's ability to perform. For example, while it is possible for a dancer to wear a full-face mask, an actor who must speak should wear a half face mask to make sure the mouth area is left open or a mask that has a capacity to amplify the sound. Research found that wood and leather (rawhide) work best for this kind of application (Vovolis & Alström, 2005). Additionally, it should be considered whether the mask needs to be static or move with the face of the performer. Most commercially available mass-produced liquid latex Halloween masks feature static expressions that do not allow change in facial expression (Slusser, 2006).

3.6 Conclusion

This review explored the multiple reasons for mask wearing and evaluated traditional and modern materials used in mask making as well as the purposes for the material selection.

Different sources were explored to gather and compare the data evaluating material characteristics, however many of the sources proved to be ambiguous, dated and incomplete. Traditional makers were noted to primarily use materials found in their immediate environment, often with customs, rituals and taboos influencing their choices. In a more contemporary setting, such as film, advancements in motion picture technology were found to generate a need for more innovative materials like silicone to achieve highly realistic or fantasy-based appearances and the ability of the face covering material to move along with the facial expressions of the actor. Some literature sources have indicated how technological developments can help to push innovative prosthetic and mask making methods and materials, with 3D technology demonstrating how materials can be manipulated to have their properties enhanced, such as Rottlace mask.

The review also examined the effects of mask wearing on the performer considering restrictions such as limited verbal communication, facial expression or vision. Additional user comfort issues were found to be considerable in prosthetics and special makeup field with difficulties such as lengthy application time, physical strain of wearing heavy prosthetics or discomfort due to lack of material breathability.

4. Interviews with the professional mask makers

4.1 Introduction

The chapter discusses the data analysis gained from the interviews and questionnaires. The chapter details the identified comfort factors for masks and discusses specific solutions that mask makers use to improve comfort. The interconnectedness of comfort, material properties, manufacturing and industry considerations is identified highlighting the issues and changes.

4.2 Key themes from the interviews

After familiarising with the interview transcripts and questionnaire responses, repeating ideas were grouped from the raw data into a composite list. These repeating ideas were gradually grouped into more coherent categories forming common themes. The conducted interviews were coded into five key themes:

- Factors influencing comfort when wearing a mask (which contained 33% of all the references),
- Manufacturing aspects (34%),
- Material properties (26%),
- Industry (24%)

Each theme was comprised from specialised topics which were identified through the process of isolating patterned regularities. Figure 14 shows a sunburst chart of theme and code hierarchies identified from the interviews and questionnaires with the mask maker stakeholder group. Sunburst charts are particularly helpful when representing multiple level data. Each ring in the chart is divided based on its hierarchical relationship to the parent node, giving an evident understanding of the lineage.

Interview data analysis was approached by progressively categorising the raw data into groups, incrementally building the connections between the raw data and research concerns to analyse the factors affecting mask comfort and the extent to which mask material properties such as breathability are impactful (Auerbach & Silverstein, 2003). This grouping of data was built on gradual steps moving from raw data to research concerns. These steps included raw data, relevant text, repeating ideas, themes, theoretical constructs, theoretical narrative and research concerns. Opposing opinions have been thoroughly recorded and noted, with the reasons for expressed opinions questioned and considered within the context of mask-making.

Comfort	33%
Production	34%
Industry	24%
Properties	26%

Figure 14 Sunburst chart representing theme hierarchies from the interviews with mask makers

4.2.1 Factors influencing mask comfort

The theme regarding mask comfort was the second largest theme discussed by the mask makers. Table 4 shows the repeating ideas within the theme of factors influencing comfort when wearing a mask. The most frequently occurring topic within this theme is mask fit, comprising of 18 references. The numbers referring to participants and references are significant in suggesting the hierarchy of relevance each factor has for mask comfort. Table 4 indicates that the most discussed factor to influence mask comfort was fit with the highest number of mask makers and references, noting its significance. Performer's attitude towards comfort was referenced the least, signifying it to have minor importance when considering mask comfort issues.

Factors	The number of participants	References
○ Factors influencing comfort when wearing a mask		
○ Fit	10	18
• Visibility	5	7
• Fixing the mask to the face	4	7
• Foam, Felt pads	6	8
• Breathing	6	11
○ Material breathability	6	14
• Sweat	5	15
• Smell	2	2
○ Weight	4	10
○ Tactility	6	6
○ Temperature	3	5
○ Attitude towards comfort	3	4

Table 4 References on factors influencing comfort when wearing a mask

The six main factors influencing mask comfort were categorised and explicated individually. The feedback received from mask makers on each of these factors will be discussed in detail in the following sections. The relationships between the factors were observed by identifying the interdependencies between them. The visual network of the influences between comfort factors was broken down to smaller segments so that the connections could be explored in a deeper and more meaningful way.

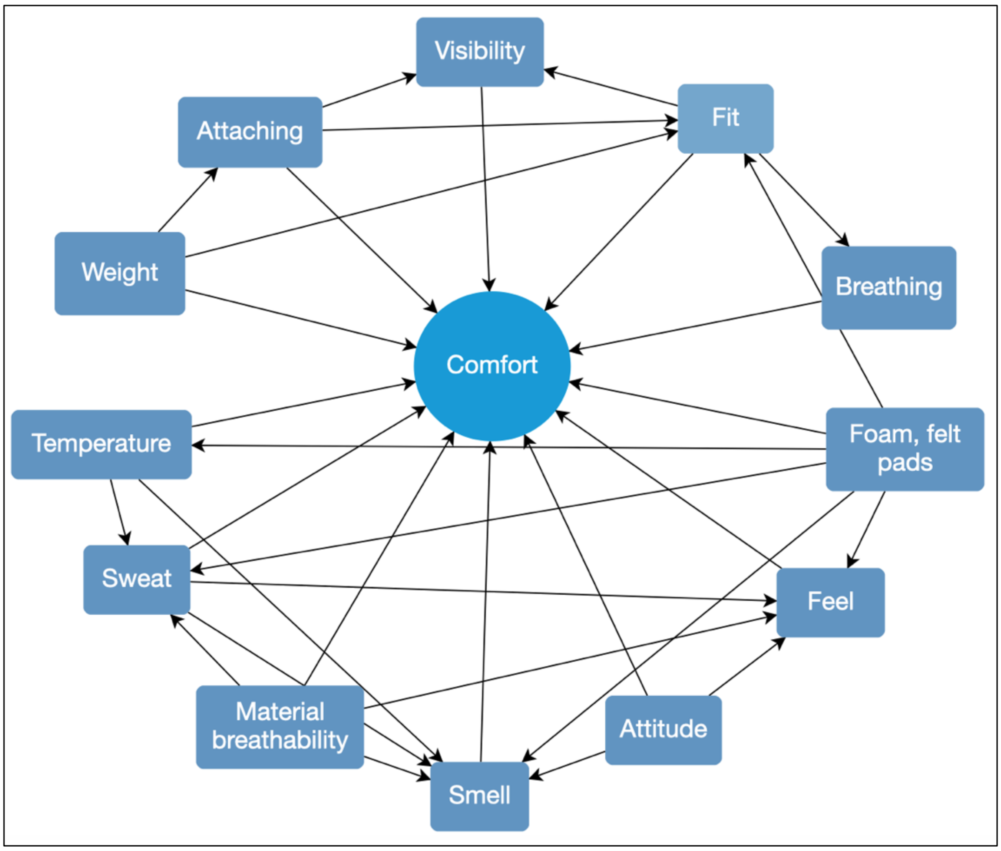


Figure 15 Diagram demonstrating the interconnectedness of comfort factors

4.2.1.1 The importance of the mask fit

Figure 16 illustrates the directions of influence links between the fit of the mask and other comfort factors. Interview analysis suggests that in addition to making an accurate mask

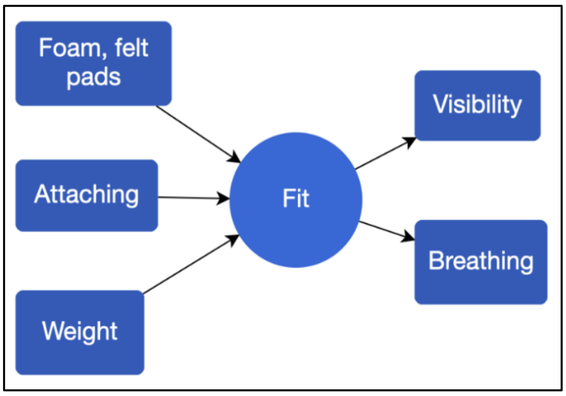


Figure 16 Figure Links of influence between the fit of the mask and other comfort factors

mould and following the correct measurements of the facial features, factors such as adding foam or felt pads and correct attachment methods significantly improve the fit of the mask. The weight of the mask and its distribution over the wearer's head is key when considering the stability of the position of the mask. Heavier masks require more complex systems of attaching to one's head to ensure the security of its position, however, that may pose separate issues, such as increase pressure to the face from the ties of the mask. The accuracy of the mask fit can affect the performer's visibility and the ability to breathe through the mask in a positive or negative way.

4.2.1.1.1 Using a mask mould and facial measurements to achieve the correct fit

Irrespective of the materials used, all mask makers unanimously stressed the importance of using a face mould to achieve the most comfortable fit. The mould can be made by life-casting a face using skin-safe silicone or alginate and then producing a positive mould from a plaster cast. The positive mould means that its outer shape is convex rather than concave. When the mask is sculpted on a particular mould, its interior measurements and shape follow the contours of the mould precisely, which means that it will fit the person whose face was cast to make that specific mould perfectly. While the exterior of the mask can then be sculpted to achieve the desired design shape, the interior of the mask will remain perfectly adherent to the contours of the face.

Participants noted that face shapes vary significantly with some people having broad foreheads or long faces. The curve of the face is also noteworthy, for example, while the measuring distance of same facial parts between two separate faces may match, the same mask could be uncomfortable for these individuals if the curvature of their features is different. Several respondents pointed out that the distance from the top of the nose to the top of the lip tends to be particularly distinctive. This measurement is critical in half-face masks so that the mask would not obstruct the wearer's oration and would blend in perfectly with the rest of the face, obscuring the lines where the mask meets the face and the head.

4.2.1.1.2 Visibility

According to participant RD, while the distance between the top of the nose and the top of the lip generally has a great significant variability, the eye distance tends to be more similar across the board. Mask makers agreed that good visibility is a priority when considering mask comfort and fit. It can be quite challenging to ensure a good field of vision for the performer unless the mask is made using a mould for a specific person closely following the measurements of their features. Even so, if the mask is designed to conceal the eye area of the face, the peripheral vision of the performer will be significantly reduced. Additionally, it is impossible to wear glasses under a mask which adds further limitations for visually impaired individuals.

Several participants expressed that getting the performer's face measurement accurate is more crucial for the half-face masks as full-face masks allow for some flexibility due to them completely covering the face. On occasions when numerous performers have to wear masks in the show, it can become too expensive and time-consuming to cast each individual face. Participant MC said that whenever he has to make a one size fits all mask, he tries to work with a cast member that has the most average facial proportions aiming to fit the most common facial proportions rather than tailoring the extremities of smaller or bigger faces. Similarly, participant JD added that it is important to avoid extreme distances between the eyes and between the eye line and the upper lip. The material properties have to be taken into account when considering the fit accuracy. Participant DK expressed that some materials shrink as they dry, for example, neoprene latex shrinks by 15%, therefore it is important to anticipate the shrinkage and make the features intentionally bigger during the initial stages of casting.

4.2.1.1.3 Adding foam or felt pads to improve the fit

During the interviews, the mask makers explained that foam or felt pads have several functions when it comes to mask comfort as they are used to improve the fit of the mask

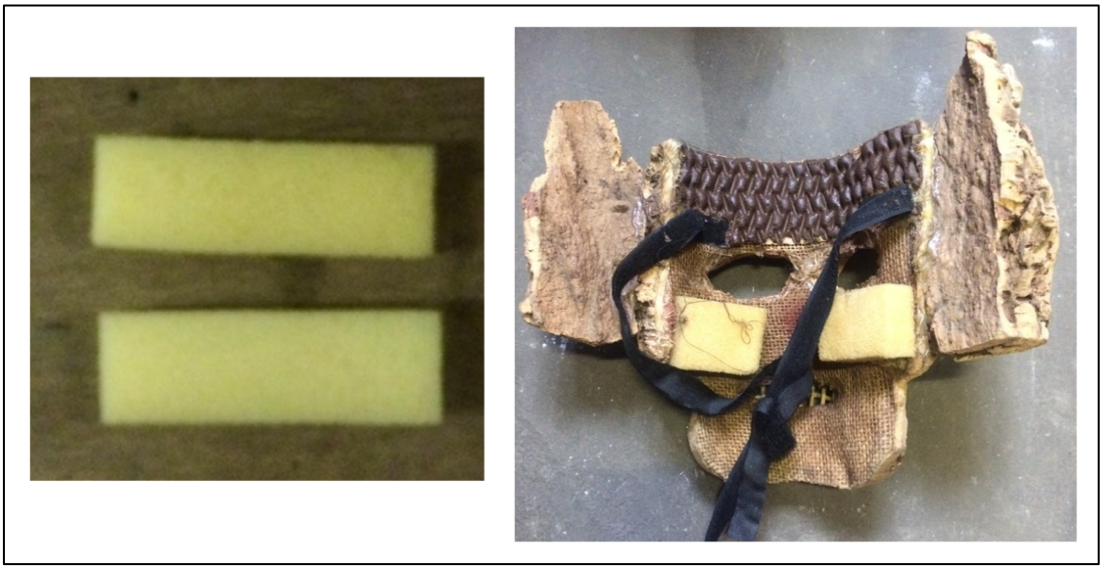


Figure 17 Foam pads attached on the cheekbone area of the mask

(section 4.2.1.1.3) and control sweat-related issues (section 4.2.1.2.1). On occasions when performers need to wear masks that do not fit their face exactly, foam, or felt pads can be strategically added to the interior of the mask to improve the fit (Figure 17). Such addition helps to keep the mask in place because these porous materials can absorb the excess sweat of the face and their textured, rough surface helps create friction and offer necessary resistance between the face and the mask. Participant RD explained that the placement accuracy of foam or felt pads is vital, stressing that they should not be positioned on the moving areas of the face, such as cheeks. Participant RD specified that the best positions to achieve a good grip between the face and the mask are directly on the cheekbones beneath the eyes and across the forehead. As further explained in Chapter 5, section 5.3, the forehead (comprised of the cranium and frontal bone) and the cheekbones (zygomatic bones) are the stationary parts of the skull and therefore are the most suitable points for contact with the mask and the pads as these parts of the face do not move when the performer speaks. However, each face varies greatly, so it is essential to spend a suitable amount of time figuring out the exact positions for the pads on an individual basis.

4.2.1.1.4 Fixing the mask to the face

According to participant AK, the performer needs to be able to move the head quickly and be able to trust that the mask is going to stay in precisely the same position. In masked theatre, performers have to find a way to create a believable, homogeneous illusion between the mask and the rest of the body, touching the face to adjust the mask would ruin the illusion. To ensure that the mask stays fixed in place, the position and the strength of the elastic used to tie the mask across the back of the head should be chosen in accordance with the size and weight of the mask. The way a mask is attached depends on its design, shape, size and weight. If it is a small face mask, one string of elastic across the back might be enough, but if it is a big mask, a more secure attaching method is needed. Participant AK emphasised the importance of understanding the needs of the performer when designing a mask "if a mask maker makes a very elaborate mask but does not understand the needs of the performer, effectively the mask might be just too heavy or unwieldy, thus the balance or the visibility might be restricted, limiting how the performer can act and move". Participant VW explained that mask design depends on the context and the character, masks don't necessarily have to cover the face, some of them can be positioned on somebody's head, a cap or a helmet can be used to make it. Such creative solutions can help to achieve wearability comfort and secure positioning in a more balanced way.

Helmet masks that fully cover the performer's face have also been seen to contribute additional functional attributes. The literature (Chapter 3) review has highlighted the capacity of the helmet masks to amplify and modify the acoustic characteristics of the voice in ancient Greek theatre. Research investigating this particular phenomenon discovered that the ancient Greek masks could magnify the spectral region up to 1000 Hz. The masks were made to enclose the entire head of the actor, creating a type of resonance chamber for the actor's voice (Figure 18) (Kontomichos et al., 2014). Although the weight of the mask would have been supported in a balanced way by the whole head, the primary intention for this shape was to transform the performer’s self-awareness and perception of the surroundings rather than ensure his comfort. This type of mask limited performer's visibility, as the eyeholes were tiny, matching the size of an actual eye of a living person. Previous research with masked

Figure 18 Ancient Greek theatre mask replica designed to encapsulate the whole head to create a resonant chamber

theatrical plays revealed that this restricted visual field helped the actor to concentrate. It could also be argued that restricting the vision leads to augmented hearing allowing an enhanced responsiveness to the presence of other performers. The helmet mask also altered the spatial awareness and physicality of the actor allowing them to achieve character metamorphosis via distinctive movements and gestures (Vovolis et al., 2013).

The functionalities of ancient Greek and more contemporary performance masks described by participant AK demonstrate a difference in attitudes regarding what derives the masked performance's essence. From the ancient Greek theatrical point of view, the mask constricted the performer, creating a meditative state and an inner space for the actor through which he was able to optimise the acoustic communication with the theatre space (Vovolis et al., 2013). Contemporary masked performances have a broader scope of the genre, rarely using full-face masks for vocal performances. Participant VW added that helmet masks that fully cover the face pose another challenge by creating a breathing chamber with little airflow, which, if not appropriately addressed, may cause a lack of oxygen or a build-up of carbon dioxide inside the mask. Therefore, in instances where full-face masks are used, performances must rely on the expressiveness of the performer’s body, thus the comfort qualities such as optimal visibility, and balanced and unobstructed breathing system need to be carefully considered and prioritised.

4.2.1.1.5 Unobstructed breathing

Having a mask covering one’s face limits the capacity for oxygen intake, the actor needs to be in good physical shape and able to deal with oxygen deprivation while moving on stage (Selde, 2012). All mask makers agreed that one of the most significant considerations in terms of comfort is the performer’s capacity to breathe properly. Participant MT explained that some flexibility towards mask fit shortcomings may be acceptable, but the mask should never obstruct the performer’s means of breathing. Participant RD raised a point that, remarkably, performers do not breathe through the nose hole of the mask. The mechanics inside the full-face mask mean that the oxygen is inhaled through the gaps around the mask, mostly around the neck area. Participant VW informed that “It is essential to address the breathing correctly in full face masks because the closed environment can create a breathing chamber where it becomes very easy for the performer to hyperventilate”.

Due to Covid-19 pandemic, the use of protective masks has spiked the discussion on mask safety concerning constricted breathing. According to haematologist Pečeliūnas (2020), the only actual outcome of mask-wearing is the so-called dead-air space which manifests when people do not fully exhale all of the inhaled air and some of it remains in the lungs, however, the effect of this phenomena on health is insignificant (Bakaitė, 2020). According to Gerlach, CEENTA Voice & Swallowing Center Director, CO2 levels must remain in equilibrium with oxygen in the human body, however, due to peoples' tendency breathing too quickly and with too much volume, the loss of CO2 occurs. The resulting CO2 deficiency cause the blood vessels, airways and nasal passages to narrow, challenging the overall health (Gerlach, 2017). Nasal breathing has been highly recommended for athletes, but it is also beneficial for performers who need to use their voices. Breathing through the nose reduces the allergen and other particle intake, minimising throat irritation and dehydration (Gerlach, 2017).

Understandably, actors must undertake intensive breathing exercises for masked performances to establish the correct breathing technique. One anecdotal example illustrates how an ancient Greek orator, Demosthenes, was thought to engage in voice and breathing training that involved speaking with stones in his mouth or while running up a hill (Wiles, 2017). Another source suggests that breathing volume is increased when wearing a mask, therefore the performer needs to be relaxed to make the breathing calmer and quieter to prevent the audience from hearing it (Roy, 2016). Reviewed sources on mask-making performances recognize that wearing a mask creates physical challenges limiting vision, changing the sense of balance, and making breathing difficult. However, these challenges appear to have been accepted and even warranted to create a trance-like state and enhance the consciousness of the performer, particularly in more archaic masking forms of Greek theatre or Balinese dance performances. These types of masks are reflective of the society for which they were produced, however these masking attributes and attitudes have long been extraneous to present-day society (Knight, 2004).

Contemporary mask makers have a variety of materials to choose from when it comes to mask making. When considering modern Western drama, the priority for mask-makers has been to translate the visual ideas of the playwright (Knight, 2004). Additionally, the live performance industry must ensure the prevention of health and safety hazards and implement precautions to ensure the performer's well-being. According to hand props and costumes safety guidelines for the live performance industry in Ontario, masks and headdress need to allow for adequate visibility, hearing and should not impede the performer's breathing. Mas should be secured balancing the weight distribution to prevent headaches, neck or back strains (Ontario Ministry of Labour, Training and Skills Development, 2017).

Participant MC explained how he adapted to produce masks suitable for eurythmy dance performances using millinery net, which is a mix of coarse weave cotton with starch. *"I used a material called millinery net because the dancers needed to breathe but also, they needed to see and have good peripheral vision. I used this material so that the performer could see from the inside, but from the outside, the audience could not see the dancer's face. It also created this translucent effect because its surface was not flat, rather it was porous, which gave an ethereal feeling."* He added that the extra benefit of using millinery for masks provided high levels of ventilation within the mask. VW, who primarily works with papier-mâché, said that she adds pinpricks in a papier-mâché larval mask (Figure 19) to ensure supplementary oxygen supply. Conversely, participant SB expressed that adding pinpricks could sabotage mask durability, consequently, she does not apply this method in her practice.

Figure 19 Larval mask set

4.2.1.2 The effect of material breathability on mask comfort

Material breathability, also known as moisture transmission through materials, has a huge effect on the thermo-physiological comfort of the human body, which is maintained through perspiration (Das et al., 2007). Material breathability permits air and water vapour to pass through allowing the accumulated sweat to evaporate through the fabric. The primary method for transferring moisture and reducing the thermal sensation of wetness in low moisture content conditions is diffusion which is mainly dependent on the fabrics' porosity (Das et al. 2007).

When asked about the effectiveness of using breathable materials to improve comfort, most mask makers expressed their reservations. Participant AK emphasised that professional masks need to be hard-wearing, therefore they should be made out of relatively firm materials. These materials should have a considerable thickness to be able to hold their shape, which would offset the capacity for material breathability. Participant RD added that even though porous materials such as leather are breathable by nature, masks made using these materials would still need to be sealed during the process of making to make them water-resistant for durability and shape retention requirements (further explained in section 4.2.1.2.1). Participant JD expressed that if the mask was left unsealed for breathability purposes, the sweat would soak into the material, causing the mask to smell and become unhygienic. Participant SB said that theatre masks are not prioritised to be breathable at present, "the priorities are time, cost and material availability, the available mask-making materials are not primarily aimed at improving comfort". Participant AK added that although material breathability can be recognised as an issue, it all depends on the individual performer and their attitude, stating that wearing a mask should not be considered a comfortable experience and that there is no such thing as a comfortable mask.

Figure 20 shows the links of influence between material breathability and other mask-making factors. The different colours in the legend show factors from other themes that also impact material breathability (these themes include material properties, manufacturing and comfort). From the discussion with mask makers, it can be understood that the requirement for durability in a mask negatively impacts material breathability. This could be attributed to the increased material thickness or added substance to form an additional layer to seal the mask and make it impermeable to moisture. In textiles, the thickness of the material is directly linked to the vapour molecule capacity for its diffusion. Thinner textiles tend to display a

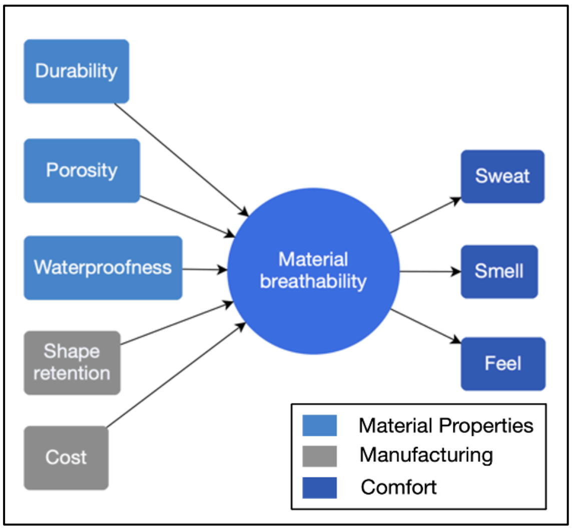


Figure 20 consisting of deductive and inductive coding approaches

higher water vapour transport ability (Bartels, 2011). It was recognised that the more porous the material, the more breathable it is; however, the porosity and the thinness of the material counteract the durability of the mask. If the sweat gets into the pores of the material, it reduces the longevity of the mask and increases the residue of sweat odour. In addition, excess moisture entering the pores of the material expands the structure, damaging the shape of the mask. Figure 21 showcases the relationships of these influences on material breathability represented in a visual diagram.

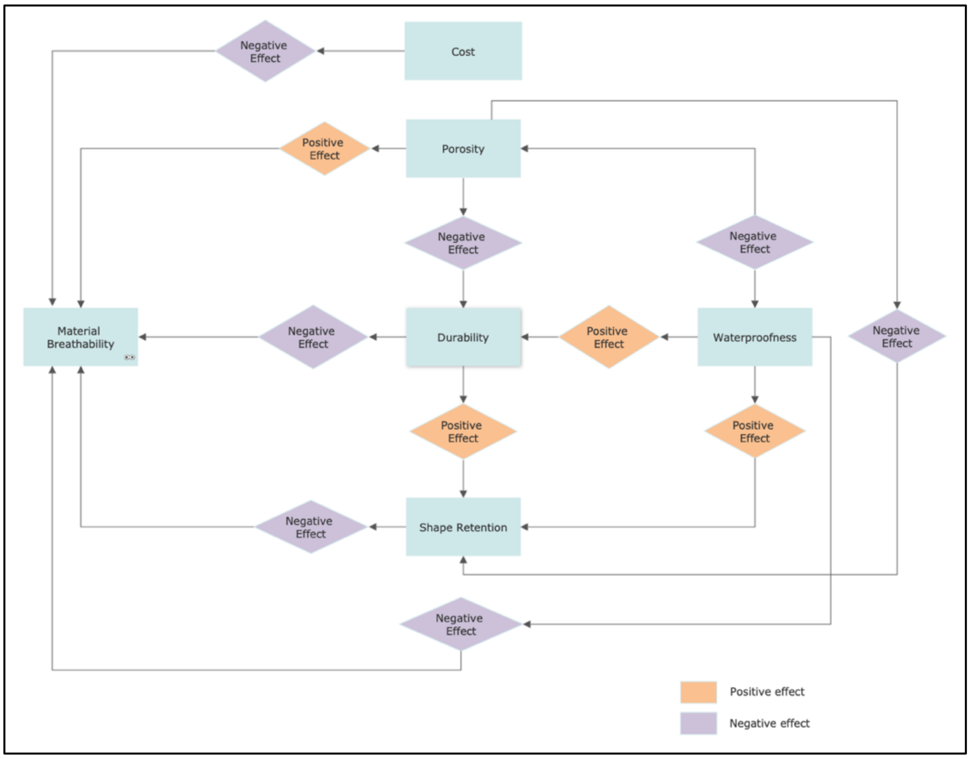


Figure 21 Influence diagram showing positive and negative connection values between the factors affecting material breathability

Currently available methods for adding water resistance to the material of the mask used by the interviewed mask makers seal the pores of the material eliminating its potential for breathability in favour of added durability. The use and the methods of water-resistance treatments on masks can be compared to other applications in the leather goods industry. For example, in footwear or clothing manufacturing, leather should be prevented from absorbing too much water, for it would dimmish its insulation ability against heat and cold. On the other hand, it is important to facilitate high water vapour permeability to support the process of removing perspiration from the body. To advance the water resistance property, several different leather surface modification processes are used in the industry: a) completely sealing the leather using heavy polymer finishes to create an impermeable layer, the leather cannot be wetted, but the water vapour permeability is reduced drastically; b) closed waterproofing – this closes the gaps between the leather fibres with water-repellent substances resulting in sealed pores and very low water vapour permeability; c) open waterproofing – creates a hydrophobic layer within the fibre network, but without filling spaces, so water vapour can travel through the material, but water droplets cannot spread of over the hydrophobic layer of the hydrophilic fibre (Jankauskaite et al., 2012).

The practices of waterproofing mask-making materials discussed by the mask makers fall into a) (sealing the leather with an impermeable layer) and b) (closed waterproofing), leaving the third option c) (open waterproofing) unexplored. The tendency to choose a) and b) methods to achieve water-repellent surfaces could be attributed to durability considerations by adding another layer to the material. As previously mentioned by participant SB, theatre mask priorities are closely linked to time, cost-effectiveness, and material availability. Commercially waterproof leathers are relatively expensive due to speciality product requirements for the waterproofing process (Jankauskaite et al., 2012).

