

THE UNMASKED TRUTH

SILICA'S SILENT IMPACT ON OCCUPATIONAL HEALTH:
A REPORT BY DARCY DUCKWORTH



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AUTHENTICITY STATEMENT

This is to certify that to the best of my knowledge; the content of this report is my own work. This report has not been submitted for any subject or for other purposes. I certify that the intellectual content of this report is the product of my own work and that all the assistance received in preparing this report and sources have been acknowledged.

I have utilised AI in this report (Atlas.ti & Otter.ai) to assist in various ways. The way I have used AI includes assistance in transcribing and coding interview and survey results. This data was then check and refined if needed by me.

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“Thank you to the unit coordinators, tutors and fellow peers of DNB311 2023 for supporting the progress of this report and my final year capstone project.”

Darcy Duckworth

The Queensland University of Technology (QUT) and I acknowledges the Turrbal and Yugara people, as the First Nations owners of the lands where QUT now stands. We pay respects to their Elders, lores, customs and creation spirits. We recognise that these lands have always been places of teaching, research and learning and that sovereignty was never seeded. QUT acknowledges the important role Aboriginal and Torres Strait Islander people play within the QUT community.

KEY WORDS

PPE

Personal Protective Equipment

RCS

Respirable Crystalline Silica

LEV

Local Exhaust Ventilation

ABSTRACT

The aim of this report is to identify the key issues construction workers face with wearing respirators and why they are not being worn for personal protection against occupational lung diseases. Despite being entirely preventable, Australians are still developing silicosis which is now being called 'the new asbestosis'. Secondary research from the literature review found gaps in academic papers surrounding respirator mask leakage in the construction industry and how facial hair affects the seal of the respirator. To further explore these gaps a survey and interview were developed to deploy to construction workers from any trade background. Initial results from 26 survey responses and 3 interviews found that majority of construction workers understand the risks of developing occupational lung diseases but continue to not wear respirators. Further results found the key issues stemmed from discomfort, adjustability, inconvenience, and temperature issues. 3D scanning technology was explored in the literature review to understand the viability of using this technology to create custom fit respirators in a digital fit test environment to increase pressure distribution and therefore comfort. Surrounding industries such as medical masks and military pilot oxygen masks found success in using 3D scanning to reduce leakage and improve pressure distribution. The survey and interview results also found workers can be put into two categories of risk levels when considering dust exposure. 'Low risk, low exposure' pertaining to those cutting medium to low silica concentration materials semi regularly and 'High risk, high exposure' for those cutting high concentration silica materials regularly. Current safety equipment has been developed for those in the high-risk category however little design intervention has been developed for those in lower risk situations. Moving forward the respirator will be designed to target key issues facing construction workers who fit into the low-risk category to have the most impact in silicosis statistics.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

BACKGROUND

AIM

OBJECTIVES

INTRODUCTION

This report investigates the way occupational lung diseases and personal protective equipment (PPE) affect the health and productivity of construction workers and tradesmen. It discusses opportunities for design interventions in the PPE industry that could increase mask comfort, and protection against airborne particles entering the respiratory system. An understanding of the underlining problems will be explored through survey results and interviews to quantify data and make conclusions to suggest 5 different design interventions. Aiming to reduce exposure to airborne particles and increase mask wearing in the construction industry.

BACKGROUND

Hailed as the asbestosis of the 2020's, the threat silicosis poses to constructions workers and tradesmen is becoming better understood. Silicosis is a long-term type of pulmonary fibrosis caused by inhaling silica minerals often found in natural and artificial stone. Over time silica particles cause lung inflammation and result in scarring of lung tissue resulting in lung capacity decreases and increased risk of cancer. Research suggests that 29% of Australian lung cancer is caused by occupational lung diseases such as silicosis, black lung, and asbestosis (Hoy & Brims, 2017). Silicosis is untreatable; however, it is entirely preventable, despite this silicosis is estimated to be silently affecting 584,000 working Australians who are exposed to drilling or cutting, natural and artificial stone such as concrete and granite (ACTU, 2022).