4.2.1.2.1 Sweat

Figure 22 demonstrates the positive and negative influence that material breathability exhibits on other comfort factors. As previously discussed in section 4.2.1.2, breathability is the common term for the moisture vapour transmission rate (MVTR); it is a measure of a material’s permeability to air and water vapour, allowing the accumulated sweat to evaporate through the fabric (Das et al. 2007). A high WVTR value, indicates that the moisture vapour permeates through the material fast (Ozol, 2019).

From data gathered from the interviews and the literature, it can be understood that the sweat management issue in masks is complex due to the opposing needs to protect the mask from sweat and find a way to remove the sweat from the face of the performer. As already explained in section 4.2.1.2, mask makers indicated the need for waterproofing the mask to achieve a hard firm surface and prevent the sweat from soaking into the mask to avoid damage occurring over time. Additionally, mask makers expressed that materials react to

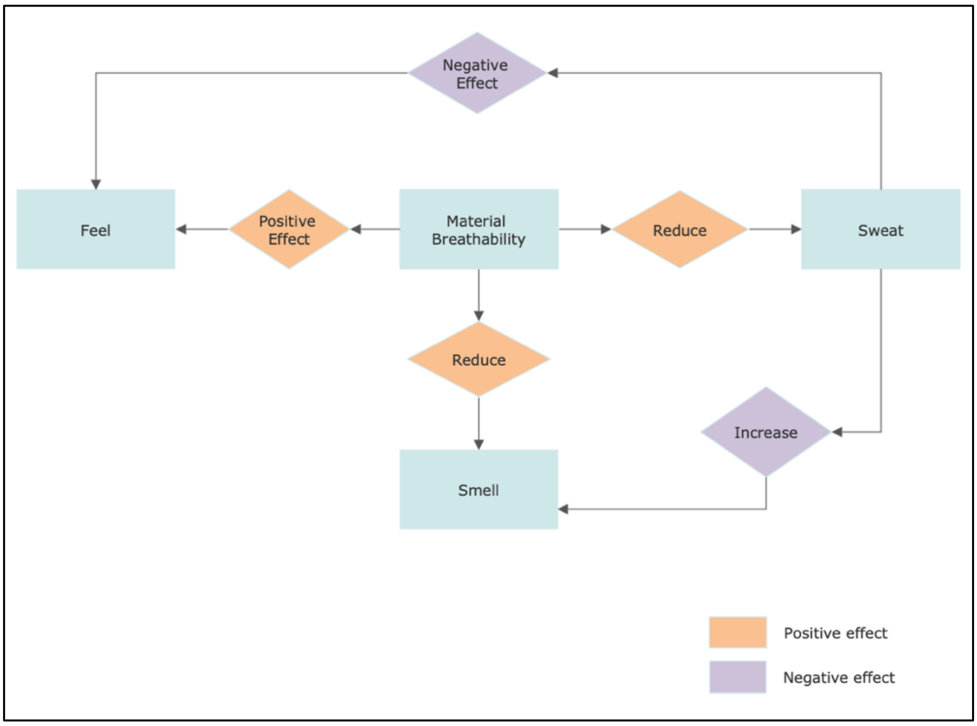


Figure 22 Influence diagram showing positive and negative values of connections between the factors that are affected by material breathability

sweat exposure differently, participant DK noted that "sweat turns neoprene latex milky white/yellow colour and it starts to smell". Participant MC informed that sweat could stretch the outer rim of the mask, especially in leather or papier-mache masks: *"If I need to strengthen them, I put a wire rim around the outside rim of the mask just to strengthen that, just for the durability, so the sweat does not expand or stretch it, make it lose its shape".*

Participant RD explained that masked performances are physically demanding with performers getting incredibly warm on stage: *"All the energy that would have gone into your facial expression, you're trying to express with your body, so you are using a lot of energy. When you're looking in some of the commedia mask performances, they are extraordinary* *and very acrobatic. The mask itself will come into quite a lot of wetting and drying out. A lot of the time the mask will need to be re-made."*

Simultaneously, although sweat is understood to be detrimental to the longevity of the mask, participant JD argued that when considering the character of the original commedia dell'arte leather, sweat, to some extent, has contributed to its infamous aged quality, colour and charm. Participant MC explained that different mask material properties contribute to the level of sweatiness felt under the mask. When talking about making papier-mache masks and papier-mache consistency preparation, he noted that "*If you put too much glue in it, it gets too rubbery or if it is hot, it tends to bend a lot if you sweat a lot inside it"*. Participant AK expressed that in his experience, the sensation of sweatiness when wearing the papier-mâché mask is more acceptable compared to the rubber mask.

Regarding sweat management techniques to improve comfort, some performers wear headbands over their foreheads to prevent sweat from getting into their eyes, which simultaneously helps to manage the issues related to the fit of the mask. Another suggested approach is to glue foam or felt pads on the inside of the mask around the forehead and cheekbone areas. The application of foam or felt pads has been previously discussed to achieve a better mask fit (section 4.2.1.1.3), but they can also be beneficial for enhancing ventilation. When attached to the inside of the mask, foam or felt pads prevent the mask from touching the face directly and, therefore, allow space for air circulation. Air movement dramatically improves body heat loss by evaporation (Choudhury *et* al., 2011).

Participant AK added that the points of contact where the foam touches the face get very hot and sweaty. Removing direct face to mask contact allows the pads to soak up the sweat, which minimises the amount of sweat absorbed by the main body of the mask. Participant JD said that foam pads could be changed when they become too sweaty, so it is better to reduce the amount of surface in direct contact with the face and the parts of the mask made from not replaceable material. These pads can be removed and exchanged for new ones as soon as they become soiled. Other participants added that foam or felt pads also help prevent skin irritation, softening the surface of the mask and absorbing the pressure in the areas of contact points between the skin and the mask. However, in circumstances when the mask is designed to cover the whole head, airflow inside the mask is very limited.

4.2.1.2.2 Smell

In the clothing industry, odour management is related to the fabric's ability to release sweat quickly before bacteria can begin to grow. Perspiration itself has no odour, the biotransformation of non-odorous compounds causes most odours to emerge from the human body by specific microorganisms or due to extended dampness. These odorants can transfer to the material through water-based media, such as sweat, where the material's hydrophilic nature can affect odour sorption (McQueen and Vaezafshar, 2020). The greater the MVTR (see section 4.2.1.2.1), the less likely the fabric will absorb and retain odour, causing wetness. Studies have shown that fibre type can also influence bacterial deposition and growth. Natural fibres such as wool, cotton, linen or silk are perceived to have lower undesirable odour characteristics than synthetic fibres such as polyester and nylon. (McQueen and Vaezafshar, 2020).

Participant DK emphasised smell to be one of the critical considerations when assessing mask comfort. He explained that one method of odour management in the mask is sealing it with PVA glue or varnish. Participant DK who mainly uses neoprene latex for mask-making, explained: *“I have to seal the mask with primer and sealers, otherwise neoprene would absorb the moisture, which turns neoprene milky white/yellow colour, and it starts to smell. To seal it, I use regular spray primer, and then I put two coats of paint”.*

Participant MC added that the mask needs to be cleaned and the excess sweat needs to be removed each time, otherwise it will begin to smell: *“You have to clean the mask to wipe it after you’ve used it to remove some of the excesses, otherwise it is like a shoe, the mask will begin to smell. Sometimes it is about disinfecting it with a little spray”.* Participant JD noted that “*It gets pretty awful pretty quickly, and you have to keep replacing that inner lining of the mask, which is possible, but my thing with latex is that you can wipe it down pretty quickly all you need to do is wipe it down with antibacterial wipes, and it's clean, it's got sweat off”*. It can be understood that the methods used to decrease the sensation of unpleasant odour are directly linked with minimising the impact of sweat on the mask, as described in section 4.2.1.2.1 as well as minimising the direct contact between sweat and the mask.

Previous textile research revealed that using fabrics with high MVTR allows sweat to evaporate from the body and the main two effective approaches to unpleasant odour control management include applying antimicrobials to the textile and integrating odour adsorbents within the textile structure. Recommended antimicrobial agents to incorporate in a material include silver, polyhexamethylene biguanides (PHMB), and quaternary ammonium compounds (QAC). There are three most common odour-control technologies for odorant adsorption, including activated carbon, zeolites, and cyclodextrins (McQueen and Vaezafshar, 2020). Conversely, fabrics that trap the moisture in the fabric and on the skin make the body odour worse.

Sections 4.2.1.2, 4.2.1.2.1 and 4.2.1.2.2 investigated factorial connections between material breathability and aspects related to perceived comfort. It can be understood that although material breathability is a crucial mechanism in sweat management alongside preventing odour retention, it is not a function that can be readily applied in mask-making. One condition for ensuring the durability of the mask lies in providing material water resistance. The most common method of waterproofing the mask recommended by interviewed mask makers is to coat the inside layer of the mask using PVA glue or varnish, which effectively closes the pores of the material or completely seals it creating an impermeable layer. This inner protective layer also prevents material odour retention as the sweat molecules carrying unpleasant odours cannot enter the material, which then, as suggested by the participants, can be wiped away using antibacterial wipes. To address the performer-related sweat issues, the participants recommend applying foam or felt pads that work to raise the mask off the face, allowing airflow and cooling the body off through ventilation. Although the described process displays counterproductivity delivering an effective sweat management system, a vital decision-making condition for theatre mask-making is to adhere to time, budget and material availability constraints.

4.2.1.3 Weight

Participant AK expressed that the mask maker needs to understand how the masked character needs to be performed. He explained that: *“Sometimes mask makers are removed from mask performances and that tends to be very ineffective, if a mask maker builds a very elaborate mask, but does not understand the performer’s needs for performance execution,* *effectively the mask might be just too heavy or unwieldly, the balance or the visibility might be off, limiting the mask performer in what he or she can do".*

The mask makers should maintain a practical balance between producing a mask that is visually exciting and evocative but also wearable. The performer needs to be able to move freely and trust that the mask is going to stay in place. The importance of headwear weight comfort has been highlighted in research on motorbike helmet wearability, which revealed that the most common causes for people not wearing a helmet during motorcycle rides were the heavy weight of the helmet (77%), increased body temperature (71.4%), neck strain (69.4%), claustrophobic sensation (67.7%), restricted head and neck movements (59.6%) (Faryabi et al., 2014).

Participant SB explained that the size of the mask proportionally impacts its weight, as does the type of material used. Participant AK noted that "*For example, wood can be very durable, but it is very heavy*" which suggests a direct link between the weight of the material or the amount of it used and the durability of the produced mask. Participant DK ranked the materials from his experience in mask making based on their weight: "*The heaviest would probably be wood, then neoprene, then leather and then papier-mache*". Even though papier-mache is considered lightweight, its weight can add up very quickly when layering to build features. To keep weight down, various kinds of foam products can be used as substitutes.

4.2.1.4 Tactility

When considering the feel of the mask, the makers expressed that leather is superior in providing a nice feel and texture and likened the sensation of its handle to that of human skin. However, participant JD described the experience of having leather that is soaked with one's sweat next to the face as horrible. *"I've used chamois leather or fabrics that are somewhat breathable for the inside lining of the mask, the problem is that sweat soaks into that material and within a few weeks of wearing it, the mask gets really horrible and "manky" and you just don't want to wear it"*. Participant JD further added that his preferred solution is to minimise the amount of material in direct contact with the face to reduce sweat saturation over time, he does this by adding foam or felt pads in strategic places.

Previous research analysis on comfort and discomfort in skin product interactions revealed the significance caused by skin friction sensation, which is dependent on two components: deformation of the skin during the impact of contact and adhesion between the skin and surface (Vilhena and Ramalho, 2016). According to Adams et al. (2007), contact is considered to be the main contributing factor to the friction between human skin and the material, whereas skin deformation processes are less relevant in comparison. However, ancillary conditions of contact, such as the presence of moisture on the skin, have a significant influence on friction behaviour. According to research, dry skin demonstrated fairly low coefficients of friction, while moist or damp skin showed considerably greater coefficients of friction (Vilhena and Ramalho, 2016). Some authors have stated that materials with the lowest friction coefficient have a greater hydrophilic tendency (Vilhena and Ramalho, 2016). Perception of pleasant sensation in textiles is highly influenced by surface texture (it can be measured by Kawabata Evaluation System - KES), the higher surface texture and the coarseness of the fabric, the lower sensation of pleasantness was observed. In wet conditions, the sensation of fabrics was perceived to be more texturized, which showed reduced pleasantness. Gwosdow et al. (1986) specified that fabrics felt more textured as skin dampness rose above 20% (Raccuglia et al. 2016).

Previous studies investigating different cues to wetness perception found significant differences between static and dynamic contact with fabric (Tiest et al. 2012). Static interactions with wet fabric showed that the perceived wetness cues were due to thermal difference and fabric pressure on the skin. When comparing the perception of wetness between lighter and heavier fabrics with the same water content, the latter were found to instigate higher wetness perception responses (Raccuglia et al. 2016). Stickiness, which was found to provide a sizeable contribution to the total perception of wetness, was not available in the static case of fabric-to-skin interactions, only in mechanical ones (Tiest et al. 2012).

Interviewed mask makers highlighted the practice of adding foam or felt pads to the interior of the mask to create necessary friction between the face and the mask to ensure the stability and security of attachment to the face. Following previous research on comfort and discomfort in skin product interactions and the data revealed by mask makers, it can be understood that mask-to-face interaction is largely static, achieved by creating adherence using strategically placed foam or felt pads (see section 4.2.1.1.3). Participant RD described the surface texture of foam and felt pads as “grippy”, which indicates intentionality in choosing rough and textured material surfaces to interact with the face of the performer. When sweat is present on the performer’s face, the friction between the contact points of the mask and the face intensifies and escalates the sensation of roughness which is also related to discomfort. As noted in section 4.2.1.2.1, the points of contact where the foam touches the face get very hot and sweaty.

According to research, wetness perception instigates tactile and thermal discomfort (Raccuglia et al., 2018). It has been indicated by the mask makers that if hydrophilic or breathable materials are used for the inside of the mask the sensation of pleasantness and comfort is reduced due to the mask becoming unhygienic and smelly (see section 4.2.1.2.2). Remarkably, the mask makers did not convey the notion of unpleasantness related to the sensation of wetness due to face contact with the wet material inside the mask. The experienced discomfort was related to the thermal temperature increase, condensation and sweat on the performer’s face and the sensation of unpleasantness related to sweat soiling the inside of the mask over a period of time.

Although mask makers indicated traditionally linked fondness for natural materials with regards to “the feel of the mask”, participant DK reflected that even though papier-mache is also made using natural materials, it does not feel as nice as leather. Although paper is made from wood, it is known to be a man-made material rather than natural; however, some mask makers considered paper and some resins to be natural materials since they are made from plant-based organic compounds. In section 4.2.1.2.1, participant MC conveyed that the excess quantity of glue adds rubbery quality to the mask, which suggests the previously considered natural material property of paper is removed from the mask. Furthermore, participant MC expressed that using plastic in mask making is a bit of a ‘cop out’, “I think it has its place, but it is a dead material, it is not a living material, and to have plastic on your face is a peculiar experience”. However, the notion of plastic not being a “living material” juxtaposes the practice of “sealing” the natural materials during the process of mask making.

4.2.1.5 Temperature

Humans are homeothermic beings who generate and maintain their internal temperature within a relatively narrow range. Heat exchange with the environment depends on individual metabolic rate and physical activity. The excess of the internal temperature becomes waste and is dissipated through the skin. Heat transfer into the environment is depends on activity, surface area and ambient conditions. The heat can be released through conduction, convection and direct radiation from the skin (Riversong, 2011). Research has shown that the head area has a very high metabolic activity which is crucial for body temperature reduction, particularly, when the rest of the body is obstructed to disperse the heat in some way (James et al., 1984). Mask makers expressed that it feels very hot wearing and performing in a mask. The level of heat felt by the performer will vary depending on the environment, the physical exertion of the performance as well as the mask type, for example, with a full-head mask, there will be very little airflow going in and out of the mask. The type of material used for the head covering will also affect how hot it will feel when wearing a mask, for instance, fur would make it hotter, whereas millinery net or buckram would allow some ventilation to take place. Research on heat retention mitigation associated with wearing a protective face mask indicated that breathing through the nose could result in lower heat and humidity accumulation within the microclimate of the mask which could help to cool down the brain structures more effectively as well. The research suggests that optimal material breathability could lead to the reduction dead space humidity levels within the mask and thus improve comfort (Roberge, 2011).

A study on warmth sensitivity evaluated the temperatures among six different facial regions in thermoneutral, warm and exercise conditions (forehead, nose, cheekbone, upper lip, cheek and chin). The study showed that the forehead area has the highest temperatures at all three conditions. These findings were related to the forehead's closeness to the brain to facilitate the regulation of brain temperature. The lowest temperature values were located in the nose area under thermoneutral conditions and the chin area during heightened temperature conditions (Kim et al., 2019). These findings are significant as theatrical masks (except for the domino mask, which disguises only the eye area) cover the forehead (Knight, 2004).

4.2.1.6 Attitude

According to Copeau, the first Western practitioner to use masks in training actors: "The actor who performs under a mask, receives from this papier-mâché object the reality of his part. He is controlled by it and has to obey it unreservedly" (Knight, 2004). The mask makers noted that the performer's attitude is paramount when it comes to comfort. Participant AK said that things like mask breathability are an issue, it all depends on the individual "*wearing a mask is never comfortable, there is no such thing as a comfortable mask*". Participant SB added that on occasions when it is impossible to cast each face, performers simply have to cope with the imperfectly fitting mask as they have to wear them only for a short period of time, "*most performers just cope with most things, as long as you give them that 'TLC'."* However, it is essential to understand that people have different tolerance levels on how long they can wear a mask.

4.2.2 Material properties

Table 5 demonstrates the topics comprising the material properties' theme. The discussion about mask material properties had a significant overlap with information already revealed in section 4.1.1 on material factors influencing mask comfort in. The main purpose of the material properties topic was to extricate and record as much detailed information on material properties that mask makers had experience working with as possible. Table 6 shows the list of mask-making materials which are evaluated based on shape retention, durability, flexibility, porosity, weight and resonance.

Factors	**Number of participants**	**References**
○ Material Properties	1	1
○ Shape	6	10
• Thickness	1	3
• Durability	8	29
○ Water resistance	6	11

○ Flexibility	4	6
○ Porosity	1	1
○ Resonance	1	1
○ Weight	4	4

Table 5 Material properties theme and topics

4.2.2.1 Material properties

Properties / **Materials**	**Shape retention**	**Durability**	**Water resistance**	**Flexibility**	**Porosity**	**Weight**	**Resonance**
Latex	Good shape retention when right thickness, flexible	Durable when has right thickness	Water resistant	Good flexibility	Somewhat porous	Heavy if thick	NA
Leather	Needs to be thick enough to hold its shape	Durable	Not water resistant unless sealed	Has some flexibility	Porous	Light	NA
Neoprene latex	Good shape retention	Very durable	Not water resistant unless sealed	Some flexibility	NA	Somewhat heavy	NA
Papier-mâché	Needs to be thick enough to hold its shape	Somewhat durable	Not water resistant unless sealed	Some flexibility	Not porous	Light	NA

Plastazote	Good shape retention	Very durable	Water resistant	Good flexibility	Not porous	Light	NA
Plaster bandage with resin	Good shape retention	Very durable	Water resistant	Some flexibility	Not porous	NA	NA
Silicon	Good shape retention, flexible	Durable	Water resistant	Good flexibility	Not porous	Heavy	NA
Vacuum formed plastic	Good shape retention	Somewhat durable, can crack	Water resistant	Some flexibility	Not porous	Light	NA
Varaform	Gets heat activated, loses shape if hot	Somewhat durable, can crack	Water resistant	Some flexibility	Porous	Light	NA
Wood	Good shape retention, thick	Durable, but brittle	Not water resistant unless sealed	Low flexibility, brittle	Porous	Heavy	Allows for resonance
Worbla	Gets heat activated, loses shape if hot	Durable, but brittle	Water resistant	Low flexibility, brittle	NA	Somewhat heavy	NA

Table 6 Material properties

4.2.3 Manufacturing aspects of mask-making

Table 7 gives an overview of the main topics within the manufacturing aspects of mask-making theme. Four main topics related to mask manufacturing stood out during the interview analysis: creative expression, economic considerations, experience and safety.

Factors	Number of participants	References

○ Manufacturing aspects of mask-making		
○ Creative expression	5	8
• Detail	5	10
• Paint	2	3
○ Economic considerations	5	13
• Cost	5	7
• Speed	6	12
○ Experience	0	0
• Knowledge	3	4
• Making experience	6	9
• Performing	7	8
• Skills	6	7
○ Safety	1	1
• Hygiene	4	5

Table 7 Manufacturing aspects of mask-making

4.2.3.1 Creative expression

Material selection for contemporary mask-making entails a variety of considerations. According to participants SB and MC, the bottom line is to choose materials that are suitable for the performance, reflect the character and the director's vision and be able to adapt to situations, a sentiment that is consistent with Knight's (2004) observations expressed in section 4.2.1.1.5. Working with different materials requires specialised skills and methods, specialist tools and equipment. The level of skill possessed by the mask-maker will have a direct impact on his or her capacity for creative expression.

Participant MC expressed the need for experimentation and growth, taking opportunities to work with different materials permits having interesting challenges "Unless you experiment and progress as an artist, you get a bit bored". Justifiably, most interviewed mask makers appeared to prefer the materials and the methods that they had the most experience working with and could utilise their relevant skills in the most creative way. Participant AK conveyed that his favourite part of mask-making process is sculpting clay moulds which he then covers with papier-mâché. He favours papier-mâché because it is a very affordable and easy-to-use material and allows achieving good detail and definition in the mask. Participant JD reiterated the satisfaction of working with clay moulds, but adapted this to make latex masks by first, making a positive clay mould and then creating a negative plaster cast. Participant JD explained his preference for working with latex was because of its speed and detail: "It cuts a lot of corners because I can do a really detailed sculpt with lots of texture from clay". Similarly, participant RD confirmed the importance of speed when working with the material from the artistic point of view: *"Working with Worbla is very interesting, this material is revealing itself more and more to me at the moment, it's very quick. If you have a slightly mercurial mind, which I have, being able to work quickly and make happy accidents is something that always interested me. It's all very well to have a technique, but you have to allow to push that technique to the places where it goes wrong and then you learn other things."*

Participant RD reiterated his appreciation for efficient mask-making methods, however, vacuum forming another fast and efficient mask-making process was not regarded particularly favourably among other mask makers. Participant MC noted that with vacuum forming "*you're just churning out hundreds and hundreds of the same mask*" and expressed a preference for working with materials that required more hands-on craft work. Participant VW added that she does not like plastic masks but admitted that this could be due to her not witnessing this material being used creatively in masks. Every participant expressed their appreciation of working with leather but noted that it is a time-consuming method requiring a high level of skills. Participant RD described the whole process to be very engaging and enjoyable in a very sensuous way. He gave a detailed account of selecting the timber for mould making, soaking and working the leather, using the tools and noticing the timing of the changes in the leather during the process.

"When you first put the leather in the water to soak, you get this kind of fizz in the water and then the leather starts having this puffy-ish quality and you use your hands to massage it onto

the mould. You have to use brass tacks (because they don't corrode) to tack the leather to the mould to make sure the leather is sitting right. Then you use a hammer, I use one I made out of boxwood. Leather is a bit like felt, it has lots of hairs going in different directions, the process of wetting the leather lifts all those hairs up and then what you're doing with your hammer you are reconstituting those hairs into the position that fits onto the mould, you compact the leather into a shape. As you do that, the leather begins to dry out, the mould itself begins to take the water out of it and your body heat as you're working on it, you're pushing the water out of it".

This detailed description of working with the material demonstrates an embodied understanding of the material which is structured by connecting various patterns that emerge throughout the sensorimotor activity obtained through material manipulation and participation in every part of the making process. The gained intimacy with the material along with the engagement of the senses has noticeably contributed to the satisfaction of the leather mask-making process. Such a relationship with the materials could be linked with the other participants' descriptions of relishing the process of engaging in the craft aspects of mask making such as sculpting the mould and being able to work quickly having the integral knowledge of the material behaviour.

4.2.3.1.1 Ability to achieve detailed work

Table 8 compared the ability to achieve detail accuracy in masks when working with different materials. Mask makers named several methods of achieving detail in mask making, these included sculpting and scrimming (covering the rough surface with another material, such as fabric, which can create a more interesting texture surface). Latex casting was notably a particularly suitable method to achieve precise details in masks. Varaform was noted to be light and easy to work with, but in comparison to papier-mâché and latex, the detail work was significantly less pronounced.

Material	**Detail accuracy**
Latex	Very accurate details
Neoprene latex	Very accurate details

Papier-mâché	Good amount of detail
Leather	Good amount of detail
Wood	Good amount of detail
Vacuum formed plastic	Cannot get hard edges
Varaform	Not very accurate details

Table 8 Material capacity for detail

4.2.3.2 Economic considerations

Mask makers agreed that economic considerations are prioritised when choosing their materials and methods. They expressed that there is a tendency to stick to one thing as it creates a routine of knowing how much the materials are going to cost, the intensity of labour and the timescale. Durability was also mentioned as an economic consideration. Mask makers expressed that materials, such as plastic were preferable for performances when large quantities of identical masks were required. Masks made from high quality leather as well as silicone masks were noted to be expensive to make and therefore would have to be sold for a high price. Working with materials that produce quick results is, understandably, sustainable from a business point of view. Some materials such as papier-mâché sculpting or latex casting lend themselves to fairly quick mask-making that encompasses detailed work. Wood and leather mask-making are considered to be slow practices that require a completely different skillset. Therefore, diversifying in terms of using a variety or cheaper materials for mask-making could be more economically viable so as not to limit the pool of potential buyers. When asked if 3D scanners would be considered in theatre mask making, some respondents expressed that such technology although useful would not be expended for theatre purposes.

4.2.3.3 Experience

Mask makers unanimously felt that the research on mask making is lacking and that the only way of learning is through contacting individual mask makers and talking to them about their practice. Respondent SP expressed that "*Most of the information of making lives in people's heads. You very rarely have to write anything down*". The interviewed mask makers had been practicing mask-making in the industry for a different number of years, the shortest being 10 years, the longest - 40 years. Each interviewed mask maker came to the discipline from very diverse directions, however, most of them started as the mask performers themselves.

Respondent AK noted that if a mask maker is removed from mask performances that tends to be very ineffective, they might create a beautiful mask that is impossible to move when wearing it. Both respondents DK and MC originally were drama teachers who had to help make masks and props for the student performances, eventually they focussed on pursuing mask-making solely. In addition to that, respondent MC also worked as a drama psychotherapist where he used masks as a type of educational therapeutic tool.

4.2.3.4 Safety

When talking about mask-related safety concerns, mask makers emphasised the importance of addressing breathing, hygiene and potential allergy concerns. The significance for ensuring unobstructive breathing when wearing a mask has already been discussed in section 4.2.1.1.5. When considering mask hygiene, respondents were found to address it in a similar manner – by using antibacterial wipes, sprays or sometimes by replacing the interior lining of the mask. In terms of addressing potential allergy concerns, mask makers did this through checking in with the performers for known allergies before starting a mask and selecting the materials for it accordingly.

4.2.4 Industry

Table 9 shows has the main categories containing references on mask-making industry factors. These are grouped into film, indoor theatre, outdoor theatre and performing in a mask.

Factors	**Number of participants**	**References**
○ Industry	5	12
○ Film	3	3
○ Indoor theatre	6	10
○ Outdoor theatre	1	3
○ Performing in a mask	8	29

Table 9 Mask making industry factors

4.2.4.1 Masked theatre

There has been a considerable decline in masked theatre over the past years, respondent RD expressed that the causes were primarily financial: "There is less masked theatre these days to a degree, partially because there aren't that many mask makers, there's less money around. I think there's a bigger question of theatre, in general, suffering from the onslaughts of the box sets." Respondent MC explained that gradual shift in masked theatre landscape was also instigated by changing management attitudes of theatre companies: "*There was a lot of very powerful, warm, funny masked theatre performances in years gone by, which I don't see as much of these days. Threstle theatre company was a powerful theatre company. However, what happened was that people who started the company and were working there for maybe thirty years, got tired and the people who took over just decided to get rid of the mask. For them it seemed like masks were getting in the way of the performance."* Respondent MC explained that the nature of masked theatre is very demanding and if the director doesn't really understand how to make the mask work, it can become like a nuisance to the performance. He added that: *"A director really needs to push the actors to take on the mask."*

When talking about the lack of masked theatre, respondent AK noted that: "I think in this country there's only two or three theatre companies that do exclusively masked performances. There's almost none. I probably could think of less than 10 companies around the world that do exclusively masked performances. However, the use of one or two masked characters in theatre performance is not uncommon." *Mask makers expressed their belief that masks have a function in theatre that is vital.* Respondent MT explained: "*I still use masks a lot for training. In comedy, and it is not about what you say, but about how you move and what you do, so rather than a mask being restrictive, it can be wonderfully liberating. People from different countries, do not necessarily find verbal performances funny due to differences in culture or different rhythm language rhythm and yet, the non-verbal comedy shows, can be very funny because they transcend the cultures and language barriers and contexts. For foreign audiences, for example, it is harder to connect to the actor through verbal means, but the physicality can bring that connection., it can transcend the specific culture."*

4.2.4.2 Film

According to mask makers, film industry has also contributed to changes in masked theatre. Respondent AK noted that: *"A lot of theatre has moved towards naturalism, the audiences are too used to watching television and special effects used on camera have gone to a place where they are trying to be as realistic as possible, even if it's an imaginary creature or whatever, they use very effective computer-generated effects".* Respondent JD echoed the sentiments, saying that on film sets, prosthetics and make-up artists try to hide the fact that the actor is wearing a mask, in masked theatre, the power of the mask allows performers *"to create something extreme, something that a regular actor couldn't quite do".* In theatre, it is easier to get away with quite a lot of imperfections due to viewing distances being greater, while on camera, every detail would be obvious.

4.2.4.3 Outdoor theatre

Historically, masks were very suitable to perform outside - Greek and Roman masks were designed for big outdoor auditoriums, with masks assisting to enhance auditory and visual cues for the characters (see section 3.2.8). Lately, masked theatre has demonstrated a tendency to return to its outdoor roots. Respondent MT explained that *"Indoor theatre requires a lot of funding from the arts council, it doesn't survive without it, whereas with the outdoor theatre we can perform at outdoor festivals, which are profitable, you can get big crowds, you can perform to more than a thousand people. You can't fit more than a thousand people in a theatre."* Mask makers identified weather conditions to be the biggest concern with outdoor theatre, particularly in northern Europe, where it rains regularly even during the summer months. Outdoor conditions tend to be much harsher to masks and props, according to respondent MT, items used for outdoor theatre do not have dry permanent storing space, things get rained on, moved and bashed around a lot. For these reasons, outdoor theatre masks need to be as water resistant and durable as possible.

4.2.4.4 Performing in a mask

Mask makers explained that masked performance is very embodied and could be compared to an acrobatic performance or a contemporary dance due to the extent of physical body engagement required. Respondent RD explained that: *"In Jacques Lecoq school, they had the* *phrase that when you're wearing the mask the head becomes the eyes, body becomes the face. All the energy that would have gone into your facial expression, you're trying to express with your body, so you are using a lot of energy".* Since the mask prevents actors from conveying emotions via their facial expressions, they must be able to express them using their body. Respondent MC stated that: *"The actors need to act differently. It must appear that the mask is acting rather than the actor. The actor has to almost get himself out of the way. It is a very hard work, very challenging. Not every actor wants to act in this way. It's a physical theatre."*

4.3 Evaluation

Material selection for mask-making entailed a variety of considerations. This chapter explored mask-making considerations including comfort, manufacturing aspects, experience and context. The main seven comfort factors included fit, material breathability, breathing, weight, feel, temperature and attitude towards comfort (see Table 4). Mask fit was the area that was highlighted the most with mask makers indicating the key methods to achieve the best fit and the rationales behind it. Interview analysis suggested that in addition to making an accurate mask mould and following the correct measurements of the facial features, factors such as adding foam or felt pads and correct attachment methods in accordance with the weight of the mask are significant when considering the complexity of the mask fit. The accuracy of the mask fit was shown to affect the performer's visibility and the ability to breathe through the mask in a positive or negative way. Mask weight was considered to be an important factor contributing to mask comfort as well. Participants highlighted the necessity for maintaining a practical balance between producing a mask that is visually exciting but also wearable. Mask makers identified that the size and durability of the mask may proportionally impact its weight.

The need to address breathing correctly in full face masks was identified as the closed environment can create a breathing chamber where it becomes very easy for the performer to hyperventilate. The mechanics inside the full-face mask mean that the oxygen is inhaled through the gaps around the mask, mostly around the neck area.

Material breathability was the second most discussed comfort factor. Although material breathability was recognised as an issue, when questioned about the effectiveness of using breathable materials to improve comfort, most mask makers expressed their doubts as this property was considered to be incompatible with the requirement for mask durability, shape retention and currently practiced hygiene solutions. Current mask-making practices focussed on addressing sweat-related mask damage by adding water-resistance property and sealing the pores of the material, thus eliminating its potential for breathability. What is more, the mask makers admitted that breathability comfort was not prioritised due to budget and time restraints. Existing sweat management techniques to improve comfort included the application of foam or felt pads and headbands to soak up the sweat and prevent the mask from touching the face directly allowing space for air circulation. Research on material properties has shown that using breathable fabrics with high MVTR allows sweat to evaporate from the body. The main two effective approaches to unpleasant odour control management in the textile industry include applying antimicrobials to the textile and incorporating odour adsorbents within the textile. However, the existing methods used to provide hygiene and decrease the sensation of unpleasant odour in masks are directly linked with minimising the impact of sweat on the mask, preventing sweat penetration and removing the excess sweat from the water-resistant inner surface of the mask using antibacterial wipes.

When considering the tactility of the mask, participants expressed that leather is superior in providing a nice feel and texture and likened the sensation of its handle to that of human skin. However, to avoid discomfort related to sweat saturation within the mask interior, the preferred solution was to minimise the amount of material in direct contact with the face by adding foam or felt pads in strategic places. It has been indicated by the mask makers that if hydrophilic or breathable materials are used for the inside of the mask the sensation of pleasantness and comfort is reduced due to the mask becoming unhygienic and smelly. The conveyed notion of unpleasantness was not related to the sensation of wetness caused by the face to wet inner material of the mask. The experienced discomfort was related to the thermal temperature increase, condensation and sweat on the performer’s face and the sensation of unpleasantness related to sweat soiling the inside of the mask over a period of time.

Mask makers expressed that it feels very hot wearing and performing in a mask. The level of heat felt by the performer will vary depending on the environment, the physical exertion of the performance as well as the mask type, for example, with a full-head mask, there will be very little airflow going in and out of the mask. Previous research on protective face mask performance indicated that material breathability can lead to the lowering of dead space humidity levels that impact comfort and tolerance (Roberge, 2011). A study that investigated warmth sensitivity across six different facial regions in thermoneutral, warm and exercise conditions, showed that the forehead area demonstrated the highest temperatures at all three conditions (Kim et al., 2019). These findings are significant as theatrical masks (with the exception of the domino mask, which disguises only the eye area) cover the forehead (Knight, 2004).

The last factor was related to the performer's attitude towards comfort. Participants expressed the sentiment that wearing a mask should not be expected to be a comfortable experience and that most performers "just cope with most things" as long as they are looked after. The overall analysis revealed contradictory attitudes towards material breathability. While material breathability appears to have a potentially positive effect on performer's sweat, temperature and smell management as well as pleasant tactility, there is a lack of research and experimentation working with breathable materials in mask prototyping and addressing durability concerns. According to the majority of the participants, the bottom line in mask-making is to choose materials that are suitable for the performance, reflect the character and the director's vision and be able to adapt to situations.

Mask makers discussed their preferences for working with certain materials considering the balance between the economic considerations, the process preference, the skill set and the ability to achieve desired design details. The changes in masked theatre industry have also been highlighted as the indoor masked theatre was seeing to become more outdoor focused. These changes presented even greater requirements for masks to be durable and waterproof.

Following the key themes discussed by the mask makers the main findings from the interviews were summarised as follows:

- Ensuing the previous research on comfort and discomfort in skin product interactions and the data revealed by mask makers, it can be understood that mask-to-face interaction is largely static, achieved by creating adherence using strategically placed foam or felt pads on stationary parts of the face. Avoiding direct mask-to-face contact not only solves fit issues but also provides better ventilation and airflow and improves capacity for breathing (since the oxygen mainly is inhaled through the gaps between the edges of the mask and the face). The lack of the direct contact between the body of the mask and the face, reduces the amount of sweat getting inside the material, thus reducing the amount of bad odour trapped inside the material. It was also understood that the sensation of unpleasantness with regards to tactility is higher with larger adhesion areas with the material, therefore, raising the mask of the face also helps to reduce the number of contact points between the face and the mask.

- Exploring working with porous hydrophobic materials in mask-making could be innovative and beneficial for mask makers as using hydrophobic materials would alleviate durability concerns related to moisture damage. Sweat would not be able to wet and penetrate the material due to its hydrophobic nature, however, water vapour could evaporate through the pores, facilitating a way to transport the moisture away from the face. The issue with using leather in mask-making is that it is very hydrophilic, absorbent and becomes damaged when too much moisture gets inside. Open pore sealing should be explored further in mask-making to address the need for protection from moisture as well as facilitating water vapour transfer to take place. Currently, the principal methods for hygiene maintenance in masks involves their disinfection with antibacterial wipes or sprays. The capacity of adding antimicrobial particles to the material structure to reduce the bad odour occurrence could also be further explored.

- Mask makers expressed their interest to physically engage with the materials when making masks. For example, the gained intimacy with the material along with the engagement of the senses has noticeably contributed to the satisfaction of the leather mask-making process. Such a relationship with the materials could be linked with the other participants' descriptions of relishing the process of engaging in the craft aspects of mask making such as sculpting the mould and being able to work quickly having the integral knowledge of the material behaviour. Working with materials found in nature was perceived more favourably even after having to alter (e.g. seal them) using man-made compounds. Some participants expressed their reservations about working with materials such as plastic that as they had not witnessed them used in a creative way in masks. Using new manmade, technologically advanced manmade materials could be made more attractive if the hands-on approach of material manipulation was introduced as a possibility.

4.4 Conclusion

The chapter discussed the topics and key themes uncovered from the interviews with the mask makers evaluating the factors influencing comfort mask comfort, material properties, manufacturing considerations as well as the specifics and changes within the masked theatre industry. The following chapter will discuss how the electrospinning technology could be used to address two key findings of this chapter: adapt a new breathable, hydrophobic manmade material that could potentially be used as an alternative in mask-making; and introduce a possibility of working with technologically advanced manmade materials using a hands-on approach. The chapter will discuss the prototyping journey and the decisions made along the way.

5. Prototype production

5.1 Introduction

This chapter will explain the process of prototyping and the decision-making involved in producing 3D electrospun PU samples. The initial prototyping process will focus on the electrospinning process and experimentation with 3D collectors. The chapter will examine the methods used to achieve 3D forms using 2D sheets through thermal methods without needing to compromise the breathability of the electrospun PU fabric.

5.2 Introduction of new technologies in crafts development

Various sectors across the creative industries have always been motivated to adopt new technological innovations in product design and development (Leal, 2018). However, the transition to adopting new technology into existing craft practices may not be very straightforward; difficulties tend to occur when experiencing steep learning curves, expensive equipment or discouraging feedback from colleagues (Ricci, 2008). Throughout the twentieth and twenty-first centuries, craft activities have been experiencing a steady decline propelled by ever-increasing market demands and the inability to match competitive prices that large-scale mechanised productions were capable to offer. The perception of basic needs has evolved with the ever-present focus on prioritising and upgrading convenience and consumerism. Individuals are no longer encouraged to creatively come up with their own solutions to problems as everything can be replaced by purchasing cheap, ready-made objects. This development has led craftsmen to lose their ability to compete for power in the market and has created a complex and conflicting relationship between craft and technology. The threat of skill and craft cultural significance extinction has made craftspeople mistrustful of technology, which, conversely, does offer useful product development solutions that fit the demands of modern society (Alexandre et al., 2017). To some degree, keeping up with technology is necessary to preserve the craft, on the other hand, it is the traditional techniques themselves that should be considered the most tangible manifestation of intangible cultural heritage (Ich.unesco.org, 2000).

The introduction of computers into the design process has given way to prototyping in a virtual world, increasing the speed of the design process. However, these CAD tools are primarily based on form and function and fail to represent the materiality in design. In most programs, materials are epitomised through a library of skins or patterns, which makes this method of selecting materials fundamentally based on pure aesthetic motivations rather than because of the functional properties of these materials. Small imperfections derived from physical material manipulation may give rustic aesthetic qualities to the design and inspire the course of the creative process. Niedderer (2012) indicated that the 'learning by doing' process has a synergetic relationship between material, function and form. Physical engagement with the material in craft allows the development of sensory knowledge about the behaviour of the material (Adamson 2007; Ingold, 2013; Nimkulrat, 2012).

Existing literature does not place masks into a clearly defined craft category. During the interviewing process, it was noted that many mask makers share a background in sculpture, puppet making, and prop-making with skillsets that feature carving, casting, modelling, construction or assemblage. The variety of skills and materials used in mask-making suggest an open and adaptable nature of the activity. In the context of design practices, Vallgårda (Vallgårda, 2009) explains that materials such as wood, clay, textile and metal are often considered traditional materials due to their association with culture, long crafting tradition, specialized tools and hands-on techniques that have evolved over centuries. Manmade materials that have specific functionalities are devised by means of chemistry, physics, and engineering applications seeking to study and improve materials (e.g., plastic, fibreglass, electroluminescent film) (Vallgårda, 2009).

As already mentioned throughout the thesis, the researcher of this study had previous experience in creating textile related products, including upholstery items, theatrical costumes, millinery and shoes as well as some understanding of electrospinning technology, gained through researching it for her MSc in Advanced Textiles. The reoccurring process of reinstating the accumulated experience of the researcher was important to contextualise project planning and decision-making, which according to Groth and Mäkelä (2016) is governed by an accumulated embodied knowledge of the individual (Groth and Mäkelä, 2016). Accordingly, the viewpoint the researcher inherently adopted for this study is based on experience via past engagement with materials. The researcher's primary understanding of how to manipulate textiles into 3D forms was through assembling different pieces by stitching with the needle and thread and creating support by layering or introducing stiffening agents. Much of these textile manipulation processes were based on technical knowledge and understanding of textile fibre types and fabric structures. However, the skills were developed through tactile interactions with the fabric, which allowed the researcher to develop an instinctual ability to predict textile behaviour.

This study intends to bridge the gap between the use of new technology and craft thinking and skills in the mask-making field by developing and evaluating the application of new material for masks while engaging in both scientific and embodied cognition of its physical properties. Having already built some fundamental knowledge of electrospinning technology, process and applications during her MSc, the researcher selected this method for this research project due to its relative familiarity as well as awareness of already existing applications in medical PPE manufacture. Melt electrospinning could have been an alternative nano-fibre manufacturing method for this project. Melt electrospinning was seen as particularly attractive due to the absence of toxic solvents during the process, high production rates and its applicability to a large variety of polymers (Xue, 2019; Wei, 2018). On the other hand, research studies have shown that electrospun nano-fibres have demonstrated better breathability, which is particularly important for this study (Karabulut, 2020).

Electrospinning is a unique fibre-creation method that has not found its way into the mask-making field yet. However, this novel fibre production technology has the potential to produce a fabric with desirable functional properties such as material breathability, which would add a novel characteristic to mask-making with regard to the comfort of the performer. The advantage of the electrospinning set-up could be used to employ a location-specific application as well as the ability to produce a fabric that does not fray. Particles such as celite can be added to enhance the anti-slip property of the material, while particles such as silver can create antimicrobial properties (Goswami et al., 2016). These features would be advantageous in mask making as an alternative to latex or silicone products, increasing user comfort, helping to avoid potential allergies, as well as extending the life of the product. Introducing different coloured pigments during the solution-making stage could help to achieve the desired colour effect during manufacture.

The embodied understanding of the material is relational and dynamic, situated and organised around various behaviour repetitions which appear throughout the sensorimotor activity obtained through manipulating materials and built on the experience of previous failures and risks. Therefore, craft thinking can be applied to understanding the nature of the new material which can inform design decisions (Härkki et al., 2016). In contrast, a technical understanding of the new material can set new product standards. To build intimacy with the material, the researcher engaged in the process of the manufacture of the electrospun PU fabric itself. Participation in fabric manufacturing was beneficial in deepening the technical understanding of the fabrication process and allowed instigating mask development decision-making at the beginning of the raw material processing stage. Furthermore, direct access to the machinery allowed the researcher to produce samples autonomously and take control and responsibility for quality. This interaction with the technology was operative in minimising the feeling of disconnect that is the effect of the division of labour in the craft sector and establishing a better relationship between the technology, the product and the maker.

With that in mind, it was pertinent to evaluate the behaviour of the fabric and its application potential from the craftsperson's point of view. Yvonne Mouser, an artist, builder and designer whose work spans furniture design and fine art, explained that when defining craft and design, she thinks of them as overlapping rather than separate. She considers craft being more about "the how" of an object, the understanding of the material, technique and hand practice. The intimacy with the material guides the craft person in what he or she is trying to achieve. Design is more about "the what" or the idea of an object, how it will function or what it means (American Craft Council, 2020). The prototyping stage of this study was also primarily concerned with figuring out "the how" of using electrospun PU fabric in a 3D mask-making capacity.

5.3 Considerations for creating complex 3D structures

A mask by its definition does not have to be strictly a three-dimensional covering of the face. However, irrespective of the material used for theatrical mask making, the intention is to create face-covering structures that would adhere to the human head in a harmonious three-dimensional manner to create a seamless illusion of a new character. To understand how a mask can be moulded to follow the contours of the face or exaggerate them, it was necessary to consider the structure of a human head. The craniofacial region comprises several complex forms that create the overall facial shape.

The skull has two main parts the cranium and the mandible, the latter is the only moving element in the skull since this is where the lower jaw is located. The mandible is a particularly significant part of the skull when considering the type and the purpose of the mask that needs to be produced. Half-face masks are generally used when speaking is required, and full-face masks are created for silent parts of the performance. As already discussed in Chapter 4, section 4.2.1.1.3, foam or felt pads that are usually glued inside the mask need to be attached to the static parts of the skull, typically the cheekbones. The function of the foam and felt pads is to raise the mask off the face and create a narrow gap for airflow inside the mask, what is more, the pads absorb the pressure and decrease the friction between the mask and the face. Figure 23 depicts the bone structure of the skull. Facial bones include: the nasal bones; the temple (made up of temporal and sphenoid bones); the cheeks (consisting of zygomatic bones); the jaw – (comprising of the upper jaw area called maxilla, and the lower

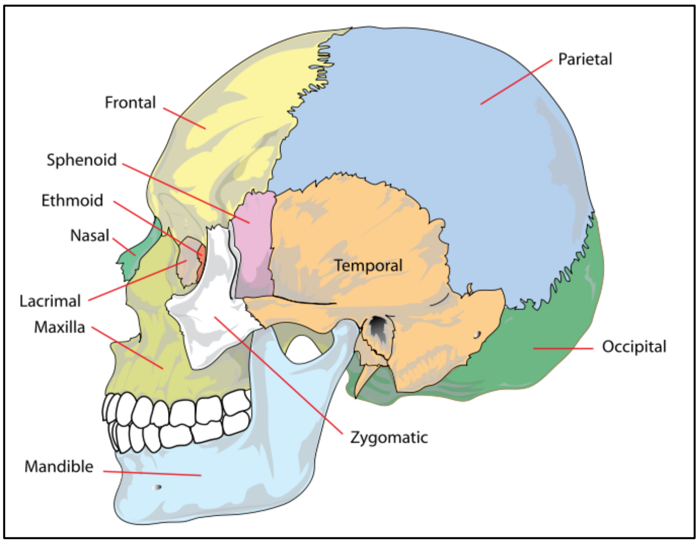


Figure 23 The bone structure of the human skull (H&MUA Team, 2012)

jaw -mandible); the eye socket – formed by the seven joined facial bones (H&MUA Team, 2012).

To create 3D shapes out of textile materials, two types of methods are commonly used - the physical-based method and the thermal-based method. The physical-based method includes pattern making, 3D knitting technique, crinoline technique, padding technique, and 3D printing. The thermal-based method uses heat to mould 2D fabric into a 3D form by stretching and compressing the fabric and bonding it to a thermoplastic material, such as fibre, powder, or film, and creating the new composite fabric with added properties (Yu et al., 2019).

The prototyping considerations in this study focussed on exploring the capacity of using electrospun PU fabric to create 3D structures. The surface curvature is an essential factor overseeing differential 3D structures. To create complex 3D structures, the curvature of the 2D sheets needs to be adjusted in a controlled way. To produce simple curved shapes, 2D flat sheets could be altered by simply bending or rolling. However, complex 3D forms that display spherical or hyperbolic geometries are characterised by double curvature that can, which can be achieved by subjecting the 2D sheets to in-plane distortions while simultaneously limiting material distortion (Callens and Zadpoor, 2018).

Human faces are comprised of complex geometries, with most facial features comprising of convex regions, with concave areas focused on the corners of the eyes, nose and mouth. The most outwards curved or convex areas correspond to the nose, eyebrows, lips and chin, while the most inwards curved - concave areas are found in inner eye corners, the sub-nasal region. The most extreme curve values (both concave and convex) are found on the central area of the face (Tsagkrasoulis et al., 2017). The existing mask-making methods address in-plane distortions through different means depending on the material used. Wood can be carved, and 2D paper structures can be altered by tearing them into small pieces that can be put together using papier-mâché techniques. Leather is very pliable by nature, but it can be subjected to further in-plane distortions by stretching it after it is soaked with water and then drying it (Li and Zaidi, 2004).

5.4. Exploring the electrospinning process and its capacity for mask making application

To investigate the design potential of using electrospinning in mask making, methods for applying it on 3D collectors were explored to establish knowledge and understanding of how they could be used to produce a fully functioning prototype mask. The intention was to create face-covering structures that would adhere to the human head in a harmonious three-dimensional manner to create a seamless illusion of a new character. The key concern when prototyping the mask was developing a method of altering the dimensions of 2D material into a 3D prototype without compromising the material properties (specifically breathability) of the electrospun PU fabric. Primary data was collected through experimenting and prototyping 3D collectors to achieve consistent and even electrospun PU fabric distribution over the 3D structures.

5.4.1. Preparing an electrospun PU fabric sample (2D sample)

The physical production of the initial sample allowed the researcher to engage and familiarise herself with the electrospun PU fabric manufacturing process. Additionally, the initial PU fabric sample was used to examine the produced fibre web porosity by scanning electron microscopy (SEM). The production of the sample initiated the applied section of the study and facilitated the acquisition of the embodied understanding of the electrospinning process and the physical behaviour of the produced PU fabric. While it is possible to imagine and visually present a design by drawing it or drafting it using CAD technologies it is a very different experience to visualise its formative behavioural properties and predict its propensity to physical manipulation. A thorough understanding of the material can be realised by 'tinkering with the material' – engaging in an explorative process of engaging with the material, making and re-evaluating until the final desired result is achieved (Parisi et al., 2017). Therefore, the subsequent decision-making process of 3D structure fabrication would benefit from following the theoretical understanding of the electrospinning manufacturing characteristics, as well as the gained embodied knowledge of the formative behavioural properties of the fabric. A 2D PU fabric sample was prepared by applying a standard electrospinning procedure using a flat, motionless aluminium foil sheet collector. The electrospinning process and the materials used were established through the literature (Goswami et al., 2016).

5.4.2 Materials

This section will list all the materials that were used throughout the sample production.

PU solution:

- Polyurethane Selectophore (PU) - purchased from Sigma Aldrich.
- N,N-Dimethylformamide (DMF) - purchased from Fischer Scientific.
- Tetrahydrofuran (THF) - purchased from Fischer Scientific.

Collector:

- Electroconductive paint - purchased from bareconductive.com.
- Aluminium foil – purchased from Wilco.
- Modelling 100% aluminium wire mesh - purchased from Fred Aldous craft supplies.

Structural support:

- Varaform, light - purchased from Flints Theatrical Chandlers.

Paint:

- Watercolour paint – purchased from Fred Aldous craft supplies.

5.4.3 Electrospinning process

A 10 wt% solution of Selectophore™ polyurethane was prepared using a 60:40 DMF: THF vol: vol (N,N-Dimethylformamide and Tetrahydrofuran) solvent ratio. 1g PU was dissolved in a 10ml of the DMF: THF solvent mixture. PU DMF/THF solution was poured into a 10ml glass syringe and positioned at 18cm distance from the tip of the needle and the grounded target. Other electrospinning parameters included: 2.0ml/h flow rate; 18kV voltage supply; temperature of 20°C ± 1; and relative humidity of 65% ± 5. All nanofibers were collected on a stationary electrically grounded aluminium foil 10x10cm square sheet. The aluminium foil collection plate was periodically rotated 90 degrees to ensure a more uniform fibre coverage.

To produce a 10x10cm square sheet of aluminium foil covered with electrospun PU fibres at roughly 0.22mm thickness, it took 21 hours of electrospinning and 40ml of PU solution. Figure 24 demonstrates the sample of electrospun PU fabric, and the picture on the left shows the structure and morphology of the electrospun PU fibre textile sample examined by scanning electron microscopy (SEM). The structure of the electrospun PU fibre web was magnified 2000x demonstrating the porous nature of the textile sample with the mean fibre diameter being 2µm which was measured using a ruler and calculated employing the provided scale of 10µm in SEM picture.

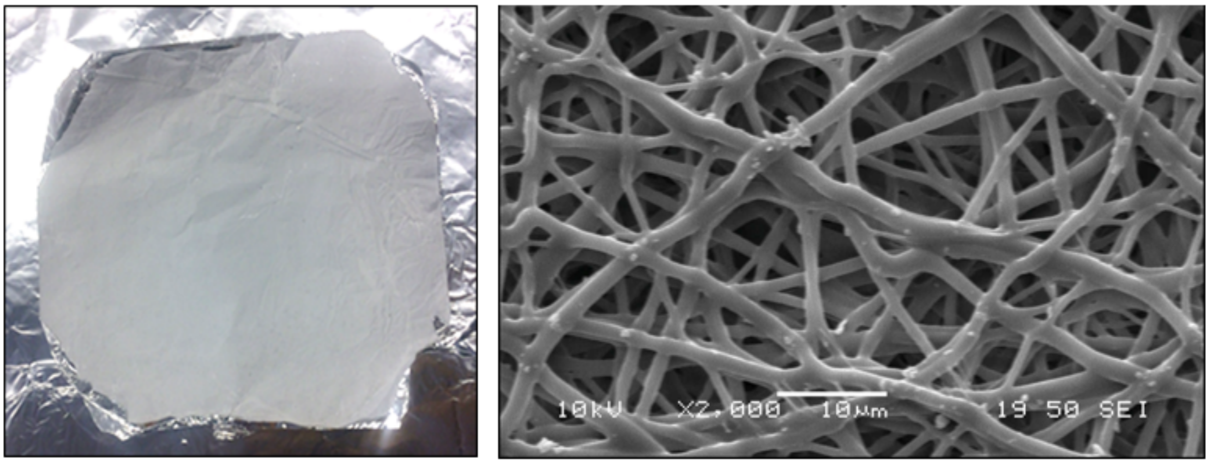


Figure 24 The image on the left shows the prepared 10x10cm square electrospun PU fabric sample. The picture on the rights is done using scanning electron microscopy (SEM)

5.4.4 Electrospun PU sample using a 3D collector

In this study, technology is understood from a pragmatic perspective – electrospinning can be seen as a tool, and its applicability is dynamic and reflexive as is devised throughout the process (Coyne, 1995). Dewey originated the concept of 'ends-in view' to portray his end-goal vision as a plan that guides the making of an artefact (Marshall, 2002). In this study, the 'ends in view' could be perceived as the capacity to create a 3D breathable structure from the electrospun PU fabric. The sample produced and described in section 5.4.3 using the standard process of electrospinning on a static flat sheet of aluminium foil collector, demonstrated a porous breathable fabric sample with a relatively uniform thickness (32mm average) across the 10x10cm aluminium foil square. The following prototyping stage was to investigate the methods of manipulating the structural design of the collector to evaluate the effectiveness of using 3D collectors for mask prototyping. The experimentation process was instigated following and exploring some of the ideas mentioned in section 3.4.4 specifically electrospinning directly on specifically designed 3D collector templates.

The collector was prepared following a traditional mask-making method using papier-mâché. A positive mask mould was sculpted on top of a plaster cast of a model's face to create a mask design (see Figure 25). The collector shape was designed following the areas that contained the contrasting concave and convex lines (such as a cheekbone or browbone) to check the uniformity of the collected fibre mat at different extremities on the collector and the transition between these areas.

Figure 25 Mask mould

The first 3D collector (sample A) was prepared using papier-mâché, it was sculpted to match the shape of the browbone-forehead connection area. The 3D collector was painted using electroconductive paint and set aside for 15 minutes until completely dry. Since the electrospun fabric would be collected on the surface of electroconductive paint, it was essential to use non-toxic paint to avoid the risk of dangerous substance residue on the collected fabric. The ingredients of the paint used for this study included carbon black and graphite dissolved in a water-soluble solution, it was solvent-free and non-toxic (Bareconductive.com, 2020). The selection to use electroconductive paint over aluminium foil was made to ensure a smoother surface coverage across the 3D structure. Electroconductive paint was advantageous when achieving a smooth application over the concave areas of the sample. The PU solution was prepared by applying the process and the materials described in sections 5.4.2 and 5.4.3, 84ml of PU solution was used.