Silicosis is a preventable disease that associated risks of exposure can be mitigated by using personal protective equipment and dust suppression methods such as water suppression. Developments in technology surrounding 3D printing, scanning and mass customisation are paving the way for designers to develop comfortable respirators that addresses the key concern of masks from construction workers. Adjacent industries such as military aircraft oxygen masks (Wonsup et al., 2013), and effective masks for the medical industry targeting Covid-19 (Carter et al., 2021) are using these technologies to develop and enhance user experience and protection by improving the masks seal. A gap in literature and market research on respirators has found the need for better mask fitment and design to prevent occupational lung diseases.

AIM

The aim of this report is to identify the key issues construction workers face with wearing respirators and why they are not being worn for personal protection against occupational lung diseases.

OBJECTIVES

- Study and understand the problems associated with current off the shelf respirators.
- Gather and analyse data for human focused design and how the user interacts with their current respirators.
- Design and develop solutions using alternative technologies from surrounding industries solve current interaction issues that are not currently on the market

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THE SAFEST MASK
IS THE MASK THE USER
CHOSES TO WEAR.

100 AUSTRALIANS SILENTLY
AFFECTED BY SILICOSIS (ACTU, 2022)

10% OF LUNG CANCER POTENTIALLY
LINKED BY OCCUPATIONAL LUNG
DISEASES (HOY & BRIMS, 2017)

02

CHAPTER 02

LITERATURE REVIEW

INTRODUCTION OF SILICOSIS EPIDEMIC AND STATISTICS

PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS ON WEARABILITY

RESPIRATOR FITMENT

3D SCANNING TECHNOLOGIES

APPLICATION OF 3D SCANNING TECHNOLOGIES IN MASK DESIGN

LITERATURE REVIEW

With the introduction of artificial stone bench tops and rising rates of occupational lung disease is one of the most common work-related injuries (Arlene & Kanne, 2009); despite federally mandated safety standards on worksites and being completely preventable. Extrapolated Finnish data suggests roughly 29% of lung cancer cases in Australia may be due to inhaled dust exposure (Hoy & Brims, 2017). This data is supported by a study which estimated 10%-30% of global lung cancer cases may be attributable to hazardous occupational exposures (Arlene & Kanne, 2009). This literature review aims to explore and identify the problems of respiratory masks used in the prevention of occupational lung disease in the construction industry.

INTRODUCTION OF SILICOSIS EPIDEMIC AND STATISTICS

Respirable Crystalline Silica (RCS) is becoming a global contributor to occupation lung disease cases and is being called a silent endemic (Turner et al., 2019). It is estimated that a total of 584,050 Australian workers are exposed to RCS which occurs when products such as natural and artificial stone are processed via drilling, cutting, or grinding (ACTU, 2022). Inhaled dust can result in lung tissue damage and lung disfunction as the disease progresses (Leung et al., 2012) it can become fatal (Austin et al., 2021). Literature supports that silicosis is a completely preventable and untreatable disease (Austin et al., 2021; Hoy et al., 2022; Leso et al., 2019). The development of silicosis depends on several factors including “lifetime cumulative exposure, total amount of inhaled RCS and individual genetic susceptibility” (Leso et al., 2019). Workers from small business, immigrants and casual staff may be more susceptible to RCS exposure (Hoy et al., 2022) due to limited dust suppression or extraction methods.

An Australian National Dust Disease Taskforce was established to address RCS in the workforce. One hundred and five members of the Australian Institute of Occupational Hygienists were surveyed and found that based on professional experience, 71% were concerned about the potential for RCS over-exposure. With the top barriers of reducing exposure coming down to poor management, commitment, and lack of financial resources (Cole

et al., 2022). Akbar-khazadeh and Brillhart (2002) found more control methods such as Local Exhaust Ventilation (LEV) and personal respirators, as well as administrative controls, would help reduce RCS exposure on workers.

PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS ON WEARABILITY



Figure 1, *Construction worker demonstrating correct usage of disposable respirator*

(Jones, 1991) found that wearing disposable N95 face masks were proven to increase respiratory rate, heart rate, blood pressure and increase anterior face temperatures by an average of 7.5 degrees Celsius . It was concluded that there are physiological costs to wearing a face mask especially at medium to heavy workload. Similarly, Johnson et al. (1997) found although visual acuity was not compromised by wearing a mask with varying levels of clouded lenses, subjects work performance was affected by other mask factors such as respiratory stress, thermal stress, and other vision elements. Furthermore, Johnson et al. (1995) explored the influence of anxiety levels on work performance with and without masks found that participants performed a workload quicker without the mask. Anxious subjects experienced more discomfort adding to the physiological cost of mask wearing. White et al. (1988) found a decrease in speech intelligibility as distance increased when wearing a respirator. Johnson (2016) and Salaza et al. (2001) found respiratory masks influence “respiration, thermal equilibrium, vision, communication, feelings of well-being, personal procedures such as eating and sneezing and other equipment”. They also noted individuals experience different negative effects, with some worse than others. The negative effects of face masks are reducing the quality and duration of participants work. User focused design particularly around physiological considerations could have a large effect on the psychology of wearing a mask

(Johnson & Cummings, 1975). A 1988 study explored social influences as determinants of respirator usage among construction painters which found the most important beliefs concerned discomfort and inconvenience. Despite the studies age, it still holds relevance today as recent reports agree with this claim (Johnson & Cummings, 1975).

RESPIRATOR FITMENT

Wearability and minimising negative physiological and psychological effects are important when considering mask design (Johnson & Cummings, 1975). The overall effectiveness of protection is another large area of design consideration. Adhikari et al. (2018) suggests N95 masks are 95% protective against most categories of smaller particles of 11.5nm and 20.5nm and therefore the filter material mostly protects the user from silica dust passing the filter. However, the effectiveness of a mask worn by a user varies when considering the fitment of the mask as face seal leakage diminishes the effectiveness of the mask. A study on half face respirators found “Fit checks were found to be fairly useful, easy-to-learn tools for respirator wearers to discriminate between good and poor fitment” (Myers et al., 1995). However, most respirator brands only offer a one size fits all, with some brands offering a “custom” fit of small, medium, and large sizes. From survey results further discussed in this report, it was found that fitment was a large reason for discomfort. There is minimal research specifically on construction industry respirator leakage. However, a survey conducted by the Korean Air Force (KAF) in 2006 found a large percentage of pilots wearing MBU-20/P oxygen masks identified significant mask leakage around the nasal root due to poor fitment. This was solved using 3D facial scans to create custom fitting oxygen masks (Wonsup et al., 2013).

3D SCANNING TECHNOLOGIES

During the Covid-19 pandemic and the uptake and increased usage of personal respirators in the medical field inspired new research into custom fit respirators to improve comfort and increase effectiveness. With the accessibility and technological improvements to 3D scanning and cloud-based printing (Kang et al., 2023), 3D scanners can accurately capture three-dimensional format within a few seconds. This technology is being successfully used in the medical industry to create unique, custom fit for user

prosthetics, dental appliances, custom implants, and custom orthosis (Haleem & Javaid, 2019; Leong et al. 2022). A report by Swennen et al. (2020) found a full-face 3D scan could be exported in 2 minutes and 30 seconds. Mass customisation techniques and services (Shu et al., 2022) for custom fit respirators could allow workers access to comfortable and effective personal protective equipment (PPE).



Figure 2, - Image of 3D scanning application in the dental industry.

APPLICATION OF 3D SCANNING TECHNOLOGIES IN MASK DESIGN

Wonsup et al. (2013) found success in facial 3D scanning and collection of facial measurements, surface area and volume, and utilised computer aided design (CAD) for virtual fit evaluation. Healthcare applications for custom fit medical face masks were found to conform accurately to specific and unique facial features. This work showed evidence that personalised respirators are more comfortable to wear during long and stressful working operations. Another medical study by Carter et al. (2021) found all volunteers wearing custom fit prototype 3D scanned face masks passed a qualitative fit test, noting the effectiveness of protection for the user. A similar study found there was no sacrifice in communication with the masks despite a face conforming fit with minimal gaps or leakage (Roche et al., 2022). All covered literature followed a similar methodology using a 3D scanned CAD model and a Boolean operation to subtract the face from a mask gasket in CAD, which could be 3D printed, casted, or subtractive manufacturing using a hotwire on a 5 axis robotic arm. This methodology could be used in increasing end user comfort and safety when applied to the construction industry in the prevention of occupational lung disease.