The produced sample was evaluated visually, noticing that the electrospun fibres did not cover the 3D collector in an even layer (see Figure 26). The fibres exhibited the propensity to deposit on the flatter areas of the sample. The more sharply concave areas of the sample did not attract enough fibres to show noticeable coverage even though the sample was rotated periodically (every 10 minutes) to achieve a more uniform fibre deposition. The lack of regularity in fibre growth on the produced sample indicates the predisposition for lack of uniformity in fabric sample thickness which could negatively impact its durability and breathability properties.

Figure 26 Electrospun PU fabric structure using 3D collector painted with electroconductive paint (sample A)

One explanation for the low fibre deposition on the produced sample could be the insufficient conductivity of the electroconductive paint. Research on electrospinning parameters indicated that the collector can have a considerable influence on the electrospinning output and arrangement of collected nanofibers. When using a less conductive collector, deposited fibres may retain some of their charges which, consequently, may repel the incoming fibres, thus decreasing fibre collection output (Stanger, 2009). To measure the conductivity of the sample painted with electroconductive paint, an electroconductivity meter was used. The electroconductivity meter confirmed that the conductivity of the electroconductive paint (0.26 Ohms) was lower when compared to that of a standard aluminium foil.

To test if the higher conductivity of the collector could improve the fibre deposition, a second 3D structure (sample B) was covered with aluminium foil (Figure 27). Figure 27 shows a sample of a fibre web that was formed using a 3D collector (sample B) covered with aluminium foil. The shape of sample B was chosen to mimic the exaggerated shape of a protruding cheekbone as this was considered to have a more contrasting topography compared to that of sample A. The PU solution was prepared following the process and the

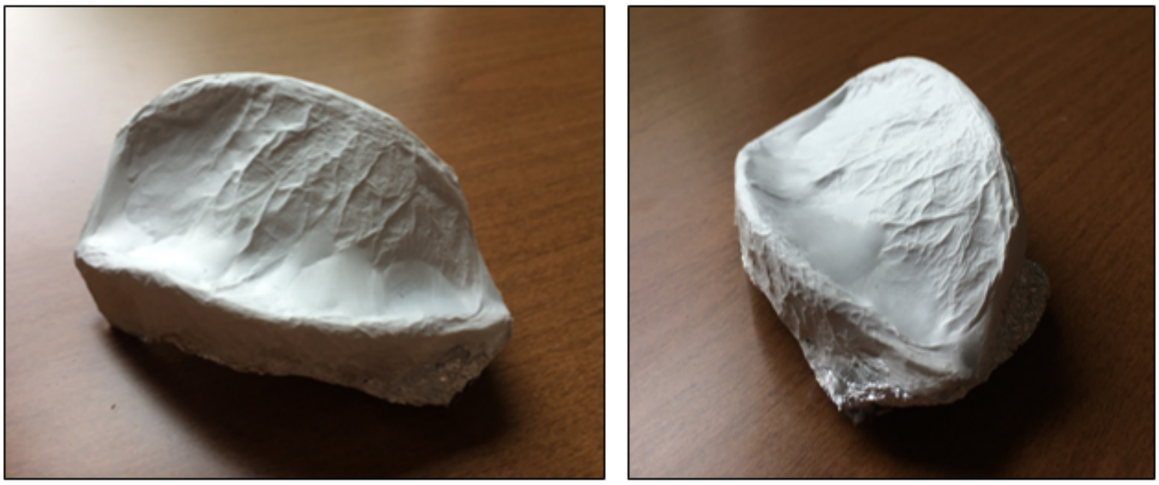


Figure 27 Electrospun PU fabric structure sample using 3D collector covered with aluminium foil (sample B)

materials described in sections 5.4.2 and 5.4.3, 84ml of the solution was used to cover the collector with fibres. After comparing both A and B samples, sample B demonstrated a significantly better 3D structure coverage with electrospun PU fibres. Overall, the collected electrospun fabric on sample B was lacking in uniformity with most of the fibres densely populating the most convex area of the sample. The most concave area of the sample B collector did not attract many fibres at all; instead, the nanofibers formed a bridge between the two walls of the sample. The fibre accumulation on the most convex area of the collector could be attributed to it being the shortest distance from the tip of the needle, with fibres having to travel a shorter distance and depositing on the first point they reach of the conductive collector. During electrospinning, the jet usually travels along the electrical potential gradient, following the path where the potential difference gradient is the steepest which is the shortest distance between the tip of the needle and the collector (Tan and Hzou, 2018).

Lubasova and Netravali (2020) experimented with collecting electrospun fibres using v-shaped collectors made from cardboard. Metal plates were strategically placed in different locations behind the collector to observe the effect of their location on fibre deposition. In the first variation of the experiment, a flat metal conductor plate was horizontally positioned behind the cardboard collector (see Figure 28a)). In contrast, in the second variation, nanofibers were spun onto a similar v-shaped cardboard collector with metal blades placed behind each groove of the collector (see Figure 28b)). In variation a), initially, the nanofibers were densely populated at the base of the v groove, the area that was touching the metal conductor and with time, nanofibers filled the entire v-shaped space. In variation b), nanofibers formed a bridge between the sides of the collector, connecting the highest points where the metal blades were present behind the collector walls (Lubasova and Netravali, 2020). This suggests that manipulating the needle to grounded metal plate distance and positioning can be a significant factor in nanofibre deposition.

Both, Lubasova's and Netravali's (2020) experiments as well as results witnessed using a sample B collector, demonstrate that when a 3D collector is used to collect nanofibers, the electric field does not distribute uniformly on the collector. The tips of the collectors display the tendency to centralise the electric field, and as a result, drawing more nanofibers to these areas (Niu *et* al., 2019).

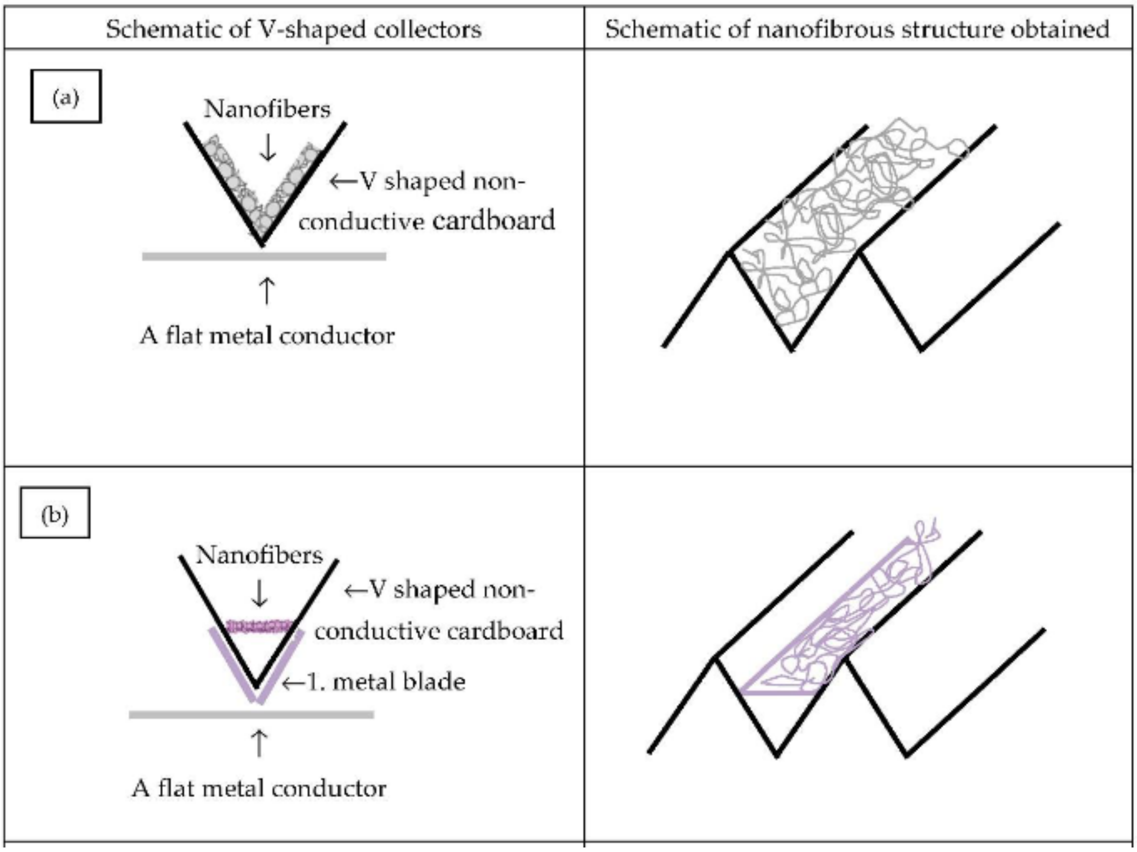


Figure 28 Schematic of 3-D nanofibrous layer producing setups for variations a) grounded metal plate placed flat behind v-shaped cardboard collector. b) Grounded metal plates placed behind the v-shaped cardboard collector following the groove of the collector.

5.4.5 Electrospun PU sample using a 3D wire mesh collector

Existing research on electrospinning parameters denotes the significance of the collector geometry and its effect on electric field distribution. It was found that wire and mesh collectors generate higher electric field values on the collector surface and also demonstrate a more uniform electric field distribution compared to aluminium foil collectors (Demirtas, 2018). The results show that a more uniform electric field allows for an appropriate electric field distribution which results in the production of thinner fibres as they are stretched out further due to the larger bending speed (Yang et al., 2008). A more uniform electric field distribution was found to produce a more uniform fibre mat thickness across the sample; therefore a 3D collector made from a wire mesh (sample C) (see Figure 29) was prepared to evaluate whether using wire mesh over aluminium foil would help to achieve a more even fibre coverage across the 3D sample.

The electroconductivity of the wire mesh was tested using the electroconductivity meter and was found to be equally as conductive as aluminium foil. Sample C was produced by shaping wire mesh over the clay mould replicating the shape of an exaggerated cheekbone. The PU solution was prepared following the process and the materials described in sections 5.4.2 and 5.4.3, 84ml of the solution was used for the electrospinning process. The results of sample C were very similar to those of sample B. Similar to the 3D aluminium foil collector, the fibres on the 3D wire mesh collector did not cover the concave areas evenly, the collected fibres were stretching over forming bridges between the convex areas of the collector.

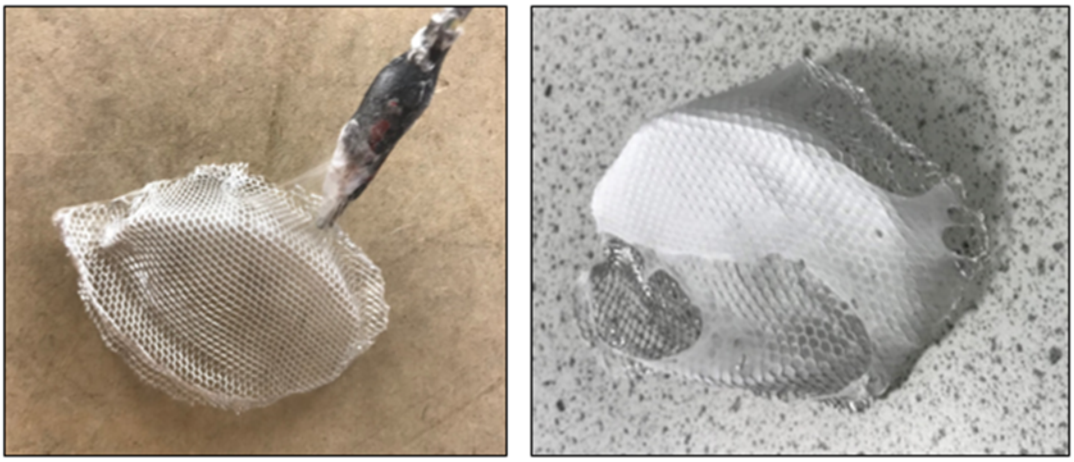


Figure 29 Electrospun PU fabric structure using 3D collector made out of wire mesh (sample C)

All three experiments using different types of 3D collectors (A, B and C) to produce 3D electrospun PU fabric structures demonstrated issues with achieving an even fabric coverage over the 3D collector structure. Failure to cover the surface of sample A with an even coating of electrospun PU fibres could be attributed to the lower conductivity of the collector as a result of using electroconductive paint. It also showed a propensity for the fibres to deposit more easily on the more raised areas of the collector. Both collectors B and C demonstrated the same tendency to experience fibre deposition over the most convex areas, forming a sufficiently thick layer there yet failing to reach the most concave areas as fibres formed a bridge between the two raised walls of the collector. These results correspond with previous research findings affirming that when a 3D collector is used in electrospinning, the electric field does not distribute uniformly over the collector, which causes the fibres to deposit on the area of the collector that is the shortest distance away from the source of where the solution is ejected (Niu *et* al., 2019; electrospintech.com, 2016). Sample C was used to test if a wire mesh collector would improve the uniformity of the electric field distribution over the collector; however, the collected fabric did not demonstrate any improvement in the quality of the collected fabric regularity across the 3D collector compared to that collected on sample B. On the other hand, the fabric collected using the wire mesh displayed a patterned and textured surface, which could be an appealing feature in mask-making.

5.4.6 Forming a double curved complex shape from a flat 2D wire mesh collector

Experiments with samples A, B and C established the complexity of achieving an even electrospun PU fabric distribution over the 3D structures. To ensure fabric uniformity across the sample in the subsequent experiment, a flat wire mesh collector (sample D) was used to collect electrospun PU fibres instead, which was shaped into the desired form after the electrospinning process.

German architect Frei Otto introduced the model of grid shells where a square grid can be shaped to a double-curved surface by distorting the grid squares into rhombi shapes (Liddell, 2015). The bending of the ribs within the grid structure results in much larger expansions and contractions of the mesh nodes than could be achieved in a continuous sheet (Chu, 2019). 2D materials that can be used for in-plane distortions should have a degree of elasticity (Callen & Zadpoor, 2018). The property of multidirectional stretchability of the electrospun PU fabric allows the possibility of achieving double curvature as the surface of the fabric can curve in two perpendicular directions while the mesh could provide support in the tensioning process (Massachusetts Institute of Technology, 2019). In the following experiment, a 2D flat wire mesh (a square grid) (see Figure 30) was used to collect the fabric, which was then shaped into a 3D sample by moulding it on a clay mask mould and pressing it into the desired 3D shape after the electrospinning process.

Figure 30 Moulding the wire mesh with the electrospun PU fabric into the shape of the cheek using the clay mask mould

The PU solution was prepared following the method and the materials described in sections 5.4.2 and 5.4.3, using 84ml of the PU solution. A 10x10cm wire mesh was used to collect the fibres and, later, to support and shape the collected fabric into the desired double-curved form. The resulting 3D sample (see Figure 30) showed much better 3D collector coverage regularity overall; however, the concave areas still lacked definition as the material did not lie flat, visibly stretching between the two convex walls. The concept of ridge and valley structures studied by Frei Otto is based on the creation of the small saddle by laying cables in an adjacent pattern with opposing curvature. The membrane is formed by two opposite support and anchor points to the ground. This type of curvature is relatively small and therefore is not suitable for all applications.

Sample D (see Figure 30) demonstrates that the fabric is deformed by stretching fittingly between two support ridges; however, the tension is lost in the concave area as the fabric lacks anchoring there. To explore the anchoring further, another sample was prepared; this time, the wire mesh collector was sprayed with multi-purpose adhesive spray prior to the electrospinning process. The idea behind it was to create a stronger attachment link between the collected fabric and the wire mesh that would be able to withstand the tensioning deformations. However, the achieved bond was not strong enough, and the valley areas were not anchored sufficiently to achieve the desired shape of the 3D structure.

5.4.7 Composite 3D electrospun PU and Varaform sample

Section 5.3 describes two types of methods that are used to create 3D forms from textiles which include physical (pattern making, 3D knitting) and thermal-based (using heat to shape the 2D fabric into a 3D form by stretching and compressing the fabric and bonding it to a thermoplastic material) methods (Yu *et* al., 2019). Following the experimental results described in section 5.4.5, the new focus became finding an appropriate method to anchor the stretched fabric part in the concave area of the sample, so that the desired deformations could be achieved to create a double curvature topography. One of the main findings from the interviews with the mask makers was to explore applying porous hydrophobic materials in mask-making as it could both allow water vapour to evaporate via the pores and sidestep the durability issue caused by moisture damage (see section 4.3). Previous research studies have indicated that electrospun PU (Selectophore™) fabric had contact angle higher than 90°, indicating its relative hydrophobicity (see chapter 3, section 3.4.1).

Consequently, this research project focused on ascertaining a method of creating a structurally effective electrospun PU fabric 3D form without compromising its porosity. Considering the possibility of using a thermal-based method to create a 3D electrospun PU form, it was necessry to identify a thermoplastic material that would possess hydrophobic properties but would not completely seal the pores of the electrospun PU fabric. Using a grid support structure to tension the electrospun PU fabric and thermally bonding on the intersections between the grid and the fabric to anchor the tension areas would leave a considerable PU electrospun fabric surface unsealed and therefore breathable.

To create a mesh support structure for the electrospun PU fabric, a material called Varaform was selected (see Figure 32). Varaform is a lightweight thermoplastic mesh and is a well-known material in prop, mask-making and medical (used as an alternative to plaster bandages for casts) communities. It has become a valuable material in stage costuming, especially when creating large, lightweight costume pieces or under structures for mascots and monsters. This material has the advantage of being lightweight and easy to work with, it is stiff and solid at room temperature, but once heated to 70 °C (which can be done using warm water or a heat gun) it becomes very pliable and self-adhesive. Once it cools down to room temperature, it becomes rigid again; however, it can be re-shaped by re-heating. Another advantage of using Varaform for masks is that it is non-toxic, therefore skin-safe (Material district, 2010).

The selection of this material to help solve electrospun PU fabric issues could be considered inadvertent. During the interviews with the mask makers, Varaform was frequently mentioned as a valuable, practical and economic material for mask work. Mask maker SB gave the researcher several samples of different materials used for theatre mask-making, one of which was Varaform. While the initial prototyping attempts focussed on achieving a 3D PU fabric structure via manipulating the collector parameters, having not been able to achieve a uniform sample coverage using 3D collectors, the researcher re-evaluated the strategy. Having experimented with wire mesh collectors while making samples C and D (see sections 5.4.4 and 5.4.5), the researcher made a mental connection to Varaform as another mesh material that could potentially support and solidify electrospun PU fabric into a 3D form.

Sample E was prepared using the same methods as sample D - a 2D flat wire mesh (a square grid) was used to collect the electrospun PU fabric, with PU solution being prepared in the same manner as with previous samples (A, B, C and D). The collected electrospun PU fabric thickness was around 0.4mm. A sample piece of Varaform was heated up using a heat gun at 70 °C and was then shaped by moulding it on a clay mask mould and pressing it into the desired 3D shape (the cheekbone area). The collected electrospun PU fabric was removed from the wire mesh collector and moulded over the activated Varaform piece by stretching over convex and concave regions to achieve double curvature (see Figure 31). Due to

Figure 31 Activated Varaform is moulded over the clay mask mould, and electrospun PU fabric is stretched over, tensioned and bound to Varaform

Varaform having adhesive properties when activated, the electrospun PU fabric was successfully stretched, compressed and anchored, adhering to the desired 3D shape. After the Varaform had cooled down to room temperature, the new composite Varaform and electrospun PU fabric structure retained the formed 3D shape of the mask mould cheek (Figure 32).

Figure 32 Composite 3D structure made from Varaform and electrospun PU fabric32

5.4.8 Mask prototyping with Varaform and electrospun PU fabric

Having successfully achieved a tangible 3D Varaform and electrospun PU sample featuring double curve topography, the researcher wanted to explore the potential practicality of a larger scale prototyping of producing a half mask. To achieve this, two A4 size electrospun PU fabric membranes were produced using wire mesh collectors, producing fabric samples of around 0,4mm thickness following the same electrospinning process described in section 5.4.3.

Varaform was cut into smaller pieces, heated up to 70°C and shaped following the clay mask mould. Since Varaform is self-adhesive when activated, it was easy to seamlessly connect the separate pieces without overlapping them. Once the mask structure was completely covered with Varaform, it was heated up once again at 70°C to re-activate its adhesive properties, so that the electrospun PU fabric could be stretched over and attached to the structure. Electrospun PU fabric was also cut into smaller segments, so it would be easier to manipulate it to achieve the desired accuracy. Another reason for cutting the electrospun PU fabric into smaller pieces was to prevent wasting the PU fabric, due to its production being very time-consuming. Figure 33 demonstrates the progress of electrospun PU fabric and Varaform mask formation. When exposed to the heat of 70°C, the electrospun PU fabric was not damaged, however, the increased temperature between 80-90°C caused the fabric to start melting.

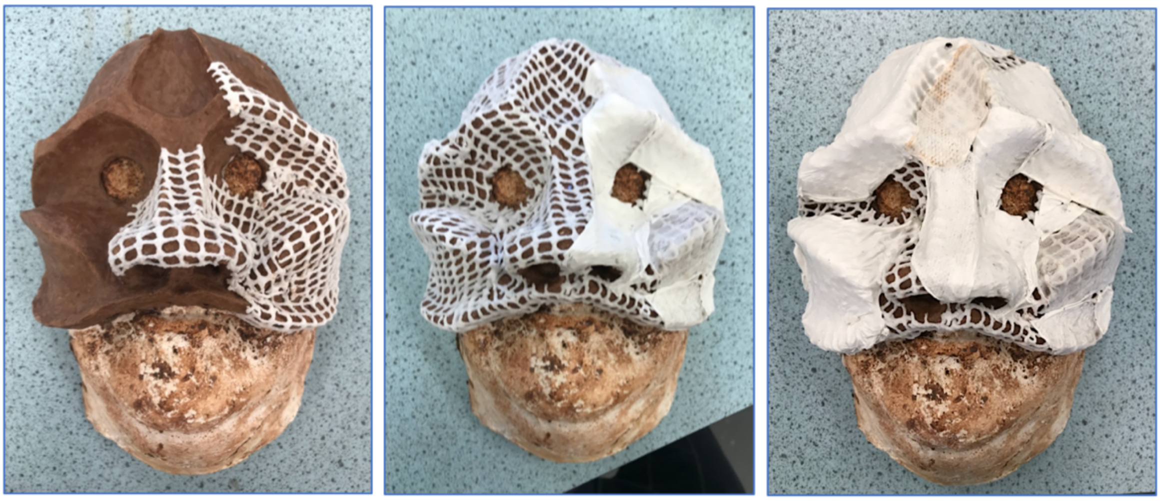


Figure 33. The process of constructing a mask prototype using electrospun PU fabric and Varaform

To explore the capacity of using the electrospun PU fabric for mask-making further, it was critical to assess the possibility of exploring creative possibilities of working with fabric, such as adding colour, for example. Previous research has reported that electrospun fibres, in general, are difficult to dye because of certain limitations, namely their size. Due to the very small diameters and higher specific surface area of the electrospun nanofibers, they reflect back a higher fraction of the incident light making it very difficult to achieve intense colours (Jatoi, 2020). One method of achieving strong colours in electrospun PU fibre mats is adding colour pigments directly into the PU solution before the electrospinning process (see Figure 34) (Goswami *et* al. 2016). Adding colouration in such a way produces excellent colourfastness as the pigment particles are locked inside the fibres during the fibre formation process. Colourfastness is a significant feature when considering theatrical masks, given that the performers sweat a lot beneath them. An important advantage of adding colour pigments during the electrospinning process is that it does not compromise the breathability property.

Figure 34 Electrospun PU fabric with added pigments before the electrospinning process

On the other hand, the controlled colour application directly on the produced mask material is also an important consideration when imparting colour for aesthetic and creative purposes. Mask makers frequently use acrylic-based paints to decorate masks due to their vividness, durability and versatility, the higher-quality acrylic paint dries to form a layer of coloured plastic with near permanence (Bahr, 2007). For the development of this project, a critical aspect was to maintain the breathability property of the fabric; therefore, the feasibility of using watercolour paint was tested, with the intention to deposit pigment on the surface of the fabric without entirely obstructing the pores of the fabric. Watercolour paint is made from a colour pigment dispersed in a suspension that binds the pigment and allows it to adhere to a surface when dry. In commercial watercolour paints, the binder is usually made from natural gum Arabic or synthetic glycol, which are both skin-safe. The binder prevents the pigments from dissolving in water, and it also helps with adhering to the medium (Marder, 2019). The toxic effects of watercolour pigments may arise from direct inhalation of pigment powder, however, when used and disposed of properly, nearly all pigments used in modern watercolour paints have no toxic consequences (MacEvoy, 2015).

The method of adding coloured pigments directly to the PU solution could be used to create a base colour for the mask that could be built upon; alternatively, a mask could be assembled using differently coloured fabric, mimicking a mosaic or patchwork effect. On the other hand, a more controlled colour application such as watercolour paint, could allow for a different style of artistic expression. To test the effectiveness of painting the electrospun PU fabric, two strips of electrospun PU fabric were painted with watercolour paint in a colour segment scale to show the intensity and vividness of different hues (Figure 35).

Figure 35. Testing the effectiveness of using watercolour paint on electrospun PU fabric

The application technique of watercolour paint on the fabric surface was found to be effective; however, the waterproofness of the fabric necessitated minimal water application with intervals of waiting to allow for water evaporation. The advantage of using watercolour proved to be the capacity to build layers and create contouring effects, highlighting the 'peaks' and the 'valleys' of the mask, which is critical for adding a visual dimension to the mask, particularly when it is viewed from a distance (Figure 36).

Figure 36. Testing the effectiveness of using watercolour paint on electrospun PU fabric

5.5 Water vapour permeability

The electrospun PU fabric was subjected to water vapour permeability tests before and after it was changed into a composite Varaform electrospun PU structure. The test was carried out following the British Standard BS7209:1990.

Test specimens were sealed over the open mouth of a test dish which contained distilled water (complying with grade 3 of BS 3978) and the assembly was placed in a controlled atmosphere. To establish an equilibrium of the water vapour pressure gradient across the sample, a period of 1 hour was provided. Successive weighings of the assembled dish were made and the rate of water vapour permeation through the specimen was determined. The water vapour permeability index is calculated by expressing the water vapour permeability of the fabric as a percentage of the water vapour permeability of a reference woven fabric which is tested in a similar manner and parallel alongside the test specimen.

- Electrospun PU fabric – thickness – 0,4mm.
- Reference fabric - precision high tenacity polyester woven monofilament mesh having the following characteristics:

  Mesh aperture 18µm;

  Yarn diameter 32µm;

  Threads per cm 196.1;

  Open area % 12.5.

  The fabric is tightly woven and constructed from synthetic fibres of low moisture regain to avoid sagging under conditions of high relative humidity.
- Test chamber – laboratory room controlled at the relative humidity of 65±2% and a temperature of 20±2°C.
- Turntable - Testex TF165 Water Vapour Permeability Tester, carrying 8 test dishes, which rotates uniformly to avoid the formation of still air layers above the test dishes. Movement of the dishes does not exceed 6m/min.

Test fabric and reference fabric were conditioned for an hour in the test chamber. By the means of the burette, 46g of distilled (grade 3 of BS 3978) water was transferred to 7 dishes at 20 ± 2°C temperature. A thin layer of solvent-based contact adhesive was applied on the rim of each dish to hold the test fabric in place and help seal the dish (solvent-based contact adhesive was chosen because the test fabric is PU based). Utmost care was taken to make sure PU test fabric was not stretched in the process of covering the cups, this was achieved by removing the supportive layer of the wire mesh (which was originally used as a collector for these fibres) only after the PU test sample was securely attached to the test dish with the solvent-based contact adhesive. The test fabric was positioned in a way that the surface of the fabric was intended to be the face side of the fabric. The corresponding cover ring was placed and sealed over the rim of the dish with the solvent-based contact adhesive followed by the strip of adhesive tape.

Each assembly was numbered and placed on the turntable and triplicate specimens were arranged from each of the two test fabrics (A – electrospun PU fabric and B – electrospun PU and Varaform composite) and the reference fabric. Assemblies were rotated on the turntable for a period of 1h to establish an equilibrium of the water vapour gradient for each assembly in the test chamber. At the end of the equilibration period, each assembly was weighed on the balance to the nearest 0.001 g. After the initial weighing, the turntable was rotated within the controlled atmosphere for a period of 24 hours after which, the samples were re-weighed and the new mass was noted (see Table 10).

Sample type	Weight before the test M_1	Weight after the test M_2	M – loss in mass over t (24h)
1. Reference Fabric	136.688g	131.950g	4.738g
2. PU sample 1	140.845g	135.996g	4.849g
3. PU sample 2	137.780g	132.885g	4.895g
4. PU sample 3	137.116g	132.224g	4.892g
5. PU composite sample 1	138.653g	134.746g	3.907g
6. PU composite sample 2	143.301g	139.353g	3.948g
7. PU composite sample 3	141.896g	138.061g	3.835g

Table 10 Sample mass indexes before and after the water vapour permeability test

The water vapour permeability (WVP) in g/m^2/day is given by the equation: $WVP = \frac{24M}{At}$

Where:

M is the loss in mass of the assembly over the time period t (in g);

t is the time between successive weighings of the assembly (in h);

A is the area of the exposed test fabric (equal to the internal area of the test dish) (in m^2), In this case A = 0.0054113m^2.

The water vapour permeability index (I)% is given by means of the following equation:

$$I = \left\{\frac{(WVP)_f}{(WVP)_r}\right\} \times 100$$

Where:

$(WVP)_f$ is the mean water vapour permeability of the fabric under test;

$(WVP)_r$ is the water vapour permeability of the reference fabric.

Sample type	M_1	M_2	M	t	A	WVP	I
1. Reference Fabric	136.688g	131.950g	4.738	24	0.0054113	875.5752	100
2. PU sample 1	140.845g	135.996g	4.849	24	0.0054113	896.0878	102.3428
3. PU sample 2	137.780g	132.885g	4.895	24	0.0054113	904.5885	103.3136
4. PU sample 3	137.116g	132.224g	4.892	24	0.0054113	904.0342	103.2503
5. PU composite sample 1	138.653g	134.746g	3.907	24	0.0054113	722.0077	82.46095
6. PU composite sample 2	143.301g	139.353g	3.948	24	0.0054113	729.5844	83.3263
7. PU composite sample 3	141.896g	138.061g	3.835	24	0.0054113	708.7022	80.94133

Table 11 Water vapour permeability index

The data provided in Table 11 shows the water vapour permeability index (I) of electrospun PU samples and PU Varaform composite samples. A value of zero implies that the fabric is impermeable to water vapour and a value of 100 indicates that it has the same thermal and water vapour resistance as a layer of air of the same thickness. It can be seen that the samples are at least as breathable, and generally more so, than the polyester reference sample, PU Varaform composite fabric samples demonstrated slightly lower breathability, which could be explained by Varaform obstructing and therefore reducing the surface area of porous PU fabric.

Based on Ghezal *et* al. (2022) findings, the most optimal water vapour permeability index for commercialised waterproof breathable fabrics is 50% - 80%, therefore electrospun PU Varaform composite fabric (with 80-82% values) was considered adequate when equated to commercial product standards (Ghezal *et* al., 2022). Although the tests demonstrate very positive material breathability results, a longer-term study would have been needed to test its practical application and effectiveness during the performance. The electrospun PU fabric thickness was 0,4mm for all samples produced, which is a considerably thin material. While the fabric was by no means fragile at the thickness of 0,4, to demonstrate the durability required for theatrical performances it would need to be much thicker. With increased thickness, the breathability would diminish. Further durability and breathability tests are needed to establish the ultimate thickness to breathability balance.

5.6 Prototyping limitations using a laboratory-scale electrospinning setup

For this project, a laboratory-scale standard electrospinning setup was used, which consisted of Cole Parmer/200 Dual Syringe pump 78-9200C in conjunction with a counter electrode collector connected to a high voltage supply. This type of laboratory set-up posed considerable restrictions considering that the quantity of the material needed for mask production compared to the more typical electrospun nanofibre applications in industries such as tissue engineering, was much greater. The previously discussed issue of low nanofibre material production rate was a significant limiting factor during the development of this project as the laboratory scale set-up allowed the use of only two nozzles. The low laboratory production rate (2.0ml/h speed with 2ml of PU solution being electrospun into fibres, requiring 42 hours of spinning to produce a 10X10cm square sheet, around 0.4mm thickness PU fabric) of the nanofibre material had a time-constraining effect on producing 3D samples and scalable prototypes which had an inhibiting effect on the range of design ideas and reducing the solution space, restricting the practice of the artistic play with the material. The physical experimentation with the novel electrospun PU fabric which entailed designing and producing different collectors that would allow 3D sample structures to be created was an important element in this study as this enabled the researcher to explore the physical behaviour of the material and determine the scope of potential construction techniques without jeopardising the material properties of the PU fabric. Additionally, having access to the electrospinning set-up was key to explore not only the application of already produced material but also to altering and manipulating the manufacturing parameters, specifically, the collectors, to further explore the scope for 3D structure electrospinning.

5.7 Conclusions

This chapter outlined and discussed the prototyping process and related decision making. The prototyping process was commenced through exploring the capacity of collecting electrospun PU fibres directly on 3D shaped collectors. Experiments with samples A, B and C repeatedly demonstrated that fibres had a tendency to accumulate on the most convex areas of the collector. These results corresponded with previous research findings affirming that when a 3D collector is used in electrospinning, the electric field does not distribute uniformly over the collector. The tendency of the electric field to centralise on the most convex points of collectors causes fibre deposition to these areas.

To achieve complex 3D forms characterised by double curve from 2D material sheets, ftat sheets should be subjected the to in-plane distortions while simultaneously constricting the distortion. To create a structurally effective electrospun PU fabric 3D form, thermal based method was used by stretching and compressing the electrospun PU fabric and bonding it to a thermoplastic material – Varaform. Following the insights gained from the interviews with the mask makers, researcher focussed on exploring the application of porous hydrophobic materials in mask-making to allow water vapour to evaporate via the pores (to address comfort issues) and sidestep the durability issue caused by moisture damage by using hydrophobic materials. Using a grid support structure and thermally bonding the PU fabric only at the intersections between the grid and the fabric left a significant amount of unsealed, breathable electrospun PU electrospun fabric surface.

6. Discussion

The research described in this thesis not only added significantly to practice-led and user-oriented exploration in mask-making, but it also presented a diverse range of opportunities for design research in costume and mask studies as well as technology diversification to crafts. This research contributed to new knowledge in several ways. The research approach introduced a new way of thinking about mask-making as the researcher brought the performer's comfort needs to the forefront and shifted the focus away from purely aesthetic or robustness requirements. Furthermore, this study found a new potential application for electrospun PU fabrics outside the biomedical industries. The collected data from the interviewed mask makers allowed researcher to amass and present valuable insights on mask-making material properties, mask comfort, the manufacturing aspects situated within the context of this particular industry.

One of the key findings drawn from interview and survey analysis indicated the need for hydrophobic breathable materials in mask-making. Excess sweat and other types of moisture damages masks over a period of time, to prevent moisture inflicted deterioration, the interior of mask is usually sealed with PVA glue or varnish. The action of sealing material pores removes the capacity for water vapour transmission. When discussing comfort in masks, material, breathability was the second most debated comfort factor by the mask makers. Although significant, it was not being addressed during the making process, this paradox prompted the inquiry into the lack of advances in mask breathability. Though material breathability was recognised as an issue, when questioned about the effectiveness of using breathable materials to improve comfort, most mask makers expressed their doubts as this property was considered to be incompatible with the requirement for mask durability, shape retention and currently practiced hygiene solutions.

Both primary and secondary data indicated that the sensation of temperature increases when wearing and performing in a mask is high. The level of heat felt by the performer varies depending on the environment, the physical exertion of the performance as well as the mask type. Previous research on protective face mask performance indicated that material breathability can lead to the lowering of dead space humidity levels that impact comfort and tolerance (Roberge, 2011). The experienced discomfort was related to the thermal temperature increase, condensation and sweat on the performer's face and the sensation of unpleasantness related to sweat soiling the inside of the mask over a period of time. Material breathability was found to have a potentially positive effect on the performer's sweat, temperature and smell management as well as pleasant tactility.

The aim of this project was to explore the capacity of adding breathability functionality in performance masks without it interfering with other necessary mask attributes. Selecting breathable hydrophobic materials for mask-making could help reduce the risk of moisture induced damage as well as improve mask wearer comfort. Mask makers drew attention to the ongoing changes within the masked theatre, highlighting the growing focus on outdoor masked performances which would increase the demand for water resistant and durable masks. Researcher attempted to address this finding by proposing to employ the electrospinning technology for the production and application of breathable, hydrophobic PU fabric that could potentially be used as an alternative in mask-making. Previous research studies have indicated that electrospun PU (Selectophore™) fabric had contact angle higher than 90°, indicating its relative hydrophobicity (see Chapter 3, section 3.4.1). Water vapour permeability test was performed on electrospun PU Varaform fabric sample showed WVP Index values 80%-83%, which according to (Ghezal *et* al., 2022) research falls into the bracket commercialised waterproof breathable fabrics (with 50% - 80% values).

Being involved in the fabric manufacturing process directly and overseeing the development from raw materials to a fabric structure, the researcher was acutely aware of the advantageous (Goswami *et* al., 2016) properties of the electrospun PU material, specifically breathability, and therefore shaped the making process around preserving this property. This breathability property informed the decision-making involved in choosing a structurally effective method of supporting electrospun PU fabric in a 3D form without compromising its its porous structure, which meant abstaining from sealing the whole surface of the membrane. To achieve complex 3D forms characterised by double curve from 2D electrospun PU fabric, thermal-based method was used by stretching and compressing the 2D fabric and bonding it to a thermoplastic material – Varaform. Using a grid support structure to tension the electrospun PU fabric and adding adhesive on the intersections between the grid and the fabric anchored the stretched concave areas by adhering them to the grid. Selecting grid thermoplastic material for thermal bonding permitted keeping the majority of electrospun PU fabric surface unsealed, therefore sustaining the breathability property.

The interview analysis with the mask makers identified that there are substantial links of influence between the comfort factors (the fit of the mask, the material breathability, the weight, the tactility, the temperature and the performer's attitude towards the comfort) with their interdependency sometimes being in conflict with comfort solutions. The reasons for prioritising mask durability over breathability should not be disparaged, as the mask makers unanimously expressed that cost and speed are essential requirements for their craft practice to be viable. Experimenting with new materials and developing additional skill sets are time consuming and costly. Interviews with mask makers also revealed the overall sentiment that wearing a mask should not be expected to be a comfortable experience and that most performers just cope with most things as long as they are looked after. From a craftsperson perspective it may appear counterintuitive to invest in innovations, such as finding ways to incorporate material breathability into masks, as it may be seen as economically counter effective for the short term.

The advantage of employing bricolage methodology, allowed the researcher not to feel tied to any particular mask making process, it permitted the freedom to select processes that would support the breathability factor of the finished product while at the same time choose sampling methods that had aspects of physical manipulation of the material. Primary data anlysis revealed the intrinsic need of the mask makers to physically engage with materials and the craft practice when working on masks. An underlying notion during the interviews with the mask makers indicated that working with natural materials was more physically satisfying and, therefore, preferential. For example, using vacuum forming technology to make masks was viewed as "soulless" and done from nescessity, however, admittedly, some makers confessed that this bias could be due to not having seen this type of material used creatively. To foster an interest in technology and its advantages in craft practitioners, it is important to maintain a degree of hands-on practice and physical material manipulation. Throughout the research study, the researcher was mindful to appreciate that the value of craft is often seen to lie less in aesthetics (which can be reproduced by machines), and more in the process and the element of human labour involved.

According to Nimkulrat (2010), in material designated disciplines such as textiles, the concept of craft is understood not only as a way of making things by hand, but also as a way of thinking through the process of manipulating the material by hand. According to Groth (2017), much of experiential knowledge is situated in action and in relation to previous experiences and material skills, this supports the researcher's own experience of being able to progress with creating 3D structures much more successfully after engaging in a direct physical interaction with the material, experimenting and learning through trial and error. Just as Aldersey-Williams (2004) suggests, "A tool or technology always distances maker from object". Introducing new technologies to crafts also bring new layers of mediation between the maker, the object and the tools, because ultimately, an entire object can be created through machines, reducing the space of human intervention to directing the making process.

Bricolage methodology enabled the researcher to select the most appropriate techniques and materials recombining these to create something new. Researcher's background in technical textiles was advantageous when contemplating electrospinning parameter manipulation aspects. The duality of researcher's background in technical textiles and costuming was purposively applied to refine the research problem – improving the comfort in a fit-for-purpose way through the correlation between the technical and scientific properties of textiles and the physical aspects of material handling and artifact construction. The benefit of this research approach was that the researcher could solve the development issues using both scientific and craft methods.

The advantage of having access to electrospinning equipment and necessary materials enabled the researcher to consider new possible innovation approaches in mask making. Additionally, the researcher was also attempting to test the capacity of using electrospinning to formulate fibres directly on a three-dimensional structure without added manufacturing steps and not compromising the breathability property induced via the electrospinning. The initial stage of prototyping was heavily focussed on technical electrospinning process and manufacturing parameters manipulation in order to create a 3D fibre matt structure directly from raw materials during the fibre-to-fabric production process.

A variety of 3D collectors were produced to determine the capacity of producing a 3D electrospun PU web (see Figures 37 and 38). However, it was quickly established that the collected electrospun fabric was lacking in uniformity with most of the fibres densely populating the most convex area of the sample indicating that when a 3D collector is used to collect nanofibers, the electric field does not distribute uniformly on the collector. Further experiments with manipulating the collector shape into a 3D structure showed much better results when electrospun fibres were collected on a flat surface (a wire mesh), which was moulded into a 3D shape post-spinning. This followed the second prototyping phase which incorporated a more physical interaction with the material involving handling and manipulating the already produced material.

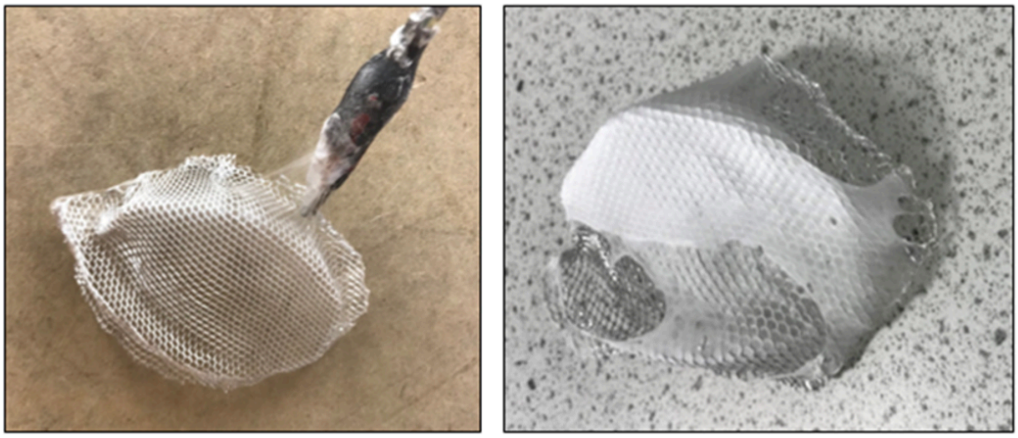


Figure 37 Electrospun PU fabric structure sample using 3D collector covered with aluminium foil

Figure 38 Electrospun PU fabric structure using 3D collector made out of wire mesh

The concept of utility was an underlying notion involved in the decision-making process throughout the project finding pragmatic solutions to problems as they occurred. The initial attempts to collect fibres directly on 3D collectors did not produce even coverage of good quality material over the collector and created a lot of waste (fibres formed bridges between the most concave areas of the collector, which had to be discarded). Consequently, the resolution for this issue was to reverse the process forming the electrospun fabric into a 3D shape post-production, ensuring that the quality and uniformity of the collected fabric is prioritised. Decision-making was further influenced by the particulars of the technology as well as accessibility to and availability of the materials. The requirement to use a grounded metal coated target such as tin foil, for example, prompted the researcher to explore using wire mesh as a collector during a later phase of the development, which, in turn, later gave an idea of adding Varaform as a support structure for the electrospun PU fabric.

There is a definite lack of research and experimentation working with breathable materials in mask prototyping and addressing durability concerns. The initial plan of the project included an important validation phase. The researcher aimed to collect feedback from focus groups consisting of experienced mask performers in an attempt to critically evaluate the effectiveness of added comfort (specifically breathability) compared to masks made from other materials (such as papier-mâché, latex or leather). The testing part had to take place after the prototype was made, which regrettably happened during the period when the Covid-19 pandemic commenced. Due to safety regulations with regards to Covid-19, the mask making material comparison trial had to be cancelled as handling and exhalation onto the masks could not be permitted.

To collect the feedback regarding the effect on perceived comfort using the electrospun material for masks the researcher aimed to use a focus group of participants who have had extensive experience in masked performance. Focus groups are designed to provide exploratory rather than conclusive research data so they expand the understanding to not only what the respondents think, but also to the background data behind it. The intended sampling of the participants would have included an even proportion of male and female participants (10 of each gender) to take into account that the material breathability results might be impacted by gender factors such as muscle mass or facial hair. Although both men and women maintain an internal body temperature of 37°C degrees, men typically have more muscle mass and generate more heat by using more calories to feed those muscles. Therefore, it would be conceivable to expect that men are more prone to anticipate the feeling of discomfort with regards to lower breathability mask materials than women.

Having already interviewed the mask makers, the researcher was aware that in this specific research project, the understanding regarding mask comfort was not always easily communicated in a succinct manner. According to Burcikova (2017), tactile engagement with material often precedes any verbal description, more importantly, it also helps to articulate what may first seem hard to put into words. Using the identified comfort factors from the literature and the interviews with the mask-makers to support the focus group discussion and to compare and contrast the insights.

Factors influencing comfort when wearing a mask
○ Fit
• Visibility
• Fixing the mask to the face
• Foam, Felt pads
• Breathing
○ Material breathability
• Sweat
• Smell
○ Weight
○ Tactility
○ Temperature
○ Attitude towards comfort

Table 11. Most significant factors for mask comfort

Table 11 indicates six factors that mask makers indicated to be the most significant for mask comfort. It would have been noteworthy to have received the insights of the participants from the focus group asking them to rank each factor in terms of importance from their perspective in a scale from 1 to 10 (1 – being the least important and 10 – being the most important) and discuss the reasoning behind it. Additionally, participants would have also been asked to complete four performance mask trials including a prototype electrospun PU mask and three other masks made out of the most commonly used materials (leather, papier-mâché and latex). Each trial would have consisted of 10 minutes low-to-moderate physical activity and 10 minutes moderate-to-intensive physical activity). The participants would have been asked to compare the levels in wetness and temperature rise sensations on their faces while performing in each mask, ranking each of these factors in a scale from 1 to 10 (1 – being very low and 10 - being very high). The main purpose of the mask trial would have been to compare the subjective perception of differences in levels of wetness and heat sensations owing to different materials.

7. Conclusion and suggestions for future work

This research project contributes to academic research by critically evaluating the existing mask making materials and methods currently used in theatre mask making and related challenges affecting mask wearer comfort. This research project presents a body of work supported by the insights from mask makers regarding current materials, methods and challenges in contemporary mask making.

The researcher has thoroughly analysed the design challenges with regards to comfort, analysing the interconnectedness and interdependency between comfort and durability factors. The interview analysis with the mask makers identified that the links of influence between the comfort and durability factors may sometimes be in conflict with comfort solutions. Although material breathability was the second most discussed comfort factor by the mask makers, it has not been addressed by makers due to its realisation being in conflict with other necessary mask functionalities, such as durability. Additionally, the mask makers admitted that breathability comfort was not prioritised due to budget and time restraints. Existing sweat management techniques to improve comfort included the application of foam or felt pads and headbands to soak up the sweat and prevent the mask from touching the face directly allowing space for air circulation. One of the key findings derived from the interviews and surveys with the mask makers was indispensable and multifunctional use of foam and felt pads. The strategic placement of foam or felt pads on unmoving parts of the face, can help to alleviate the pressure from the mask, reduce the number of contact points (which helps to minimise the amount of sweat penetrating the mask) and improve ventilation and breathing capacity.

The capacity of 2D PU textile application for 3D complex structures using 3D collectors has been explored. Initially the research concept was directed toward exploring the capacity of the electrospinning technology to create a 3D fibre mat structure directly from raw materials during the fibre-to-fabric production process. Experiments with samples A, B and C repeatedly demonstrated that fibres had a tendency to accumulate on the most convex areas of the collector. These results corresponded with previous research findings affirming that when a 3D collector is used in electrospinning, the electric field does not distribute uniformly over the collector. To achieve complex 3D forms characterised by double curve from 2D material sheets, flat sheets should be subjected to the in-plane distortions while simultaneously constricting the distortion. The property of multidirectional stretchability of the electrospun PU fabric allowed the possibility of achieving the double curvature as the surface of the fabric could curve in two perpendicular directions. A mesh material called Varaform was found to be suitable as a support structure for the electrospun PU fabric. The grid support structure was thermally bonded to the PU fabric only at the intersections between the grid and the fabric which left a substantial quantity of unsealed, breathable electrospun PU electrospun fabric surface. The insights gained from the interviews with the mask makers indicated a need for porous hydrophobic materials that could be used in mask-making to allow water vapour to evaporate via the pores (to address comfort issues) and avoid the the moisture damage caused by sweat or rain.

Finally, to address the importance for crafts people to engage physically with materials, researcher explored the capacity of physically manipulating electrospun PU fabric and exploring its behaviour with 3D collectors as well as moulding it on the activated Varaform. Experiential knowledge gained through previous experiences and material skills, helped researcher to progress with creating 3D structures much more successfully after engaging in a direct physical interaction with the material, experimenting and learning through trial and error. Discovering new ways of approaching technologically advanced manmade materials through physical interaction could make more it more attractive in crafts communities attractive if the hands-on approach of material manipulation was introduced as a possibility.

7.1 Suggested future work

As already mentioned in the discussion chapter, further validation work for the effectiveness of mask breathability from the perspective of the performers would be incredibly beneficial for this body of work. Focus groups of experienced mask performers could give valuable feedback with regards to a better understanding of mask comfort factors and the extent of effectiveness of the prototype mask to improve ventilation and reduce sweat and facial temperature.

In addition:

- Further colouring applications could also be explored, as previously mentioned, electrospinning technology allows the possibility of adding coloured pigments directly into the solution, which is able to produce a very colourfast material. Developing different ways to introduce colour to this material could pave the way for new creative explorations in mask making.
- For this project, a laboratory-scale standard electrospinning setup was used, which posed considerable restrictions considering that the quantity of the material needed for mask production compared to the more typical electrospun nanofibre applications in industries such as tissue engineering, was much greater. The previously discussed issue of low nanofibre material production rate was a significant limiting factor during the development of this project as it had a time constraining effect on producing 3D samples and scalable prototypes which had an inhibiting effect on the range of design ideas and reducing the solution space, restricting the practice of the artistic play with the material. It would therefore be considerably beneficial to advance this project using a more commercially relevant machinery such as Nanospider™ technology.
- More rigorous prototyping process could be developed to expand on using different methods to create and consolidate electrospun PU fabric into 3D structures.
- Material durability and abrasiveness tests could be used to evaluate the capacity of the fabric to withstand rough handling at theatre.
- Water vapor permeability tests could be subjected on thicker electrospun PU samples, the optimum thickness for the mask should be evaluated that could still be in balance with breathability.

Appendix A: Interview transcripts

Part 1

<u>Interview with mask maker AK</u>

Interviewer: How long have you been practicing mask making?

AK: I've been making masks for over 15 years.

Interviewer: What materials do you work most with when making masks and why?

AK: The most common material I work with is papier-mache, sculpted out of clay and then papier-mached on top of it. That's usually my favourite material because I like to work with clay to sculpt things with, I can get a really nice shape that way and papier-mache mostly because I've been working with that material for a long time and also it's something that is very affordable but also very easy to use. I often do workshops and that's a very accessible form and you can get as much detail as you want. And if I'm making a more professional mask, I will treat it a little bit differently because you will sweat on the inside of the mask obviously, so you do have to coat it with a layer of varnish or PVA glue or something that's waterproof on the inside and then on the outside I will treat it with a scrim of cotton, with a loose cotton weave and then build up layers of paint and varnish. Even though it's a paper mask, it will be waterproof for the most part. I've also made wooden masks, more recently I have made leather masks. Also, more recently I've been working with Worbla and that's been really great because it's completely waterproof because it's a plastic and it's really fast to work with and you get really nice results really quickly. I've been using that for the last few shows. The only problem with it is that apparently if you leave it in a hot place it can get heat activated and then it can get the misshapen.

The breathability is an issue but to be quite honest it all depends on the individual. Wearing a mask is never comfortable there's no such thing as a comfortable mask, unless it is something that is very small on your face like a nose or something like that. It's always a problem with the visibility, especially if you wear glasses because you can't wear glasses and a mask. And if you are a type of person that sweats a lot, there is just no way of getting around it. I mean I know there are techniques like some people wear headbands like tennis players so if you sweat so it doesn't get into your eyes because it makes it gets very hard to perform. Or sometimes another thing to do is put the foam and glue it on the inside around where the forehead is and where the cheekbones are places on your face which are furthest out and this allows a bit of space for air to move around the mask however it all depends because if it's a full head mask obviously there is very little air flow going in. If it's just the face mask it depends on what's around it, fur or fabric, it will make it hotter to be in. But even with foam you'll have a problem because just the places that touch the foam, they will get very hot and sweaty. Honestly, I don't know if it makes a difference what material the mask is made off because none of the materials that are suitable for the professional use are going to be breathable in a sense, because they need to be really hard wearing and if it's going to be hard wearing it needs to be made out of fairly firm material. Even papier-mache or leather when it's professional, it needs to be thick enough so that it holds its shape and so then you lose the ability for it to be breathable.

Interviewer: Could you please tell me more about sealing the mask?

AK: So if you are using a paper mask it's important to put something waterproof on the inside of the mask, sometimes the thing to use is just the waterproof PVA glue because that will give you a really hard firm surface and it prevents from your sweat going into it because obviously if you are sweating into the mask, over time it's going to destroy the mask. But also a person's face has a lot of natural oils and so if the oils get into the mask, overtime it is going to make the layers separate it's not going to be nice so you need a waterproof layer, either PVA or varnish or sometimes I just paint it black and if I want to be really careful I'll put another layer of varnish. If it's a mask that needs to be one professionally for many performances, I need to make sure that is completely waterproof.

Interviewer: Do you tend to make the masks more for theatres for outdoor performances?

AK: I used to do a lot of indoor theatre but that work is a little bit harder to come by now and so we do most of our work outdoors. Almost all our work is now for outdoor use. So, of course, the masks have to be waterproof as well. A lot of theatre has moved towards naturalism, the audiences are too used to watching television and film special effects have gone to a place where they are trying to be as real as possible even if it's an imaginary creature or whatever, you have a very effective computer-generated effects. It's really hard to sell a masked show now, I'm not entirely sure why. Puppetry is also hard but not nearly as hard as masked performances. I think with puppets you can go for younger audiences, you can't really have a younger audiences for masks because masks are a little bit scary for younger audiences because of what it's asking you to do, that sort of confusion between what is real and what is not real and so I think it's very hard to do for younger audiences and for the older audiences in theatre it has just gone out of fashion but like I said, there are exceptions. I think in this country there's only two or three theatre companies that do exclusively masked performances. There's almost none. I probably could think of less than 10 around the world that do exclusively masked performances, but often times there will be one or two masked characters in theatre performance.

Interviewer: You mentioned durability, what other considerations do you have when making a mask?

AK: They need to be comfortable, light enough to perform in. Sometimes mask makers are removed from mask performances and that tends to be very ineffective, if a mask maker makes a very elaborate mask but doesn't know what a performer needs to perform in it, effectively they might be just too heavy or unwieldly, the balance might be off or the visibility is off and so the mask performer is very limited in what he or she can do and that's not good for anybody. A good mask maker needs to understand how that character needs to be performed. For instance, with a good mask, it needs to be able to move in every direction. Sounds a bit obvious, but sometimes you get masks that are a little bit too big so you can't move in every direction. The size and the weight is very significant of course, you want it to be visually exciting and evocative, but it also has to be wearable and then of course the visibility is a big thing with masks.

Interviewer: And how do you make sure that the mask is comfortable?

AK: It all depends on a mask, how big and how heavy it is, if it's a small face mask one string of elastic across the back might be enough, but if it's a big size mask, one elastic might not be enough, because you need to be able to move your head really fast and then trust that it is going to stay in exactly same place, because the worst thing you can do is have to touch your mask to adjust it that just ruins the magic, so you might need a whole lot of straps or find a way to fit it on the head.

Interviewer: Which materials do you find to be the most durable?

AK: I think if you put extra layers, papier-mache is very durable. Obviously, wood can be very durable but it's very heavy. Worbla is also very durable but, for example, if you drop a piece of wood it can break, if you drop a plastic mask it will bounce, however, like I said, it can change its shape because of heat and also you can't bend it too far because like every plastic it will break. the other thing about papier-mache is that you can repair it. I've only used leather a couple of times so I don't know enough about it but if you made a small leather mask I think it would be very durable as well and of course leather has a really nice feel to it, it feels like a skin. It can last for a very long time if you look after it, if you make sure it doesn't get too dry. There are other materials that are like mesh, I think it's called Varaform, you use boiling water and it gets soft. I made masks from it, it's ok and it's nice and light, it's lighter than papier-mache but I found that you can't get as much detail as you can with papier-mache, so I prefer papier-mache.

Interviewer: How important is the material flexibility in a mask?