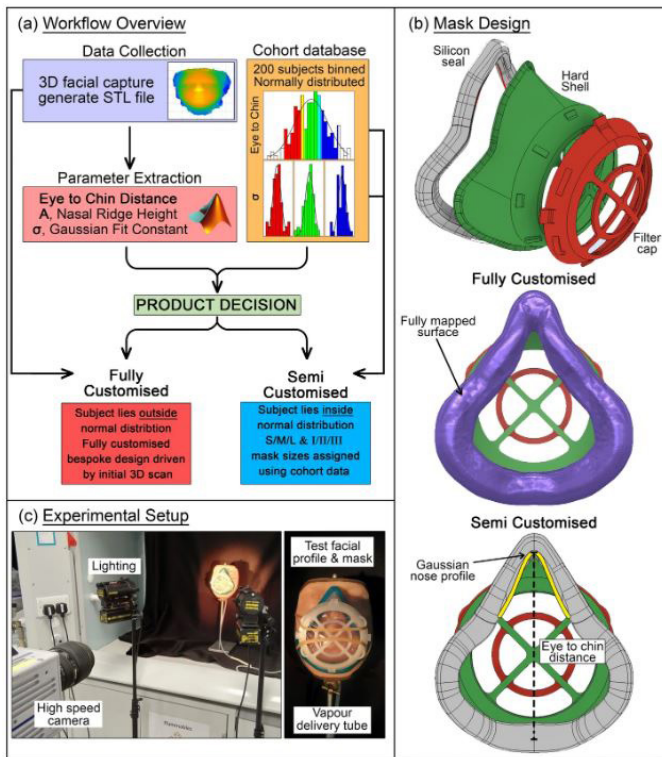


Figure 3, - Carter et al., (2021). *A feasible route for the design and manufacture of customised respiratory protection through digital facial Capture*

Gaps

- Lack of reports around respirators (N95 + half or full face) leakage or fitment in construction zones
- No mention of facial hair interference with mask seals

In conclusion, the literature report found evidence that using mass customisation and 3D scanning technologies could have positive effects on the physiological and psychological impact of respiratory PPE for construction workers. Customised masks have the potential to increase comfort, wearability, and effectiveness in prevention of occupational lung diseases such as silicosis.

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**Respirable Crystalline
Silica (RCS) is becoming
a global contributor to
occupational lung disease
cases** (Turner et al., 2019)

**Reusable N95 face masks were proven
to increase respiratory rate, heart rate,
blood pressure and increase anterior face
temperatures by an average of 7.5 degrees
Celsius** (Johnson et al., 1997)

**Engineered respirators are more
comfortable to wear during long and stressful
working operations** (Carter et al., 2021)

03

CHAPTER 03

RESEARCH OVERVIEW

RESEARCH DESIGN

SURVEY DESIGN

INTERVIEW AND OBSERVATION DESIGN

RESEARCH DESIGN

The literature review found there were gaps in the research relating to respirator fitment specifically in construction environments and a lack of analysis on facial hair interference with the respirators. A survey and, semi structured interview and observation were used to retrieve qualitative and quantitative data from key users in the construction industry. These methods of data gathering were chosen to understand context, background, wearability issues and design problems associated with personal respirators of N95 or half face design. Participants from any construction industry were asked to complete the survey deployed via social media. Social media seemed the most effective way to get response due to the ability to share and reach larger audiences. In person recruitment of survey participants at a silicosis rally was also deployed to get data from union members concerned about government regulations surrounding silica exposure and safety.

SURVEY DESIGN

The purpose of the survey is to gather quantitative and qualitative data from constructions workers who frequently use respirators on-site. The survey was designed to be as concise and comprehensive as possible to reduce time taken from participants and therefore encourage them to complete the survey.

Typical format for questions asked in to different scales.

Rate the comfort of your respirator from 1-5
26 responses

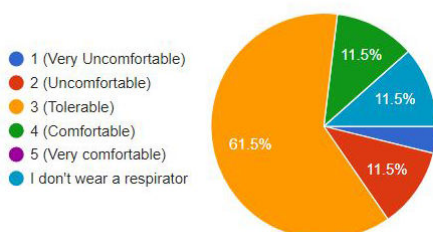


Figure 4, Example of Likert scale

Have you been required to undergo a fit-test for your respirator?
26 responses

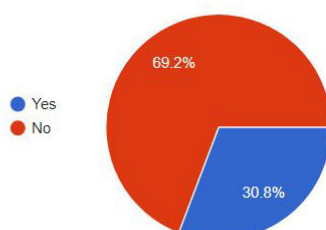


Figure 5, Example of Binary scale

The Likert Scale was used for quantitative questions when applicable, otherwise participants used a binary Yes/No response. The participants were also asked to answer a short response on aspects of respirators they found irritating or uncomfortable. Users who gave a short answer response on “Is there any aspect of wearing a respirator that you find uncomfortable or irritating?” gave qualitative results. Therefore, thematic analysis was used to quantify written data into key themes that could be tallied and compared.