AK: To be honest, I haven't had a lot of experience with latex masks, I had to wear latex masks for two shows and it was horrible, I don't like the quality of it, I don't like the movability of it, this is my personal opinion. I think I come from a much more folk tradition where the masks don't move and they are fixed, it's all about the movement of the performer and that's the magic of it, the mask seems like it's changing the expression based on the performance, with latex I just don't like the wobble. The sweaty inside of the papier-mache mask is more acceptable to me than the sweaty inside of the rubber mask. Also latex degrades over few year.

Part 2

Interview with mask maker DK

Interviewer: How long have you been making masks and what masks do you make in particular?

DK: Sure, so I was a drama teacher for many years, so at one point I had to make some masks for the hobbits, so I bought this book and taught myself to make masks from books. I went to Bali and studied mask carving. I think I've been doing it for over 15 years.

Interviewer: What materials do you work most with when making masks and why?

DK: I've got here some of the materials that I use. So, I work with wood, papier-mache, leather. But I mainly use neoprene latex. You have a negative mould and you slip cast it, you pour it into the mould and two hours later you take it out and there's this skin, which dries in a day and then becomes a mask. But there is no latex in it so it doesn't cause any allergies. It is nontoxic. I use it for two reasons. One, I can sculpt anything, when you cast it you get very precise details, all the expression, all the sculpting lines. It is easy to work with. It is also very economic. Another thing about neoprene, it is very durable, it will last forever and it's not going to crack. But neoprene is not breathable. To make it comfortable I put foam inside on the forehead, so there's a gap, and the air can go in. I have to seal the mask with primer and sealers, otherwise neoprene would absorb the moisture, which turns neoprene milky white/yellow colour and it starts to smell. To seal it I use regular spray primer and then I put two coats of paint. Even the leather masks are sealed with something. Moisture will eventually kill a mask.

Wood, it takes a long time to make and it is a completely different skillset to make them. Balinese masks are not supposed to completely cover the face, they sit on top of the face. So breathability is not a issue, because there are a lot of gaps for ventilation. Wood would absorb moisture if you wore it for a prolonged period of time.

Papier-mache is one of them, I have some negative moulds. But they are a lot of work. When I make papier-mache masks, I add a layer of buckrum in it and then finish it with one more coating of papier-mache, so it is very sturdy.

Good leather masks are very expensive. Purists and a lot of actors prefer leather masks because they are natural, they are made out of skin, it feels better on your skin. Papier-mache is natural too, but it doesn't feel the same. Leather has a feel to it that people like. It absorbs the sweat and won't fall apart, whereas papier-mache will absorb the sweat and will fall apart.

Papier-mache is the lightest. The heaviest would probably be wood, then neoprene, then leather and then papier-mache. So leather mask takes the longest to make, then papier-mache, then neoprene.

Vac formed masks using some kind of urethane. but actors would never wear these masks in a performance they would wear something made out of papier-mache or leather or neoprene or latex.

Interviewer: What are the key considerations when thinking about mask comfort?

DK: Sealing a mask so it wouldn't smell.

When I make a mask, I have to make sure I get the eye measurement right, so they can see what they are supposed to see. Neoprene by its nature shrinks 15%, so I need to take that into account, with the half mask I need to make sure that it ends at the right place (so say it wouldn't cover the mouth). So male masks are bigger than female masks. Sometimes I make sure that the nose holes in female mask are big enough so that men could wear them too.

Interviewer: How would you address different issues related to comfort?

DK: Foam padding, sealing, tightness of the string.

Interviewer: Which materials provide the best breathability?

DK: Leather, papier-mache.

Interviewer: Which mask design allows for more breathability?

DK: Why do you choose to work with neoprene latex mainly?

The economics of it and the accuracy of detail, also very durable.

The eyeholes, according to Lecoq, eye holes shouldn't be too close to the face, because it would break the illusion of the mask and would draw too much of the attention to the actor.

Part 3

Interview with mask maker JD

Interviewer: I don't know if you've experienced this but there's not that much research done and mask making. I'm trying to contact different mask makers, talk to them about their practice and what the learned through doing it.

JD: Yes definitely. That's the key point, It's one of the big problems.

Interviewer: How long have you been making masks?

JD: For the past 25 years I've been working as a theatre performer, mask & puppet maker.

Interviewer: In terms of your mask making practice what materials do you most work with and why?

JD: I use the whole range of materials. The only thing that I haven't really used as leather because I just haven't had time to master that skill. Because it's a very specific skill. Although I would be interested at some point in doing that. But as a mask maker for commissions one way of cutting down costs is by making things in a quick and efficient way. My main way of making things actually would be latex because I can get very quick results with it, I know how to do it and I think the speed comes in a sculpt really. First, you'll sculpt anything you want in a clay, you'll sculpt a positive shape then you make a plaster cast, the negative shape, then you pour liquid latex into this negative shape and then you're left with the skin that becomes a mask. I use this method because it's really quick and basically you get all the detail. And that cuts a lot of corners because I can do a really detailed sculpt with lots of texture from clay, I found it fairly easily to do and then you've got that in the latex.

When it comes to painting it's really quick, you don't need much time painting I use dark base colour to get all that texture back out again which is different from making a basic mask and then sticking lots of materials on top of it. That's just the habit of what I do because I know how much it's going to cost, I know how long it's going to take so I can quote someone a realistic price. Also, latex is a pretty durable material the masks are thick enough, there's a degree of flexibility so you're not going to get any cracking or splitting when it's too thin. For example, with varaform masks if you sit on them, they get cracked.

It's really difficult to get a breathable mask. I'm not sure if it's actually possible I've made masks that are made out of fabrics that have a bit of breathability in, the problem is that sweat soaks into that material and within few weeks of wearing it you have a really horrible manky mask So whenever you stick a bit soft sponge or felt or foam to make it more comfortable doing the shows, it gets pretty awful pretty quickly and you have to keep replacing that inner layer. which is possible but my thing with latex is that you can wipe it down pretty quickly all you need to do is wipe it down with antibacterial wipes and it's clean, it's got sweat off, it it's ready for the next use. Using chamois leather for the inside you have to try it out and from my own experience in both making and wearing masks eventually it becomes really grim and you just don't want to wear it. Even if it's really comfortable and fits really well to your face it's pretty grim so my feeling is if you can get the shape as close as possible to the wearer and then maybe use smaller bits of sponge or foam to fill it out around the forehead or the cheeks or the lips, perhaps you need a bit more softness those are the things that you can easily replace once it gets too awful you take them out and you put the new piece in so I would say that the method that's the best for me is reducing the amount of material that's going to soak up the sweat over a period of time. which is not a very glamorous thing. I know the original commedia dell'arte masks is that when they age they take in sweat and they get coloured in the sun which is the part that gives them the that quality, that character. you want to be wearing something that's pleasant to wear.

Interviewer: Also, I guess latex is good because it's stretchable and moulds around your face less rubbing on your face?

JD: It can be it depends how thin you do it. The thinner your latex is the more possible it will rip. I find it's pretty forgiving actually if it's too thin it will not necessarily hold its shape especially if you make a mask with quite an extended nose and big features. If it's too thin it will not necessarily hold that shape. So, you will have to fill out that shape internally with foam or whatever so sometimes it's actually quite good to have quite thick latex it's quite robust but if it's really nice actually and especially around the eyes so it almost becomes more like prosthetics.

Interviewer: The masks that you are making are they mainly for theatre or for film or for other uses?

JD: Mostly theatre, I've done some film but not so much really. Like I say film work is a different world that's when you're trying to hide that you wearing a mask I'm kind of less interested in that world of prosthetics because actually to me the power of the Mask is when you are going to be extreme creating something on stage that a normal actor can't quite do.

Interviewer: When you are making masks do you ever get the requirements from the performers in terms of comfort.

JD: If I'm making a mask for a specific person, I will make sure to fit that mask to that person face, make something that's really comfortable and blend well with face. trying to fit something for a variety of different faces is really a challenge because faces are so different: how far apart are people's eyes, the distance between the eye line and the upper lip, they are all massively different and that can be a real challenge making something that would not be too small but isn't going to swamp other people, yeah that is a bit of a challenge. In general, I go a bit safer making sure that the distance between the eyes pretty good, if it's a half mask I will make sure that speaking is possible. Also I will try to work as much as possible with the performer and the director and guide them how to wear a mask, because you have to use your body and your facial expression if that's a half face mask to enhance what that mask is meant to be doing and as you know something with the mask works really well and sometimes it doesn’t and it’s a nature of facial dynamics. When I just start making a mask, I will try to make the eyehole as little as possible and increase it if needed as the actor tries it on.

Interviewer: What are the key considerations for you as a maker when you make a mask for many people if you can't quite measure one actor.

JD: It is difficult and it may well be that you can't always bridge that gap if faces are too different. I don't think there are any rules that you can apply each time you are kind of assessing with the parameters are and you are trying to leave the room for manoeuvre if I'm trying to make something that will fit a number of people I will not go to extreme with the eye distance and I will try to not make the distance between the eye line and the upper lip not too extreme either if it's a full mask then it's different you have a lot more flexibility that way, also not going too small is a key.

Interviewer: What paint do you use for your latex masks?

JD: Acrylic. I will mix the darkest colour that I'm using with a slush and use that as a base and put lighter colours on top of it and that is very easy it's almost like dry brushing on top of the base and that allows you to achieve a really lovely blending of tone and also that means that you have a very thin layer of paint because you don't want to layer up paint, you don't want it to crack. I tried to use as little paint as possible, it's almost a little bit like water colouring your building thin layers rather than big bold colours especially if you're doing flesh tone because it's not just one colour it's a whole range of shades.

JD: I think there is no other method other than just trying a bunch of stuff trying, different materials and see what works. Also, as a mask maker it is incredibly useful to actually wear and perform in a mask, I think that's what puts me heard of other.

Part 4

Interview with MT

Interviewer: Do you work with masks much?

MT: We do, we used to. I use them a lot in training. My training comes from school called Ecole Jacques Lecoq, where very early on in your training you will do at least a month, maybe longer, training with a neutral mask. This mask is made out of leather. They were made by Sartori, an Italian maker. Lecoq talks a lot about how the neutral mask is a great training tool for the actor, cuts off the head and allows the body to be more expressive. So, we use that a lot.

Interviewer: So, what do you find this training helps to achieve?

MT: Mainly it's about stopping the face, preventing the actor acting too much from the face and backing everything up with the body. So, for example if you want the actor to be surprised, it's not just the facial expression, it's the whole body. Western theatre approach, you could say Stanislavskian approach it's very much about the brain and the head, about thinking and about emotions and the audience can't see into your head, but the audience can see your body. So, this kind of training makes the body expressive. The French translation of Lecoq's training is the poetic body, so I think for me what a mask helps you do is to make your body become poetic. I think this kind of acting is more of a European style and less of a British style.

Interviewer: So, is it also because these are full face masks, so they can't speak?

MT: Absolutely. And for me it has to be where we start, because speaking is a whole different thing, it's like an added element of acting. So, for example, some of our shows are nonverbal, so training with a mask is crucial to be more expressive.

Lecoq always worked with leather masks, they were beautiful, what was so lovely about the material and texture, it made you treat it with a lot of respect.

Interviewer: When you would put that mask on, how would you feel? Restricted? Liberated? Alienated?

MT: It took a long time, you were not allowed to think in it or talk in it. Lecoq would give you an exercise, an exercise would always be something very simple, like waking up, the mask wakes up or the mask would pick up a stone and throw it into the sea and you would learn how your body would express that. So not a lot is happening but, you have to learn to express that sort of feeling through your body, because the masks face is not going to change. So it was wonderful and hard and so difficult to achieve.

For training, I still would use masks like Trestle (they are made out of plastic). We work a lot in comedy, and it is not about what you say, but about how you move and what you do, so rather than a mask being restrictive, it can be wonderfully liberating. Be funny rather than try to say funny. We have such a tradition in this country about stand up comedy and it can be great but it is very verbal. People from different countries, do not necessarily find these words funny, it's a different culture, it's a different rhythm of language and yet, the non-verbal comedy shows, can be very funny because they transcend the cultures and language barriers and contexts. For foreign audiences, for example it is harder to connect to the actor through verbal means, but the physicality can bring that connection., it can transcend the specific culture.

Interviewer: How would the mask feel on from the comfort side?

MT: I was always brought on a tradition, in which you would make a mould of your face, which doesn't happen anymore. So, the mask would fit you quite well. I think you have to stop thinking about the mask so it can't be uncomfortable, it doesn't have to be perfectly moulded to your face, as long as you can see through it clearly, you have to be able to breathe. A lot of neutral masks when you buy them are closed, there is no gap in the mouth, Lecoq would say that if there is no gap, the mask is dead, so he would always advocate a slight gap, if your mouth is closed you can't breathe, so the mask has to be able to breathe to be alive. But it's amazing how Lecoq's masks would fit everybody. But the eyes were different for male and female masks. The male mask was slightly bigger and they had slightly different eyes. They had a little bit of foam inside, for padding. But they were very expensive masks. They were very lightweight as well.

There's a lot of people in our world, which is a festival theatre world, that use masks.

Interviewer: Do you perform in theatre as well, or is it mainly festivals?

MT: We do. But mostly we perform outdoors, in festivals, where lot's of different companies from around the world come to perform, circus, physical theatre, comedy. We like performing at these kind of gigs, it's fun, it's outdoors. Indoor theatre needs funding from the arts council, it doesn't survive without lots of funding, whereas outdoor theatre at outdoor festivals, we can get paid for, you can get big crowds, you can perform to two thousand people. You can't get two thousand people in the theatre. For example, Tramlines, we got paid by Yellow Bus

Events, they got paid for by the University I think. So, you get the funding from many different sources.

Interviewer: So, do you think that in Britain at least, masks are not used that much for indoor theatre anymore?

MT: I think it's very specialist, companies like Trestle, but it's almost like a company would decide to be a mask company or they won't be. I think it's because of the different training that happened over the past twenty or thirty years. So, my company, we would use mask and a lot of festivals would use mask, primarily because outdoor festival companies are a lot freer, they can try something. Masks were very suitable to perform outside, like Greek and roman masks were designed to perform outside in big auditoriums. If you think about the size of the theatre, it was huge, the masks were big, the sound had to be big and the concept what they were talking about had to be big, Sophocles, Oedipus, they were big important issues. The commedia mask was a bit smaller, sillier, didn't have to deal with important issues. Masks are used more by outdoors companies than indoor companies. Outdoor theatre is a bit more European, because we don't have such a good weather.

Interviewer: Do you ever use latex or silicon masks?

MT: I don't think we have any, but we would do.

Interviewer: How do you choose the materials you work with?

MT: It would be up for the designer, it would be their choice, something that they are used working with.

Interviewer: What about the durability of the mask?

MT: The rigours of touring affect the durability, especially with the outdoor theatre. Things get rained on and bashed around. Outdoor stuff has to me much hardier and waterproof as much as possible.

Part 5

<u>Interview with mask maker MC</u>

Interviewer: How long have you been a mask maker?

MC: I started to make masks when I was in my early 20s So about 40 years ago. I've been a drama teacher at colleges and universities. I also work as a drama psychotherapist. So my personal application of mask has been around using a mask as sort of educational therapeutic tool and interspersed that work with performance as a director and as an actor.

Interviewer: What materials do you use for mask making?

MC: I used to make masks out of leather. I was working in a commedia dell'arte theatre company touring around Europe and we performed in leather masks. The thing with leather there's porosity, it can breathe like with shoes. You sweat in a mask and the mask starts to take the shape of your face, your skin can breathe, it's not like with synthetic material, so that's a great material for that kind of half mask Italian theatre. It's difficult to make a good leather mask, it's difficult to make a good commedia mask generally, it's a huge science in a way, which a lot of people really don't get. I won't say I've got it. I was trained by some of the big commedia guys. There's a big question around the material for the commedia mask. Leather is the ultimate one. You've got to carve it in wood first, beat the leather over the wood. I haven't made leather masks for some years now, but I can certainly vouch for how they work.

I guess the next mask that is relevant to talk about in terms of breathability and porosity is a mask made out of millinery net. I made these masks for dance performances. There's a dance form called eurythmy, it's invented by an Austrian philosopher called Rudolph Steiner. I made quite a lot of masks for that kind of dance. What I used for it was millinery net, because they need to be able to breathe but also they need to be able to see and have peripheral vision. So I used the material that the performer could see from the inside but from the outside you couldn't see the dancer's face. That also meant that even though it was hot, the millinery net, or buckram, which is another material that is used, it really enables this kind of breathing to take place. Millinery net is a coarse weave cotton with starch in it. You can warm it up or wet it and mould it over the mould or into the mould. It's very effective for the dance performance because the performers could see through it and breathe through it. It also created this translucence because it wasn't such a flat surface, it was this porous surface which gave this ethereal feeling.

Different materials help with different functions of the mask. I was working with a Greek mask maker Thanos Vovolis, he has done a lot of research on resonance and consonance. He is working with masks which are made from resonant materials so the function there is not porosity but resonance, trying to support the resonance of the voice and in order for it to be comfortable they put sound pegs, sound posts like in a violin - little pieces of wood inside the mask to measure up to your head so that the resonance of your head would go into the sound post and into the mask, so the idea is not to use the foam or soft materials to soak up the sound, but to create a resonance chamber and a breath chamber around you. Those masks are used specifically in Greek tragedy. So, you have these big voices, inside big full face masks with open mouths in huge auditorium and you have to be heard by thousands of people and so the masks are created to support that process otherwise you go to microphones.

Interviewer: Could you please talk about the durability in theatre masks and how you would address it.

MC: What tends to happen more and more these days is that masks tend to be made out of plastic. I had a choice of going into plastic and following this trend. But I decided not to, I decided to stay and research the materials that could withstand heat, could withstand perspiration and could withstand various knockings, durability for the long runs. And what I've come up with, I don't know if anybody else has come up with it independently, but I use plaster bandage with resin. Plaster bandage itself is not good for masks at all because it is a very vulnerable material, unless you make it very thick it will break, so if you want to make it very thin like for a mask, it's not strong enough, it will just fall apart. It is not supposed to last, it is not made to last. But if you use resin, there's polymer resins that I've been using, which react with the plaster and create very strong, waterproof, slightly flexible, durable material.
I made masks out of different materials in the past and my friend was performing in it in Brazil and it was very very hot and they became very very flexible and they started to break, so I remade them with this plaster bandage resin stuff and it is working much better now.
So yeah, in terms of durability, this is the material I use because it is also cost effective because it takes so long to make a mask and you can only charge so much. So if I charge £120 for a half mask, there's many many hours of work that goes into that, which I have to pay people or pay myself, so I've got to work out how I can do that both in a way that is cost effective for

me so I'm not losing money. Plastic I think is a bit of a cop out. I think it has its place, but it's a dead material, it's not a living material and to have plastic on your face is a peculiar experience.

Interviewer: By plastic, do you mean vac formed masks?

MC: Yes

Interviewer: why do you think many theatres went down the plastic route?

MC: I think it's cost. If I charge £120 for a half mask, you can charge £120 for four half masks made out of plastic. Theatres can afford it. Polymer resins I think support more natural materials, you still have the craft factor that is involved in a mask. Every mask is different. If you're vac forming it, you're just churning out hundreds and hundreds of the same mask. I think the really serious people who are wanting to get into the nuanced work are prepared to pay for them. I mean there are some really good actors out there and theatre companies using plastic, don't get me wrong.

Interviewer: In your experience, what are limitations in terms of mask comfort? What are the aspects that you try to take into account when making a mask to make it a little bit more comfortable for the wearer?

MC: First and foremost, I tend to work off face casts so they fit perfectly and so the performer also knows that it fits well. For example, if it is a half mask and the performer needs to sing or speak, the distance between the mask and the top lip is very important.

When I have to make a one size fits all mask, I design it on a face cast and I try to work with a cast that is not too big and not too small. So, for a small face it looks a bit too big and for a big face a bit too small but for the average face in the middle it's a fit. And to that I also put a little bit of foam on forehead, cheeks, top lip just to keep the mask away from the face so the mask is not touching the face directly. When a mask is required for a particular actor for a particular role, it's a real relationship with the actor to get it fit. Understanding the role, understanding the design side of the concepts and the images they are working with understanding the director's take on what they are trying to bring out of the actor, what are they trying to bring out of the character and then making the mask specifically within those confines to fit that particular function and fitting is a very important part of it. It is very challenging and very costly for the companies to invest into that kind of relationship, but if they are going to be touring internationally for years it's worth it. Maybe they take two of the same masks to have a spare one, they can repair it if need be. I encourage them to have bags to put the mask in, a padded suitcase. They really need to take care of it and treat it like a sacred object. The danger is it's going chip and crack. But leather is different, you can chuck leather into a box. But yeah, those leather masks we're talking about cost thousands of pounds.

Interviewer: Have you ever used papier-mache for mask making?

MC: I love papier-mache, it's a very special material to me. I've got some masks that I made twenty five - thirty years ago from papier-mache and they are so robust. They take a long time to make and they don't necessarily work when working with a negative mould, so it's got limitations. What I work with are negative silicon rubber moulds because they are the most durable and most easy to release mask from. And so papier-mache is not quite straightforward with that kind of mould situation. When working with papier-mache, in my experience it's best working over a positive design. I've used blotting paper, variations of it are used all over Europe, different kinds of blotting paper. It's all about getting the glue mixture just right. There's a glue polyfiller mixture which if you get it right then it is both flexible and strong without cracking. If you put too much glue in it, it gets too rubbery or if it's hot it tends to bend a lot, if you sweat a lot inside it. Or if you put too much polyfilla or plaster or hardener in it it can crack too easily. You've got to get that glue ratio right for papier-mache, in my experience. But I still use papier-mache., I was using it recently, I was making some large puppets for the theatre production, I was using a combination of materials. I think the question of materials is more what fits in every given situation and being able to sort of adapt to that.

Interviewer: How does moisture and perspiration affect masks? What are your experiences when dealing with it?

MC: You have to clean the mask, to wipe it after you've used it to remove some of the excess, otherwise it's like a shoe, the mask will begin to smell. Sometimes it's about disinfecting it with a little spray. One of the things we've done in leather masks and other masks I've made, if I need to strengthen them, I put a wire rim around the whole outside rim of the mask just to strengthen that, just for the durability. So the sweat doesn't expand or stretch it, make it lose its shape. And I've done something similar with other materials. I haven't discovered anything else, I haven't made it my priority. And for me at the moment, I'm probably making 50-60 masks a year, it's not so many. Most of them are being used in education, psychotherapy, performance training. People aren't wearing these masks for very long. My particular area of mask is a bit like applied mask. For me the masks function is about bringing and embodying ideas and bringing them alive so that they live as living ideas rather than as dry concepts. And so that's the area I'm focussing in. My clientele is not screaming out for worlds tour performance masks anymore. Were I be making more masks for theatre I'd be having to consider this question you're asking a little bit more.

But what I found, masks are not used that much in theatre. I think they have a function in theatre which is vital. I think you have to have a relationship to wanting to get the mask to work and that is quite complicated. It's a style, it's a theatre language which is quite demanding and if you don't really understand how to make the mask to work they can just be an appendage. A director really needs to know how to direct in a mask and some directors are not very good at it. A director really needs to push the actors to take on the mask. The actors need to act differently. It has to be the mask that is acting rather than the actor. It is a very hard work, very challenging. Not every actor wants to act in this way. It's a physical theatre. It has to be the mask that is doing the acting and the speaking and be alive, not the actor. The actor has to almost get himself out of the way.

I think there was a time when in the recent past over the last thirty years there was a whole mask tradition that came with Michel Saint-Denis that came over from France sixty years ago. Mody Modrocksbe and Keith Johnstone. They brought mask theatre alive and it was interesting. There are different streams of mask that have been developed over the years. Jacques Lecoq was an extraordinary teacher, he inspired a lot of people to do masked theatre. There was a lot of very powerful, warm, funny masked theatre in years gone by, which I don't see as much of these days. Threstle theatre company was a powerful theatre company, I was in Trestle for a while. What happened was that people who started the company were working for maybe thirty years got tired and the people who took over just decided to get rid of the mask. So, it was like masks are getting in the way.

My interest in mask has changed over the years because there wasn't enough work to just work in a theatre and so I started to work in psychotherapy. Masks are used a lot in theatre schools, in universities. I think most theatre schools and universities have mask modules, but I don't know that they are done in a way that makes people want to do mask theatre. I think with the recession people are going - we need to make a living, to do commercials. I don't know that I have my finger on mask zeitgeist at the moment to be honest, I've not kept up with the cutting edge.

Part 6

<u>Interview with RD</u>

Interviewer: How long have you been a mask maker?

RD: My mother was a wardrobe assistant and I always enjoyed making things. I think I've been making masks for over 20 years now.

Interviewer: What materials do you work most with when you make masks?

RD: I make a lot of masks for schools and other interested parties. In order to keep the prices down I use a vacuum former for that. I make the moulds from clay and then I carve them in plaster of paris or sometimes resin. But apart from that I also use leather which is traditional for commedia dell'arte mask making. I also use a material called Worbla, which is really good, I am finding more and more ways of using that. I have used glass fibre and for big puppets I use plastazote. So, there's quite a big variety. Also, cardboard is a wonderful material, you can do loads of stuff with it.

Interviewer: What are key considerations for you when picking a material to work with?

RD: First of all, economical reasons are never far from the picture, people have wonderful dreams that doesn't always match the budget, so I always try to accommodate that. So, for instance I sell commedia delL'arte masks, but they are affordable because they are vacuum formed. And the material I use is high impact polystyrene, which is misleading, it is actually a plastic. When people want a real thing, which I also make then I use leather. The price difference between these masks is quite considerable wit vac formed mask costing around £55 and leather mask starting from £250.

I've performed a lot in a mask. I've learned a lot from doing shows. We would spend a long time in a mask, with the half mask, we would spend at least first day getting it comfortable and making it fit. All our show masks were made out of plastic because they were cheap, it was the quickest and most effective way to do it. I would make a face cast so the mask would fit the face, some people have very wide heads, long heads. Particularly with half mask, the distance from the eyes to the top of the lip where the lips meet is very distinctive, where generally our eyes tend to be a more similar distance apart. With regards to comfort, we would make sure we spent quite a bit of time making sure that the foam was right inside of the mask, that you could speak right, so the words wouldn't be lost in the mask and that we were making the illusion that the mask was part of the face, that the hair was right and disguising the lines where the mask meets the head. We spend a lot of time on that. I tend to use foam a lot. Antonia Fava with whom I trained in Italy, he would take the measurements of the face and the bits where the mask should touch the face is where the nose meets the head, the top of the nose. And there's also under nose, underneath the nose of the mask. So, you have those two points – between the eyes and underneath the nose. But sometimes you don't want the mask to fit the face perfectly, you may want it to be bigger than the face, so you're working quite a lot with foam there. But what you really don't want to do is put the mask on places where it's going to move. So, for example, in the half mask, the cheeks are the last place you want to put the foam on, because that is the bit that moves mostly when you are speaking. The foam is quite grippy, it has quite a lot of friction to it. Eventually, we realised that the best gripping position is directly on the cheekbones themselves, beneath the eye, because they don't move and across the forehead, these are the major points for contact. And of course, every face is different, so we would spend quite a bit of time figuring out the positions for it.

The outside of the mask is beautiful, but the inside is horrible from all the wearing, it's like a shoe. There's quite a lot of sweat, but there's also quite a lot of condensation of the breath that goes on. And foam will absorb that. Particularly, the side that is in touch with the face, you get bits of skin in there, so you change these bits of foam from time to time. Also, it is different with the helmet mask, because the condensation can't escape, the breath, the water vapour is circulating in a mask. People don't breathe through the nose hole, it is an interesting phenomenon, but if you give somebody a mask without the nose holes in it they will sometimes think "I can't breathe, I can't breathe", but actually when you think about the mechanics of breathing inside the full head mask, you're pulling most of your oxygen in from the gaps around the mask around your neck, it's not from the nose, it's just a psychological thing. We just end up using lemon scented wipes, antibacterial wipes to wipe the inside of the mask, it works pretty well. To expect the mask to last beyond the hundred shows, the mask has be phenomenally well made or very well looked after. And like I said, it's like a shoe, if you're pulling it on and off with the wig.

In theory leather mask is breathable, but what you tend to do is seal it, because you're stiffening the leather. I made masks using three millimetre leather, which is quite thick. There are two things that mask makers use to give that stiffness, you either put three or four coats of shellac on the back or cellulose both of which are non-breathable. So, the leather is actually not taking the moisture in or out.

The thing with the masked performance, particularly with the half masks is that it is nearer to the ballet or contemporary dance because of the amount you're engaging your body, you really are, it's not just head. You're communicating with your whole body. In Jacques Lecoq school, they had the phrase that when you're wearing the mask the head becomes the eyes, body becomes the face. All the energy that would have gone into your facial expression, you're trying to express with your body, so you are using a lot of energy. When you're looking in some of the commedia mask performances, they are extraordinary and very acrobatic. The mask itself will come into quite a lot of wetting and drying out. A lot of the time the mask will need to be re-made.

Interviewer: What is your preferred mask making method and why?

RD: Unless you experiment progress as an artist, you get a bit bored. I used to find that vacuum former was wonderful because it was so quick and if I have to make the mask very quickly, the vac former is my favourite way of doing. The one thing that it doesn't do is that it doesn't give you hard edges. You always have to soften the edges because you're putting another two or three millimetre over the top of the mould, so it will never give you a sharp edge.

I love leather mask making, because you get lost in the making because everything about it, every part of the process enjoyable in a very sensuous way. You go to the timber merchant, you carve the wood, you smell the wood and also, it's all quite meditative. And then you use other materials such as shellac which almost smells like brandy. And then you get into working with the actual leather and there's this wonderful moment when you first put the leather in the water to soak and you get this kind of fizz in the water and then the leather starts having this puffy-ish quality and you use your hands to massage it onto the mould. You have to use brass tacks (because they don't corrode) to tack the leather to the mould to make sure leather is sitting right. Then you use a hammer, I use one I made out of boxwood. Leather is a bit like felt, it has lots of hairs going in different directions, the process of wetting the leather lifts all those hairs up and then what you're doing with your hammer you are reconstituting those hairs into the position that fits onto the mould, you compact the leather into a shape. As you do that, the leather begins to dry out, the mould itself begins to take the water out of it and your body heat as you're working on it, you're pushing the water out of it. And eventually you get to the point when the leather starts getting this shiny smooth finish. It is a very peaceful process, far more than any other process.

But working with Worbla is also very interesting, that is the material that is revealing itself more and more to me at the moment. What I love about Worbla is it is made out of recycled timber so it has that aesthetic to it. I've been working with it to make big masks, it's also very quick. If you have a slightly mercurial mind, which I have, being able to work quickly and make happy accidents is something that always interested me. It's all very well to have a technique, but you have to allow to push that technique to the places where it goes wrong and then you learn other things.

Interviewer: Which materials provide the best durability?

RD: I use high impact polystyrene. It's pretty good, but after quite a lot of use, what tends to happen, it will absorb the moisture and become weaker, eventually it will split. There is then the material called pet, it doesn't absorb moisture and it is stronger but heavier and it is more difficult to work with, it tends to melt at a lower temperature, but if I need to make a mask that is quite strong. The good thing about working with high impact polystyrene is that you can cut it very easily and sand it.

Worbla is practically bullet-proof, but the only thing with Worbla, it is heavier and you don't want to leave it in a car if it's hot or near the radiator because it is basically a thermoplastic and it will begin to melt and soften. Leather needs looking after, it's more like a shoe, the good thing about it that it doesn't tend to get damaged if you drop it. Whereas with plastic, because it's quite rigid if you drop it on the hard floor, you will chip the paint. My endless quest is to find the unchipable mask. The quality of the mask deteriorates very quickly if it is roughly handled. All these materials have their strengths and weaknesses.

I love making masks for theatre, because it is interesting to distil the character into the mask. So rather than Venetian disguise masks or carnival masks, that interests me less, I'm not really interested in decoration. I'm much more interested in the psychology and the relationships with the mask and the way the audience interprets it. I've done masks for Vamos theatre, I've done masks for Royal Shakespeare Company, I've made masks for Channel 4 and ITV.

In this country there's a limited landscape for mask work although people do do it. It's a fairly essential part of clown training because it is a very quick way into creating the ridiculous. I think there's a bigger question of theatre in general suffering from the onslaughts of the box sets. To buy a theatre ticket might cost like £25 and if you don't really like the show in the first five minutes, it's not a great experience. We live in quite a risk averse culture. There is less masked theatre these days to a degree, partially because there aren't that many mask makers, there's less money around. To design and make a mask for one performer you are looking at about £400. So it's tricky. People who are coming through the education now are less dexterous than my generation. I am not just saying that to make a case for "back in my day". There is professor called Kneebone and he found that the surgeons that he was training lacked dexterity because we have now moved to a culture that primarily uses keyboards and mobile phones and the variation in the manual dexterity required to used is far less than what we used to do. Writing actually requires far more muscles than typing. So what Kneebone has done, he made the students learn dexterity through learning magic tricks and puppetry.

Masks were a technology of their time they have been around since before the plough and before the wheel so they will always exist. One thing I will say though, we as a culture are becoming more and more frightened, we're less and less experimental and as I mentioned before, we're more risk averse. And I think what masks can do (and this is why they will always be around) is they can provide a window into our own perception. When I do workshops with people, people seem to visibly become happier after working with masks, I think people enjoy becoming a different personality and playing around with that. However, we have a fear of becoming a different personality and that is inbuilt in the structure of consumer capitalism culture, we're constantly being groomed to celebrate the single identity because that is the way that we can be categorised and sold to. I think the reality is that human beings have many many personalities and masks give us free expression to that. And when people actually really do it, they feel this incredible sense of release.

Part 7

Interview with mask maker SB

Interviewer: What materials do you work most with when making masks and why?

SB: This mask is made out of Silicon and it can move with the performers face. Mask design depends on what your mask needs to be, this one for example sits on somebody's head. We used cap to make it. So it is as comfortable as you could possibly have. Masks don't necessarily have to cover the face.

Plastazote is another material we use. It's kind of the material your gym mat is made of and you can sculpt and form that it's a very like material and then you can scrim it and build upon it creating all sorts of forms adding bits and bobs to it.

And when it comes to putting a mask on one's face we use foam padding it out with adding bits of foam inside, it always helps. At this point you do a mask fitting so you are making it as close as you can to fit the face.

Interviewer: Is there a material that you work most with when making masks?

SB: Probably latex is the most common one. It would be quite comfortable to wear but it would still get very hot.

Interviewer: Do you ever re-use masks for different performances?

SB: You try to recycle and reuse for one Just because of the time spent. So maybe in a different show I could turn it into something else, so you kind of try to reuse it in that respect. But within a show because People sweat quite a lot It would just be very unpleasant. It would just be easier to make duplicate masks, more than one.

Interviewer: So, when you put foam inside that just sort of absorbs the sweat?

SB: Yeah but also if that just going to be against your face, it would make sure there's no hard surface in contact with it. It just takes a pressure off a little bit.

Interviewer: Doesn't that make the mask lifted off the face a little bit, should the mask not be fitting as close to the face as possible? Especially around the eyes.

SB: It's a compromise situation. Quite often when you are fitting a mask you will be there with bits of foam, you will be trying it out in different spots Trying to work out what is best for them and sometimes you might need to cut the eyes a little bit bigger than you would just to give them a bit more chance of seeing.

Interviewer: I guess as the performers are quite far away from the audience so the audience doesn't notice such a minute detail.

SB: Certainly, in theatre you can get away with quite a lot because of these distances, where in the film you suffer with it a little bit. But then again somebody is not expecting you to do as much in it you probably don't have to do lots and lots of action in it and stay in it for a very long time. Or if you are in a film there probably are breaks. Whereas in theatre you have to wear it every night for however many weeks.

Interviewer: And do you have just mask based performances or would it just be a random masked character in a play?

SB: We haven't had that in a while It really depends on the show. We did a Jungle Book a few years ago and all the human characters in it wore masks.

Interviewer: What are these made from?

SB: These are made from plastic and then sprayed, they've got a bit of flex to them so they’re not too bad to wear. They’ve got strong bit of elastic and then they’re not covering your mouth, that helps a bit. There’s a bit of palstazote inside to absorb the pressure a little bit. Latex breaks down anyway over time.

If we did a bit where everybody had to look the same, so what would have happened, the mask would have had to be sculpted in clay and then the mould would have been taken off the clay and that’s when it becomes slightly awkward because everybody has to wear them but you can guarantee that not everybody is the same shape so that’s where the padding comes in. When we have people who need to wear masks we can’t afford to individually cast everybody’s face, some people are going to love it, some people are going to hate it and then you just have to make the best of it. You get different lengths of faces and the proportions. But they are wearing them for a certain amount of time, they just get on with it most of the time.

Interviewer: So how do you pick for a show weather to make a mask that doesn’t move with a face or the one that does?

SB: If you’ve got to make a lot of the same thing, it is easier to make them from plaster cast, vac-formed just because of our limitations of what we can afford, also if they don’t have speaking parts and just are going to do actions when wearing them, nobody would have a main role, if they’re only in it for say five minutes it’s just faster and cheaper. You have to weigh it up how many people work on the show, how much time you’ve got, can afford that amount of time to spend on one character. I hate to say it, but you’re in the world where you have to cut corners.

That's a latex mask, it's quite light, you can see you can get all sorts of details onto it and work into it. That one is probably quite comfortable.

Interviewer: Would you ever make holes in it to make it more breathable (invisible ones)?

SB: It would probably risk the strength, a lot of the time people put masks on very quickly, in the dark, so they need to be fool proof really. They need to last the distance. In theatre, things get hard life.

Interviewer: Would you ever make masks from leather?

SB: Yeah, occasionally. It's quite a long process, because you have to heat it and then wet it and keep heating and wetting it. Because of the amount of time it takes to make it, it is not one of the processes that works for us. We would make it for the feel of it, the specific look, rather than anything else.

Most performers just cope with most things. As long as you give them that tlc. they go, right that bit hurts a bit, can you make that bit easier, can you make the eyes a little bit bigger. Heavy normally comes with size.

It's always a good idea to cover things, to give it a more interesting texture. It also protects the surface. Papier mache for example breaks down unless you seal it.

Interviewer: How long would a mask need to last for?

SB: Most of the shows run for four weeks, so a show a day, sometimes two shows. Also, you need them in rehearsals because people really need to get used to wearing them.

This mask was made out of cork, so this one was material led, cork is actually very lightweight.

Most of the information of making lives in people's heads. You very rarely have to write anything down.

As you can see, the majority of masks are made out of very solid materials, they are not breathable.

Interviewer: This silicon mask feels very heavy.

SB: It's because of the amount of silicon on it. But it covers the whole head, so in a way it would feel much more balanced rather than something just being attached to your face. The performer came in and participated in every stage of the making so it made him more accepting seeing the process.

Scrimming means covering the surface with glue or fabric, depending how you want it to feel.

Plastazote, a lovely material to use, it's light, you can heat it and form it, you scrim it and then you paint it.

Interviewer: What are key priorities when making a mask?

SB: The priorities are time, costs, availability. As soon as you start using silicon, the cost goes up, latex is a cheaper version, but it takes time.

3d scanners would be useful but it’s a very different world from us.

Breathability is something that doesn’t comes into masks at the moment. What we’ve got in terms of materials, it doesn’t go into the direction of comfort.

Part 8

<u>Interview with mask maker VW</u>

VW: I started my mask making training in 2013, I was on a three-year physical theatre course and on that course I was also taught to make masks. My base training was to work with papier-mache masks. Different materials affect how the mask is played on stage. I use paper and filler, which is wallpaper.

When making a mask and working with different materials what you are looking for is how that material takes shape, how it combines with other materials. There are certain connections you need in a mask.

It is amazing to work with leather and to work with wooden blocks. I don't have that knowledge and skill yet.

Interviewer: What are key considerations for you when you make a mask?

VW: So, if it is a half mask, then you're tuning into the eyes and the mouth, it really needs to fit the performer very well. If it is a full mask then it is a little bit more relaxed, because the mouth is fixed in that kind of scenario, the main thing is the eyes and the eye distance. I also make a lot of animal masks and these ones sit on top of the head. So, there are no considerations to face, it doesn't matter, I fix them on a bicycle helmet.

Interviewer: What are comfort considerations for the wearer?

VW: Firstly, it would be eye position, breathing, so you could physically breathe through the mask. Also, how you are going to maintain the hygiene of the mask, are you going to wipe it with the antibacterial wipes. How breathing is addressed is very important because if the full mask, for example, creates a breathing chamber, it is very easy for the performer to hyperventilate. With larva masks you can put in pin pricks to add to allow for more oxygen.

Interviewer: And these masks that you add pin pricks are made from papier-mache?

VW: Yes, that's right.

Interviewer: How does the moisture affects the mask?

VW: Yes, you have to keep the mask dry long term. There was a performance in this room that was extremely damp and eventually it made the mask made out of papier-mache go really soft.

Interviewer: What kind of paint do you use for your masks?

VW: I use acrylic.

I do mask research. I research how the shape of the mask influences the body movement.

The biggest considerations in terms of comfort is that the performer should be able to breathe properly. Other things, you sort of just ride through it. For me it is also about making the papier-mache paste just right, not too runny. I don’t really like plastic masks, but to be honest I have not seen plastic being used creatively to make masks.

Part 9

<u>Questionnaire 1</u>

Question 1. What materials do you work most with when making masks and why?

Answer 1. My husband started this business and is an innovator, always looking to work with the best materials available.

Q 2. What are the key considerations when making a mask?

A 2. We consider what is physically possible to sculpt onto the human form, what the customer will want and something we can stand behind.

Q 3. What is the design process when making a mask?

A 3. It starts with an idea. From there Andrew will sometimes sketch the idea. Sometimes he will just start sculpting it in clay.

Q 4. What are the key considerations when thinking about mask comfort?

A 4. It's usually about comfort vs. design. Sometimes if the design has to be pushed really far past the human shapes, we have to forgo things like ear holes.

Q 5. How would you address different issues related to comfort?

A 5. Every mask has a different comfortability level as well does every person. One mask that fits a person one way will fit someone else slightly differently. Also people have different tolerance levels on how long they can wear a mask.

Q 7. Which materials provide the best breathability?

A 7. Silicone is more breathable simply because it fits to your face. With a latex mask, it sits off your face and you breath into the mask. With silicone, it sits on your face and you breath out of the mask.

Q 8. Which mask design allows for more breathability?

A 8. The half masks are more comfortable, I've heard.

Q 9. In terms of durability, how long does the mask need to last for?

A 9. Silicone is a much longer lasting product than latex. With proper care, a mask could last you 25 + years.

Q 10. Which materials are most durable?

A 10. Silicone.

Q 11. What is your preferred mask making method and why?

A 11. Silicone.

Part 10

Questionnaire 2

Q 2. What are the key considerations when making a mask?

A 2. If speaking or singing was required, the mouth area would be left open.

Q 4. What are the key considerations when thinking about mask comfort?

A 4. Wearer comfort was always paramount for Pam, it's especially important for actors and dancers, less so for those who just want to costume for events or parties.

We would always provide plenty of self-adhesive felt pads with instructions to the user to apply as needed to get a good comfortable fit.

In order to keep weight down, various kinds of foam products were used as substrates and to build up features... the weight of Paper Mache can add up very quickly!

If care is taken as to size and placement, the felt pads will also lift the mask off the face slightly and provide some air circulation.

References:

1. Abel, S. B.; Ballarin, F. M.; Abraham, G. A. (2020). Combination of electrospinning with other techniques for the fabrication of 3D polymeric and composite nanofibrous scaffolds with improved cellular interactions. Nanotechnology 31(17);
2. Adams, M.; Briscoe, B.; Johnson, S. Friction and lubrication of human skin. Tribol. Lett. 2007, 26, 239–253;
3. Adamson, G. (2007). Thinking Through Craft. 10.5040/9781350036062.;
4. Adamson, G. (2007). Thinking through craft. Oxford, UK: Berg;
5. Akduman, C. (2017). Electrospun Polyurethane Nanofibers. Available at: https://cdn.intechopen.com/pdfs-wm/56364.pdf;
6. Alexandre, C. B.; Salguero, J.; Peralta, M. E.; Aguayo, F.; Ares, A. (2017). New design and manufacturing technologies for craft products. Procedia Manufacturing 13 pp. 1284–1291;
7. amcsupplies.com.au. (n.a.). Wonderflex and Fosshape Information Sheet. [Online]. Retrieved from: https://www.amcsupplies.com.au/manuals/Wonderflex,%20Fosshape%20comparison%20table.pdf, accessed on 16/01/2019;
8. Ardebili, H.; Zhang, J.; Pecht, M. G. (2019). Plastic encapsulant materials. In: Encapsulation Technologies for Electronic Applications (Second Edition), Pages 47-121, ed(s): Ardebili, H.; Zhang, J.; Pecht, M.G., William Andrew Publishing;
9. art-south-africa.co.za. (2018). Traditional versus contemporary African art. [Online]. Retrieved from: https://www.art-south-africa.co.za/portal/article/1544/traditional-versus-contemporary-african-art, accessed on 05/03/2019;
10. Artuso, S. (2015). The Masks of Samurai. [Online]. Retrieved from: https://kartaruga.com/2015/09/21/masks-of-samurai/, accessed on 12/11/2018;
11. Artyfactory.com. (2018). The materials of an African mask. [Online]. Retrieved from: http://www.artyfactory.com/africanmasks/information/african-mask-materials.htm, accessed on 05/09/2018;
12. Asmatulu, R. and Khan, W. S. (2019). Historical background of the electrospinning process. In: Synthesis and Applications of Electrospun Nanofibres. Micro and Nano Technologies, pp. 17-39;

13. Bahr, B. (2007). Acrylic: 10 Things You Should Know About Acrylic Paint. [Online]. [Accessed 12/12/2020]. Available from: https://www.artistsnetwork.com/art-mediums/acrylic/acrylic-10-things-you-should-know-about-acrylic-paint/;
14. Bakaitė, J. (2020). LRT FACTS. Do facemasks make you breathe CO2? [Online]. Accessed 16/03/2020. Available from: https://www.lrt.lt/en/news-in-english/19/1202844/lrt-facts-do-facemasks-make-you-breathe-co2;
15. Bartels, V. A. (2011). Improving comfort in sports and leisure wear. Engineering. In: Improving Comfort in Clothing, 1st Edition, Ed. Song, G.;
16. BBC.co.uk (2014). World's oldest masks go on display in Jerusalem. [Online]. Retrieved from: https://www.bbc.co.uk/news/world-middle-east-26533994, accessed on 15/11/2018;
17. Bezooyen, A. V. (2014). Materials Driven Design. In: Karana, E., Pedgley, O., Rognoli, V. eds. *Materials Experience: Fundamentals of Materials and Design*, Oxford: Elsevier Science & Technology;
18. Bingham, A.J., & Witkowsky, P. (2022). Deductive and inductive approaches to qualitative data analysis. In C. Vanover, P. Mihas, & J. Saldaña (Eds.), Analyzing and interpreting qualitative data: After the interview (pp. 133-146). SAGE Publications;
19. Boerner, S. and Jobst, J. (2011). Stakeholder Management and Program Planning in German Public Theaters. Nonprofit Management and Leadership 22(1), pp. 67-84;
20. Bonet, L. and Schargorodsky, H. (2018). Theatre management: models and strategies for cultural venues. Kunnskapsverket. Elverum, Norway;
21. Bort, J. (2020). Here's exactly how well 20 materials for homemade masks — from folded bandanas to blue shop towels — can filter tiny, potentially-dangerous particles, according to an N95 testing company. [Online]. Retrieved from: https://www.businessinsider.com/the-materials-that-filter-particles-best-in-homemade-masks-testing-2020-4?r=US&IR=T, accessed 05/07/2020;
22. Boyatzis, R. E. (1998). Transforming qualitative information: thematic analysis and code development. Thousand Oaks (CA): Sage;
23. Bray, S.; Debreceni, T. (2016). A lesson in latex or fun with foam. The Prosthetics. Issue 5, pp. 45-50;

24. Brown.edu (2010). The Greek Mask. [Online]. Retrieved from: https://www.brown.edu/Departments/Joukowsky_Institute/courses/13things/7420.html, accessed on 12/10/2018;
25. Braun V, Clarke V. 2006. Using thematic analysis in psychology. Qual Res Psychol. 3(2):77–101;
26. Burkett, R. (2006). Papier Mache Rediscovered. [Online]. Retrieved From: http://home.eol.ca/~props/papier.html, accessed on 05/11/2018;
27. Deluca, B. (2011). The Masks of Africa, Chapter 2. California State University Dominguez Hills. [Online]. Retrieved from: http://www5.csudh.edu/bdeluca/thepowerofmasks/hum310/2_africa.html, accessed on 22/11/2018;
28. Callens, S. J.P. and Zadpoor, A. A. (2018). From flat sheets to curved geometries: Origami and kirigami approaches. *Materials Today.* Vol. 21(3), pp. 241-264;
29. Cherrie, J. W.; Apsley, A.; Cowie, H., et al. (2018). Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occupational & Environmental Medicine, Vol. 75, p446-452;
30. Choudhury, A. K. R.; Majumdar, P. K.; Datta, C. (2011). Factors affecting comfort: human physiology and the role of clothing. In: Improving Comfort in clothing, 1st Eddition, Ed, Song, G.;
31. Chu, J. (2019). 3-D printed mesh-like structures morph from flat layers into predetermined shapes. [Online]. [Accessed on 06/11/2020]. Available from: https://www.nanowerk.com/news2/gadget/newsid=53711.php;
32. Cook, B. (2017). Are you recording this? – the case for audio recording of interviews. [Online], accessed 11/04/2020, available from: https://cdn.ymaws.com/www.awi.org/resource/collection/10D407F9-FB41-42D6-BEF0-9C506A8CAC20/Are%20you%20recording%20this%20(Paper)%20clean%20-%20Bryan%20C.pdf;
33. Courage, C. and Baxter, K. (2005). Understanding Your Users A Practical Guide to User Requirements, Methods, Tools, and Techniques. Elsevier Inc. San Francisco.

34. Creswell, J. W. (2007). Qualitative Inquiry & Research Design. Choosing Among Five Approaches. Second Edition. Sage Publications Inc, Thousand Oaks, California;

35. Creswell, J.W., & Creswell, J.D. (2018). Mixed methods procedures. In, Research design: Qualitative, quantitative, and mixed methods approaches (5th ed., pp. 213-246). Los Angeles, CA: SAGE Publications, Inc.;

36. Das, B.; Das, A.; Kothari, V. K.; Fanguiero, R.; Araújo, M. (2007). Moisture Transmission Through Textiles Part I: Processes involved in moisture transmission and factors at play. AUTEX Research Journal, Vol. 7(2);

37. Demirtas, M. S. (2018). Fabrication, Characterisation and Modelling of Alligned Polyacrylonitrile-based Electrospun Carbon Nanofibres. [Online]. [Accessed 26/10/2020]. Available from: https://shareok.org/bitstream/handle/11244/301380/2018_Demirtas_Mehmet_Dissertation.pdf?sequence=2&isAllowed=y;

38. Denzin, N. K. & Lincoln, Y. S. (Eds.). (1999). The SAGE handbook of qualitative research (3rd ed.). Thousand Oaks, CA: Sage Publications;

39. Dollah, S.; Abduh, A.; Rosamaladewi, R. (2017). Benefits and Drawbacks of NVivo QSR Application. 10.2991/icest-17.2017.21;

40. Duggan, E. (2015). An Investigation Into the Impediments to Tacit Knowledge Transfer. Level 3: Vol. 12: Iss. 2, Article 3. doi:10.21427/D7TJ1J. Available at: https://arrow.tudublin.ie/level3/vol12/iss2/3;

41. Edson, G. (2009). Masks and Masking: Faces of Tradition and Belief Worldwide. McFarland: North Carolina, USA;

42. El-Newehy, M. H.;Al-Deyab, S. S.; Kenawy, E.; Abdel-Megeed, A. (2011). Nanospider Technology for the Production of Nylon-6 Nanofibers for Biomedical Applications. *Journal of Nanomaterials*, vol. 2011, Article ID 626589, 8 pages, https://doi.org/10.1155/2011/626589;

43. Electrospintech.com (2016). Improving Uniformity of Electrospun Membrane. [Online]. [Accessed on 26/10/2020]. Available from: http://electrospintech.com/membuniformity.html#.X5cQe-1pzIU;

44. Essick, G. K.; McGlone, F.; Dancer, C.; Fabricant, D.; Ragin, Y.; Phillips, N.; Jones, T.; Guest, S. (2010). Quantitative assessment of pleasant touch. Neuroscience and Biobehavioral 591 Reviews, 34, 192-203.;
45. Estrin, D. (2014). Rare chance to snap a 9000-year-old "selfie'. The Australian; Canberra, A.C.T. [Online]. Retrieved from: https://search-proquest-com.libaccess.hud.ac.uk/docview/1506328762/abstract/93DDFDC01E854239PQ/1?accountid=11526, accessed on 21/11/2018;
46. Etzi, R.; Spence, C.; Gallace, A. (2014). Textures that we like to touch: An experimental study of aesthetic preferences for tactile stimuli. Consciousness and Cognition, Vol (29), pp. 178-188. 10.1016/j.concog.2014.08.011.;
47. Faryabi, J., Rajabi, M., & Alirezaee, S. (2014). Evaluation of the use and reasons for not using a helmet by motorcyclists admitted to the emergency ward of shahid bahonar hospital in kerman. Archives of trauma research, 3(3), e19122. https://doi.org/10.5812/atr.19122;
48. Fan, J., and Hunter, L. (2009). Engineering Apparel Fabrics and Garments, Elsevier Science & Technology, 2009. ProQuest Ebook Central, http://ebookcentral.proquest.com/lib/hud/detail.action?docID=1640082;
49. Feltz, K. P., Emily, A. G. K., Chen, C., Martin, R. S., & Sell, S. A. (2017). A review of electrospinning manipulation techniques to direct fiber deposition and maximise pore size. Electrospinning 1(1), pp;
50. Feo, K. (2007). Invisibility: Memory, Masks and Masculinities in the Great War, Journal of Design History, Vol. 20 (1), pp. 17–27;
51. Flickr.com. (2018). Burqa, Niqab and Hijab. [Online]. Retrieved from: https://www.flickr.com/photos/7772010@N07/40053501281, accessed 20/03/2019;
52. Foreman, J. (1999). Maskwork: The Background, Making and Use of Masks. Lutterworth Press: Cambridge, UK;
53. Fossey, E.; Harvey, C.; McDermott, F.; Davidson, L. (2002). Understanding and evaluating qualitative research. Australian and New Zealand Journal of Psychiatry. 2002;36:717–732. doi: 10.1046/j.1440-1614.2002.01100.x. [PubMed] [CrossRef] [Google Scholar];

54. Friend, D. (2014). World War One: Soldiers helped at Wandsworth 'Tin Noses Shop'. [Online]. Retrieved from: https://www.bbc.co.uk/news/uk-england-london-27592604, accessed 15/12/2018;
55. Gannon, M. (2014). World's Oldest Masks Show Creepy Human Resemblance. [Online]. Retrieved from: https://www.livescience.com/44078-stone-age-masks-israel-museum.html, accessed 11/11/2018;
56. Garg., K and Bowlin. G. L. (2011). Electrospinning jets and nanofibrous structures. Biomicrofluids. Vol 5(1);
57. Gerlach, T. (2017). Sing Strongly With Nasal Breathing. [Online]. Accessed 17/03/2020. Available from: https://www.ceenta.com/news-blog/sing-strongly-with-nasal-breathing;
58. Ghanem, K. (2017). Beauty Across the Middle East: Oman. [Online]. Retrieved from: https://en.vogue.me/beauty/oman-batoola-face-covering/, accessed on 20/03/2019;
59. Ghezal, I.; Moussa, A.; Ben Marzoug, I.; El-Achari, A.; Campagne, C.; Sakli, F. (2022). Investigating Waterproofness and Breathability of a Coated Double-Sided Knitted Fabric. Coatings 2022, 12, 1572. https://doi.org/10.3390/coatings12101572;
60. Goldberg, M. (1987). U.S. Patent No. 4683588.: United States Patent;
61. Gosudareva, E.Y. (2011). Carnivals. [Online]. Retrieved from: http://elib.sfu-kras.ru/bitstream/handle/2311/5776/s22_158.pdf?sequence=1, accessed on 14/08/2018;
62. Goswami, P., Smith, T., Hebden, A., Russel, S. (2016). Patent No PCT/GB2016/053112. Leeds, UK: University of Leeds;
63. Goswami, P., Smith, T., Hebden, A., Russel, S. (2016). Patent No PCT/GB2016/053112. Leeds, UK: University of Leeds;
64. Grbich, C. (1999). Qualitative Research in Health: an Introduction. Thousand Oaks, Sage;
65. Greektheatre.gr. (2015). Masks in Ancient Greek Theatre. [Online]. Retrieved from: http://www.greektheatre.gr/on-stage/masks/, accessed on 06/09/2018;
66. Greenwood, J. (2017). Finding the Character: The impact of prosthetic make-up and creature suits on the actor’s performance. [Online]. Retrieved from:

https://grimsby.ac.uk/assets/uploads/2018/06/James-Greenwood-June-2017-Prosthetics-and-Performance.pdf, accessed on 08/02/219;