INTERVIEW AND OBSERVATION DESIGN



Figure 6, Task equipment: (Top) glasses, (middle) respirator, (bottom) hard hat

An audio recorded semi structured interview and observation were conducted with 3 participants. The purpose was to see how users engaged with a medium sized 3M Facemask, glasses and a hard hat. A set of pre organised questions were asked when needed to prompt the participants. Questions were designed to identify issues relating to the gaps found in the survey such as effectiveness, seal gaps and facial hair interference. These questions were informed by the literature review and gaps in academic papers.

Feelings (qualitative)
Stress levels?
Vision impairment?
Pressure points?
Gaps?
Facial hair around seal?
Comfort / discomfort?
Weight?
Material feeling?
When would you feel the need to wear a mask?

Table 1, Qualitative prompts used in interview

As participants completed the interview, observational notes were taken during the 4 tasks the participants was asked to do noting various pain points in the design, fitment, or wearability of the mask. These tasks emulated the real world conditions the user would need to do to be protected from silica dust. The participants were asked to put on the mask, put on mask with other PPE, momentarily take off mask and lastly take off mask.

Task: Put on mask
Qualitative notes
Not sure how straps connect around back of neck on first setup.
Hard to reach around back of head.
No trouble tightening.
Multiple re-adjustments to get right fit.
Hard to hear when user has mask on.
Can't lift head up, pulls on back of neck, pull mask, pressing on chin.
Not tight around the nose
No pain in straps above ears
heavy on face
Not too bad breathing
Stuffy
Dexterity issues tightening straps.

Table 2, Example of qualitative notes taken during observation

After completing each task, they were asked for quantitative data on difficulty, inconvenience, and comfort where applicable. The data was then coded via the same methods used for the survey. Dialogue was recorded and transcribed with Otter AI, with all errors corrected. Given the nature of the conversation there were many grammatical errors spoken which have been included in the transcription.

Examples from conversation:

Darcy Duckworth

"Is irritating with your beard pushing into your face?"

Participant 3

"No. I'm probably happy about but it's I think I'm finding this one. particularly annoying right now is because I've got a different brand. I don't know the brand that I've been using been using recently. This mask is just too small. This is just it feels like it's coming down. Okay. Just pull them down."

Darcy Duckworth

"Any vision impairments? Do you feel comfortable wearing it? Like visually? Do you find it annoying is it ok?"

Participant 3

"Yeah, as I say, like, is this still annoying right now? Like more annoying than I'm used to right now. pulling it down. So, it's pulling on my nose. On the bridge of my nose."

Darcy Duckworth

"And are there any other comments on the on the fitment of the mask?"

Participant 3

"It sort of feels like it's compressing in or I can feel it almost dragging my face down a bit. I can almost feel tension on my eyes almost."

04

CHAPTER 04

ANALYSIS & DISCUSSION

SURVEY ANALYSIS

INTERVIEW & OBSERVATION ANALYSIS

DISCUSSION

GAPS IN RESEARCH

LIMITATIONS

SURVEY ANALYSIS

QUALITATIVE

Thematic analysis methods were used throughout the survey to group themes by category, making it easier to understand and represent written words into key themes. This type of analysis was used to help compare qualitative and quantitative data allowing for clear and consistent discussion. Quantitative results were coded by Atlas.ti to help understand the underlying meaning of the response. The large language model was used to initially code the data which was then refined by combining key ideas into concise categories.

Examples of coding for survey question, “Is there any aspect of wearing a respirator that you find uncomfortable or irritating?”