67. Groth, C. and Mäkelä, M. (2016). The Knowing Body in Material Exploration. Studies in material thinking. 14. 1-21;
68. Grunewald, S. J. (2015). 3D Printing Helped Bring Avengers: Age of Ultron's Breakout Superhero, The Vision, to Life. [Online]. Retrieved from: https://3dprint.com/98779/avengers-age-of-ultron/, accessed on 10/01/2019;
69. Gwosdow, A. R.; Stevens, J. C.; Berglund, L. G.; Stolwijk, J. A J. (1986). Skin Friction and Fabric Sensations in Neutral and Warm Environments. Text Res J 56:574–580;
70. H&MUA Team (2012). Facial anatomy and proportions. [Online]. [Accessed 03/10/2020]. Available from: https://hair-and-makeup-artist.com/facial-anatomy-proportions/;
71. Habgood-Coote, J. (2019). Knowledge-How, Abilities, and Questions. Australasian Journal of Philosophy 97 (1):86-104;
72. Hague, S. (2018). How to apply latex, gelatine and silicone prosthetics. [Online]. Retrieved from: https://www.redcarpetfx.com/blogs/news/how-to-apply-latex-gelatine-and-silicone-prosthetics, accessed on 10/01/2019;
73. Hammersley, M. (2004). Teaching qualitative methodology: craft, profession or bricolage. In: Seale, Clive; Gobo, Giampietro; Gubrium, Jay F. and Silverman, David eds. *Qualitative Research Practice.*Thousand Oaks: Sage, pp. 549–560;
74. Härkki, T., Seitamaa-Hakkarainen, P., Hakkarainen, K. (2016). Material knowledge in collaborative designing and making - A case of wearable sea creatures. FormAkademisk - Forskningstidsskrift for Design Og Designdidaktikk, 9(1). https://doi.org/10.7577/formakademisk.1480;
75. Harvey, I. (2016). Kabuto- Unique helmet first used by ancient Japanese warriors, and in later periods, they became an important part of the traditional Japanese armour worn by the samurai class. [Online]. Retrieved from: https://www.thevintagenews.com/2016/12/28/kabuto-unique-helmet-first-used-by-ancient-japanese-warriors-and-in-later-periods-they-became-an-important-part-of-the-traditional-japanese-armour-worn-by-the-samurai-class/, accessed on 05/03/2019;

76. Hicks, S. (2010). Pragmatic Philosophy, YouTube, online video, viewed 3 September 2015, available from: youtube.com/watch?v=lkOZ4IyAbNA>;

77. Higginbottom, G. M. A. (2004). Sampling issues in qualitative research. Nurse Researcher, volume 12 number 1, pp. 6-19;

78. History.com Editors. (2009). Samurai and Bushido. [Online]. Retrieved from: https://www.history.com/topics/japan/samurai-and-bushido, accessed on 17/12/2018;

79. Historyofmasks.net. (2013). History of African masks. [Online]. Retrieved from: http://www.historyofmasks.net/mask-history/history-of-african-masks/;

80. Howarth, D. (2018). Siba Sahabi's Persona masks look like wearable architecture models. [Online]. Retrieved from: https://www.dezeen.com/2018/10/27/persona-masks-wearable-architecture-models-siba-sahabi/, accessed on 28/02/2018;

81. Huntsman. (2010) A guide to thermoplastic polyurethanes (TPU). Available at: http://www.huntsman.com/polyurethanes/Media%20Library/global/files/guide_tpu.pdf;

82. Ich.unesco.org (2000). Traditional Craftmanship. [Online]. [Accessed 03/12/2020]. Available from: https://ich.unesco.org/en/traditional-craftsmanship-00057;

83. Ingold, T. (2013). Making. London, UK: Routledge;

84. Ingold, T. (2013). Making. London,UK: Routledge;

85. iveracademy.co.uk. (2018). A guide to prosthetics in film. [Online]. Retrieved from: https://www.iveracademy.co.uk/blog/2018/a-guide-to-prosthetics-in-film/, accessed on 21/01/2019;

86. Jaffery, R. (2018). What is the Difference Between the Hijab, Niqab and Burka? [Online]. Retrieved from: https://theculturetrip.com/middle-east/articles/the-difference-between-the-hijab-niqab-and-burka/, accessed on 20/03/2019;

87. Jankauskaitė, V.; Jiyembetova, I.; Gulbinienė A.; Širvaitytė, J.; Beleška, K.; Urbelis, V. (2012). Comparable Evaluation of Leather Waterproofing Behaviour upon Hide Quality. I. Influence of Retanning and Fatliqouring Agents on Leather Structure and Properties. Materials Science. Vol.18, No. 2.;

88. Jatoi, A. W. (2020). Coloration of electrospun polystyrene (PS)microfibers by the continuous dyeing method. The Journal of the Textile Institute. DOI:10.1080/00405000.2020.1783779;

89. Joshi, M. K., Shrestha, R. M., Pant H. R. (2020). 3D Nonwoven Fabrics for Biomedical Applications. In: Abbas, M. and Jeo, H. E. eds. *Generation, Development and Modifications of Natural Fibers* [Online]. London : IntechOpen. [Accessed 05/10/2020]. [Available from: https://cdn.intechopen.com/pdfs/68617.pdf];

90. Karabulut, D.F. (2020). Melt-Blown Fibres vs Electrospun Nanofibres as Filtration Media;

91. Kakilla, C. (2021). Strengths and Weaknesses of Semi-Structured Interviews in Qualitative Research: A Critical Essay. 10.20944/preprints202106.0491.v1;

92. Kiger, M., E. & Varpio, L. (2020): Thematic analysis of qualitative data: AMEE Guide No. 131, Medical Teacher, DOI: 10.1080/0142159X.2020.1755030;

93. Kim, J.; Seo, Y.; Quinn, T.; Yorio, P.; Roberge, R. (2019). Intersegmental differences in facial warmth sensitivity during rest, passive heat and exercise. International Journal of Hyperthermia. 36. 654-659. 10.1080/02656736.2019.1627430.

94. Kloeckner, A. P.; Libanio, C. S.; Ribeiro, J. L. D. (2017). Design Thinking Methods and Techniques in Design Education. International Conference on Engineering and Product Design Education, Oslo and Akerhus University College of Applied Sciences, Norway;

95. Knight, M. Y. (2004). Masks praxis: theories and practices in modern drama. [Online]. Acessed 19/03/2021;

96. Knott, E.; Rao, A.H.; Summers, K. (2022). Interviews in the social sciences. Nat Rev Methods Primers 2, 73, available from: https://doi.org/10.1038/s43586-022-00150-6;

97. Konow, D. (2013). How Foam Latex Spawned a Horror Makeup Revolution. [Online]. Retrieved from: https://www.tested.com/art/movies/458874-how-foam-latex-spawned-horror-makeup-revolution/, accessed on 17/11/2018;

98. Kontomichos, F.; Papadakos, C.; Georganti, E.; Vovolis, T. (2014). The sound effect of ancient Greek theatrical masks. [Online]. Retrieved from: https://quod.lib.umich.edu/cgi/p/pod/dod-idx/sound-effect-of-ancient-greek-

theatrical-masks.pdf?c=icmc;idno=bbp2372.2014.220;format=pdf, accessed on 26/08/2018;

99. Lau, W. (2016). Neri Oxman Designs Rottlace, a Series of 3D-Printed Masks for Björk. [Online]. Retrieved from: https://www.architectmagazine.com/technology/neri-oxman-designs-rottlace-a-series-of-3d-printed-masks-for-bjork_o, accessed on 01/03/2019;

100. Leal. J. (2018). Themes/Innovation: When craft and technology collaborate. [Online]. [Accessed 03/12/2020]. Available from: http://insights.arts.ac.uk/themesinnovation-craft-technology-collaborate/;

101. Learnmakeupeffects, (2016). Valuable Foam Latex Information. [Online]. Retrieved from: http://www.learnmakeupeffects.com/wp-content/uploads/2016/07/Todds-Foam-Latex-Info.pdf, accessed on 10/10/2018;

102. Lee, K. P., Yip, J., Kan, C. W., Chiou, J. C., & Yung, K. F. (2020). Reusable Face Masks as Alternative for Disposable Medical Masks: Factors that Affect their Wear-Comfort. *International journal of environmental research and public health*, *17*(18), 6623. https://doi.org/10.3390/ijerph17186623;

103. Li L.; Li, R.; Li, M.; Rong, Z; Fang, T. (2014). Theoretical selection of solvent for production of electrospun PMMA fibers with wrinkled surfaces. RSC Advances. **4**, 27914-27921;

104. Li, A.; Zaidi, Q. (2004). Three-dimensional shape from non-homogeneous textures: Carved and stretched surfaces. *Journal of Vision.* Vol. 4(10);

105. Liddell, I. (2015). Frei Otto and the development of gridshells. Case studies in structural engineering. Vol 4, pp. 39-49;

106. MacEvoy, B. (2015). Labeling, lightfastness & toxicity. [Online]. [Accessed 15/12/2020]. Available from: https://www.handprint.com/HP/WCL/pigmt6.html;

107. Marder, L. (2019). Types of Watercolor Paint and How It's Made. [Online]. [Accessed 15/12/2020]. Available from: https://www.liveabout.com/types-of-watercolor-paint-4686969;

108. Marshall, J. (2002). Craft and Technology. Presentation at: 'Craft in the twenty-first century' conference, Edinburgh School of Art;

109. Maskarts.com. (2008). Mask Arts Company Commedia dell'Arte Masks. [Online]. Retrieved from:

https://www.maskarts.com/commediadellarte.htm#history, accessed on 25/09/2018;

110. Massachusetts Institute of technology (2019). This flat structure morphs into shape of a human face when temperature changes. [Online]. [Accessed on 05/11/2020]. Available from: https://www.eurekalert.org/pub_releases/2019-09/miot-tf092719.php;

111. Material District (2010). Varaform. [Online]. [Accessed 06/04/2019]. Available from: https://materialdistrict.com/material/varaform/;

112. McQueen, R. H.; Vaezafshar, S. (2020). Odor in textiles: A review of evaluation methods, fabric characteristics, and odor control technologies. *Textile Research Journal*. 90(9-10), pp. 1157-1173. doi:10.1177/0040517519883952;

113. Mehta, P., Haj-Ahmad, R., Rasekh, M., Arshad, M. S., Smith, A., van der Merwe, S. M., … Ahmad, Z. (2017). Pharmaceutical and biomaterial engineering via electrohydrodynamic atomisation technologies. Drug Discovery Today, 22(1), 157–165. https://doi.org/10.1016/j.drudis.2016.09.021;

114. Meier, A. (2016). The Sculptor Who Made Masks for Soldiers Disfigured in World War I. [Online]. Retrieved from: https://hyperallergic.com/314255/the-sculptor-who-made-masks-for-soldiers-disfigured-in-world-war-i/, accessed on 23/11/2018;

115. Merriam, S. B., & Tisdell, E. J. (2015). Qualitative research : A guide to design and implementation. John Wiley & Sons, Incorporated;

116. Millar, R.; Crute, V.; Hargie, O. (2017), Professional Interviewing, Routledge;

117. Mishra, Oly. (2021). Design Thinking and Bricolage for Frugal Innovations during Crisis. Journal of Innovation Management. 9. 1-26. 10.24840/2183-0606_009.003_0002;

118. MIT Media Lab. (2016). Project Rottlace. [Online]. Retrieved from: https://www.media.mit.edu/projects/rottlace/overview/, accessed on 15/02/2018;

119. MoMa. (1991). Modern Masks and Helmets. [Online]. Retrieved from: https://www.moma.org/calendar/exhibitions/344, accessed on 04/03/2019;

120. Monson, K. (1939). Mask-Making Lends Mystery to Crafts. The Iowa Homemaker. Vol. 19(4);

121. Monday, T. (2020). Impacts of Interview as Research Instrument of Data Collection in Social Sciences. Journal of Digital Art & Humanities. 1. 15-24. 10.33847/2712-8148.1.1_2.;

122. Murphy, E. (1998). Qualitative research methods in health technology assessment: a review of the literature. Health Technology Assessment. 2, 16, iii-ix, 1-274;

123. Newton, N. (2010). The use of semi-structured interviews. Retrieved from: http://academia.edu/Documents/in/Semi-Structured_Interviews;

124. Niedderer, K. (2012). 'Exploring Elastic Movement as a Medium for Complex Emotional Expression in Silver Design', *INTERNATIONAL JOURNAL OF DESIGN*, 6 (3), pp. 57-69;

125. Niedderer, K. (2012). Exploring elastic movement as a medium for complex emotional expression in silver design. International Journal of Design, 6(3), 57-69;

126. Niedderer, K. & Townsend, K. (2010). Craft Research: Joining Emotion and Knowledge. The Design Journal. 17. 10.2752/175630614X14056185480221.

127. Nimkulrat, N. (2010). Material inspiration: From practice-led research to craft art education. Craft Research. 1. 63-84. 10.1386/crre.1.63_1.;

128. Nimkulrat, N. (2012). Hands-on intellect: Integrating craft practice into design research. International Journal of Design, 6(3), 1-14;

129. Niu, H.; Zhou, H.; Wang, H. (2019). Electrospinning: an advanced nanofiber production technology. In: Jian Fang, J. and Lin T. eds. Energy Harvesting Properties of Electrospun Nanofibers. [Online]. La Vergne, Tennessee, United States: Lighting Source. [Accessed: 20/20/2020]. Available from: https://iopscience.iop.org/book/978-0-7503-2005-4/chapter/bk978-0-7503-2005-4ch1;

130. Nowell, L. S.; Norris, J. M.; White, D. E.; Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. International Journal of Qualitative Methods, available from: https://doi.org/10.1177/1609406917733847;

131. O'Connor, D. (2017). Disturbingly realistic masks made with Lulzbot 3D Printers. [Online]. Retrieved from: https://www.tctmagazine.com/3d-printing-

news/disturbingly-realistic-masks-made-with-lulzbot-3d-printers/, accessed on 21/01/2019;

132. Oksanen, J. (2017). Project: A proposal of an integrated approach to practice-based, costume-led and craft-oriented research. [Online]. Retrieved from: http://artofresearch2017.aalto.fi/papers/25_Oksanen.pdf, accessed on 20/02/2019;

133. Ontarion Ministry of Labour, Training and Skills Development. (2017). Hand Props, Costumes and Make-Up Safety Guideline for the Live Performance Industry in Ontario. [Online]. Accessed 22/03/2021;

134. Owens, I. (2014). The Mask Making Traditions, Functions and Global Connections Among China, Africa and India. [Online]. Retrieved from: https://www.ncuscr.org/sites/default/files/Ida-Owens-Final.pdf, accessed on 15/11/2018;

135. Ozol, S. (2019). What is Water Vapor Transmission Rate? [Online]. Accessed 16/03/2021. Available from: https://blog.transhield-usa.com/water-vapor-transmission-rate;

136. Parisi, S., Rognoli, V., Sonneveld. M. (2017). Material Tinkering.An inspirational approach for experiential learning and envisioning in product design education. The Design JournalAn International Journal for All Aspects of Design. 20:sup1, S1167-S1184, DOI: 10.1080/14606925.2017.1353059;

137. Patnaik, A., Rengasamy, R. S., Kothari, V. K., & Ghosh, A. (2006). Wetting and wicking in fibrous materials. Textile Progress, 38(1), 1-105. https://doi.org/10.1533/jotp.2006.38.1.1;

138. Pirolini, A. (2014). Materials Used in Movie Prosthetics. [Online]. Retrieved from: https://www.azom.com/article.aspx?ArticleID=8136, accessed on 19/01/2019;

139. Polanyi, M. (1967). Personal Knowledge. London: Routledge & Kegan Paul, p.4;

140. Pollock, D. (1995). Masks and the Semiotics of Identity. The Journal of the Royal Anthropological Institute, Vol. 1(3), pp. 581-597;

141. polyformes.co.uk. (2012). About Plastazote Foam. [Online]. Retrieved from: http://www.polyformes.co.uk/plastazote.html, accessed on 16/01/2019;

142. Pulvers, S. H. (1978). The Noh Mask and the Mask Making Tradition. [Online]. Retrieved from:

file:///C:/Users/Acer/AppData/Local/Temp/b1224871x_Pulvers_Solrun_Hoaas-1.pdf, accessed on 25/11/2018;

143. Raccuglia, M.; Pistak, K.; Heyde, C. (2018). Human wetness perception of fabrics under dynamic skin contact. Textile Research Journal, 88 (19). pp. 2155-2168. ISSN 0040-5175;

References:

144. Ricci, M. (2008). New Technologies and Handmade Craft. [Online]. [Accessed 03/12/2020]. Available from: https://handmade-business.com/new-technologies-and-handmade-craft-2/;

145. Robb, J. (2015). 12 what do things want? object design as a middle range theory of material culture. Archeological Papers of the American Anthropological Association, 26(1), 166-180. https://doi.org/10.1111/apaa.12069;

146. Roberge, R. J.; Kim, J.; Coca, A. (2012). Protective Facemask Impact on Human Thermoregulation: An Overview, The Annals of Occupational Hygiene, Volume 56, Issue 1, Pages 102–112, https://doi.org/10.1093/annhyg/mer069;

147. Rogers, M. (2005). Contextualising Theories and Practices of Bricolage Research. The Qualitative report, vol. 17 (48), 1-17 https://doi.org/10.46743/2160-3715/2012.1704;

148. Roshto, R. E. (1992). Georgie and Allen Manuel and Cajun Wire Screen Masks. [Online]. Retrieved from: http://www.louisianafolklife.org/LT/Articles_Essays/main_misc_cajun_wire_masks.html, accessed on 15/10/2018;

149. Rowsell, J. and Abrams, S.S. (2022). Artifacts with Feelings/Feeling Artifacts: Toward a Notion of Tacit Modalities to Support and Propel Anthropological Research. Anthropology & Education Quarterly, 53: 280-297. https://doi-org.libaccess.hud.ac.uk/10.1111/aeq.12413;

150. Roy, D. (2015). Masks and cultural contexts drama education and Anthropology. International Journal of Sociology and Anthropology. Vol. 7(10), pp. 214 – 218;

151. Roy, D. (2016). Masks in Pedagogical Practice. Journal for Learning through the Arts, 12(1);

152. Saha, S. (2020). Different Types of Face Masks. [Online]. Retrieved from: https://www.onlineclothingstudy.com/2020/04/different-types-of-medical-masks.html, accessed on 09/07/2020;

153. SalehHudin, H. S., Mohamad, E. N., Mahadi, W. N. L., & Muhammad Afifi, A. (2018). Multiple-jet electrospinning methods for nanofiber processing: A review. Materials and Manufacturing Processes, 33(5), 479– 498. https://doi.org/10.1080/10426914.2017.1388523;

154. Salehhudin, H., Mohamad, E.; Mahadi, W.; Afifi, A. (2017). Multiple-jet electrospinning methods for nanofiber processing: A review. Materials and Manufacturing Processes. 33. 479-498. 10.1080/10426914.2017.1388523;

155. Samerender, N. H. and Smitha, M. (2019). Multi-Functional Electrospun Nanofibers from Polymer Blends for Scaffold Tissue Engineering. Fibers. 7. 66. 10.3390/fib7070066;

156. Sandberg, S. (2015). Roman Theatre Masks. [Online]. Retrieved from: http://www.uwgbcommons.org/archives/31920, accessed on 16/09/2018;

157. Sandelowski, M. & Barroso, J. (2003). Classifying the findings in qualitative studies. Qual Health Res. 13(7):905–923;

158. Schon, D. A. (1991;1992;1994;). The reflective practitioner: How professionals think in action. Arena, Ashgate Publishing. https://doi.org/10.4324/9781315237473;

159. Selde, K. (2012). Usefulness of mask technique for actors from different backgrounds. [Online]. Retrieved from: https://www.theseus.fi/bitstream/handle/10024/46893/Kaisa%20Selde%20%20-%20for%20merge.pdf?sequence=1, accessed on 21/01/2019;

160. Selde, K. (2012). Usefulness Of Mask Texhnique For Actors From Different Backgrounds. [Online]. Accessed 17/03/2021. Available from: https://www.theseus.fi/bitstream/handle/10024/46893/Kaisa+Selde++-+for+merge.pdf;jsessionid=8D929843B3806A2C3100E8EA6DFBC16E?sequence=1;

161. Sharp, H. (2019) 'Bricolage research in history education as a scholarly mixed-methods design'. History Education Research Journal, 16 (1): 50–62. DOI https://doi.org/10.18546/HERJ.16.1.05;

162. Siano, P. (2015). Types of Traditional Venetian Carnival Masks and Costumes. [Online]. Retrieved from: https://www.touritalynow.com/blog/types-of-traditional-venetian-carnival-masks-and-costumes/, accessed on 14/10/2018;

163. Siegel, A. M. (2018). Masks: A New Face for the Theatre. James Madison Undergraduate Research Journal. Volume 6 | Issue 1, pp. 6-17;

164. Slusser, R. (2006). SPFXMasks Uses Space-Age Silicone Materials to Create Halloween Masks with Unsurpassed Realism. [Online]. Retrieved from: https://www.prweb.com/releases/2006/11/prweb477140.htm, accessed on 25/11/2018;

165. Smith, R. (2008). Face Time: Masks, Animal to Video. [Online]. Retrieved from: https://www.nytimes.com/2008/01/11/arts/design/11mask.html, accessed on 28/02/2018;

166. Song, G. (2011). Improving comfort in clothing. Woodhead Publishing Limited, Cambridge, UK;

167. Spina, A. M. & Levine, H. J. (1999). Latex allergy: A review for the dental professional. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, Vol. 87 (1), pp. 5-11;

168. Stanger J, Tucker N, Wallace A, Larsen N, Staiger M, Reeves R. The Effect of Electrode Configuration and Substrate Material on the Mass Deposition Rate of Electrospinning. J Appl Polym Sci 2009; 112: 1729;

169. Stewart, C. L.; Thornblade, L. W.; Diamond, D. J.; Yuman, F.; Melstrom, L. G. (2020). Personal Protective Equipment and COVID-19. Annals of Surgery. Volume Publish Ahead of Print Issue.

170. Sullivan, K. (2017). The Brutality and Delicacy of Samurai Armor: Superior Protection with a God-like Aesthetic. [Online]. Retrieved from: https://www.ancient-origins.net/artifacts-other-artifacts/brutality-and-delicacy-samurai-armor-superior-protection-god-aesthetic-021344, accessed on 17/12/201;

171. Susniene, D. and Purvinis, O. (2015). Empirical insights on understanding stakeholder influence. Journal of Business Economics and Management, Volume 16(4), pp. 845–860;

172. Tan, G. Z. and Zhou, Y. (2018). Tunable 3D Nanofiber Architecture of Polycaprolactoneby Divergence Electrospinning for Potential Tissue Engineering Applications. Nano-Micro Letters. Vol 10 (73), pp. 71-73;

173. The-noh.com. (2008). Is it true that Noh actors' hearts beat as fast as those of athletes? [Online]. Retrieved from: http://www.the-noh.com/en/trivia/046.html;

174. Thurston, J. (1990). The Prop Builder's Mask Making Handbook. Batterway Books: Cincinnati, Ohio, USA;

175. tribal-art-auktion.de. (2017). Helmet mask "sowei". [Online]. Retrieved from: https://www.tribal-art-auktion.de/en/open-sale/object/helmet-mask-sowei-3041704/, accessed on 26/11/2018;

176. Trickortreatstudios. (2010). Why Latex Halloween Mask? [Online]. Retrieved from: http://trickortreatstudios.com/blog/why-latex-halloween-mask/;

177. Tsagkrasoulis, D.; Hysi, P.; Spector, T.; Montana, G. (2017). Heritability maps of human face morphology through large-scale automated three-dimensional phenotyping. *Scientific Reports* 7, 45885. https://doi.org/10.1038/srep45885

178. Tsagkrasoulis, D.; Hysi, P.; Spector, T.; Montana, G. (2017). Heritability maps of human face morphology through large-scale automated three-dimensional phenotyping. *Scientific Reports* 7, 45885. https://doi.org/10.1038/srep45885

179. Tucker, E. (2016). Björk unveils 3D-printed mask based on her musculoskeletal system. [Online]. Retrieved from: https://www.dezeen.com/2016/06/30/bjork-3d-printed-rottlace-mask-musculoskeletal-system-neri-oxman-stratasys/, accessed on 01/03/2018;

180. umusetsu.org. (2005). Rites of Passage: An Ode to Humanity & Culture. [Online]. Retrieved from: http://www.umusetsu.org/rites-of-passage, accessed on 10/01/2019;

181. Vasileiou, K.; Barnett, J.; Thorpe, S.; Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. BMC Med Res Methodol. ;18(1):148. doi: 10.1186/s12874-018-0594-7. PMID: 30463515; PMCID: PMC6249736;

182. Vallgårda, A. K. A. (2009). Computational Composites: Understanding the Materiality of Computational Technology. IT-Universitetet i København;

183. Vass, P.; Szabó, E.; Domokos, A.; Hirsch, E.; Galata, D.; Farkas, B.; Démuth, B.; Andersen, S. K.; Vigh, T.; Verreck, G.; Marosi, G.; Nagy, Z. K. (2020). Scale-up of electrospinning technology: Applications in the pharmaceutical industry. *WIREs Nanomedicine and Nanobiotechnology*, 12(4): e1611.https://doi.org/10.1002/wnan.1611;

184. Vilhena, L. and Ramalho A. (2016). Friction of Human Skin against Different Fabrics for Medical Use. Lubricants, Volume 4(1), 6, 10.3390/lubricants4010006. Available from: https://www.mdpi.com/2075-4442/4/1/6/htm;

185. Vovolis, T. & Zamboulakis, G. (2008). The Acoustical Mask of Greek Tragedy. [Online]. Retrieved from: https://www.didaskalia.net/issues/vol7no1/vovolis_zamboulakis.html, accessed on 10/10/2018;

186. Vovolis, T.; Tsilfidis, A.; Georganti, E.; Mourjopoulos, J. (2013). Function and Acoustic Properties of Ancient Greek Theatre Masks. Acta Acustica united with Acustica 99(1);

187. Wang, N.; Burugapalli, K.; Song, W. (2013). Tailored fibro-porous structure of electrospun polyurethane membranes, their size-dependent properties and trans-membrane glucose diffusion. Journal of Membrane Science. Jan;427:207-217. DOI: 10.1016/j.memsci.2012.09.052. PMID: 23170040; PMCID: PMC3500561;

188. Wei, Z. (2018). IOP Conf. Ser.: Mater. Sci. Eng. 452 022002;

189. Wiles, D. (2017). Greek Theatre Performance - an Introduction. Cambridge University Press, Cambridge;

190. Wingert, P. S. (2015). Mask. Face Covering. [Online]. Retrieved from: https://www.britannica.com/art/mask-face-covering, accessed on 16/11/2018;

191. Wonderflexworld.com. (2017). FOSSHAPE® – Frequently Asked Questions. [Online]. Retrieved from: https://www.wonderflexworld.com/faq/fosshape/, accessed on 16/01/2019;

192. Woodward, M. C. (2000). Masks: Let's Face It. The Cleveland Museum of Art. [Online]. Retrieved from:

https://www.clevelandart.org/sites/default/files/documents/teacher-guide/masks.pdf, accessed on 06/11/2018;

193. Woodward, S. (2016). Object interviews, material imaginings and 'unsettling' methods: interdisciplinary approaches to understanding materials and material culture. Qualitative Research, 16(4), 359–374. https://doi.org/10.1177/1468794115589647;

194. Xie, J.; Li, X.; Xia, Y. (2009). Putting Electrospun Nanofibers to Work for Biomedical Research. Macromolecular Rapid Communications, 29(22), pp. 1775–1792;

195. Xue, J., Wu, T., Dai, Y., & Xia, Y. (2019). Electrospinning and Electrospun Nanofibers: Methods, Materials, and Applications. Chemical reviews, 119(8), 5298–5415. https://doi.org/10.1021/acs.chemrev.8b00593;

196. Yaeger, L. (2020). The Artists Keeping Up the Tradition of Mask-Making. [Online], accessed 01/04/2020, available from: https://www.nytimes.com/2020/02/17/t-magazine/fashion-masks.html;

197. Yang, Y.; Qlang, L.; Wang, L.; Guan, Z. (2008). Effect of electric field distribution uniformity on electrospinning. Journal of Applied Physics. 103, 104307;

198. Yanilmaz, M., & Kalaoglu, F. (2012). Investigation of wicking, wetting and drying properties of acrylic knitted fabrics. Textile Research Journal, 82(8), 820-831. https://doi.org/10.1177/0040517511435851;

199. Yee, J. & Bremner, C. (2011). Methodological bricolage: What does it tell us about design?;

200. Yee, J.S., & Bremner, C. (2011). Methodological bricolage: What does it tell us about design?

201. Yousefzadeh, M., Latifi, M., Tehran, M. A., Teo, W., Ramakrishna, S. (2012). *A Note on the 3D Structural Design of Electrospun Nanofibers*. Journal of engineered fibers and fabrics Vol. 7(2), p.p. 17-23. [Available from: https://www.researchgate.net/publication/230578332_A_Note_on_the_3D_Structural_Design_of_Electrospun_Nanofibers] [accessed Oct 05 2020];

202. Zhang, D.; Chang, J. Electrospinning of three-dimensional nanofibrous tubes with controllable architectures. Nano Letters 2008, 8(10), 3283-3287;