Short Response	Code
hot, sweaty, itchy, P2 masks ear loops suck after a while, full face respirators are hard to keep fog free and scratch free and in BA applications to keep a good seal the mask puts a lot of pressure on the face and jaw, causing discomfort and pressure injury's	Displeasure Temperature Discomfort
Difficult to breathe normally	Discomfort
Straps, glasses, sweat,	Wearing Glasses, Adjustment Temperature Discomfort

Table 3, Examples of coded data from survey results



Figure 7, Mapping coded data from survey

Thematic analysis of short responses in the survey found discomfort and temperature to be equally problematic for the survey participants. Other users experienced having issues with wearing glasses with a mask and strap adjustments. One user noted having a negative experience with the mask and their beard despite facial hair not being permitted for mandatory fitment tests.

QUANTITATIVE ANALYSIS

Research method	Description and number of responses
Surveys	26 responses from construction workers 3 Carpenters 2 Cabinet maker 5 Electrician 3 Technician 2 Boiler maker 2 Dogman 3 Land scaping Painter Site Engineer Estate upkeep Roofing Surveyor

Table 4, Total number of responses and their respective trade backgrounds

Do you wear respirators when not required at work?
26 responses

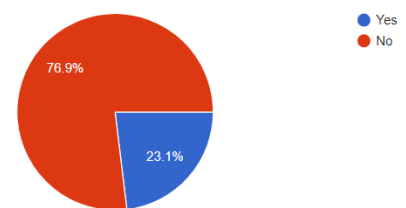


Figure 8, Survey question “Do you wear a respirator when not required at work?”

Results from 26 responses over 12 backgrounds found that different occupational backgrounds in construction wore masks for different time periods depending on their work tasks. The survey found that 88.5% of the sample group reportedly understood the risks associated with RCS exposure. Noting a further 7.7% somewhat understood the effect of silica on the

lungs. Understanding of the risks of silica exposure was dependent on the construction site risk factors, some jobsites such as tier 1 construction zones require workers to undertake online safety modules and complete a tight respirator fit test before going on site. Within the safety course workers are taught about the dangers of occupational lung diseases and prevention methods. Results found that 69.2% of the sample group have not undergone a fit test. Depending on the job site risk and activities, some small business owners may take the risk of not wearing PPE as its unlikely a health and safety officer will be on their worksite. Despite 88.5% of the survey agreeing that they are aware of the effects of silica dust on the lungs 76.9% of the survey results reported not wearing a mask when not required. The survey further found 61.5% of the participants experience a tolerable comfort level when wearing their mask. Majority of participants use their masks for 2 hours or less, with 30.8% wearing the masks for 1 to 2 hours at a time.

INTERVIEW & OBSERVATION ANALYSIS

Research method	Description and number of responses
Interview & Observation	10-minute interview and observation - 3 workshop technicians

Table 5, Total number of responses from the interview and their trade backgrounds

Short Response	Code
“Like it’s stuffy. It is stuffy but as far as masks go its not like the worst getting a bit hot. Moist and condensation.”	Temperature
“just the nose like the size of it would get uncomfortable but otherwise it gets a small price to pay for pesticides and dust. You I knew if I had to wear every day for eight hours. Yeah. I’d have to find something better”	Discomfort

“And then time as well if I’ve got to do something with a little bit you know, it’s not a huge amount for a couple of minutes. I’ll probably not put on a respiratory.”	Time-consuming Inconvenience
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Table 6, Examples of coding from interview dialogue

OtterAi was used to convert recorded audio from the interviews into text, which was then verified before analysis. Thematic analysis was then applied via Atlas.ti which uses a large language model to categorise statements into themes with any errors being corrected manually. The following results found that the three participants struggled the most with adjustment and inconvenience followed by discomfort, frustration, and time-consumption. Due to the small sample size of data collection and lack of subjects with facial hair, beard interference with the seal was rarely mentioned. It is important to note the semi structured conversation that could lead to inherent biases as the interviewer prompted the interviewee. Thematic analysis identifies key underlying themes in conversation therefore if a participant mentions discomfort multiple times these results will be added together, potentially inflating the data.



Figure 9, Mapping coded data from Interview

Interview results found that adjustments were the most mentioned underlying category of comments. With inconvenience, discomfort and frustration following in count. Due to limited participation of observation and interviews it is difficult to draw conclusions with insufficient data. However, this data can be interpreted and compared against the other survey results to understand the key gaps identified by the literature review.

COMPARING RESULTS

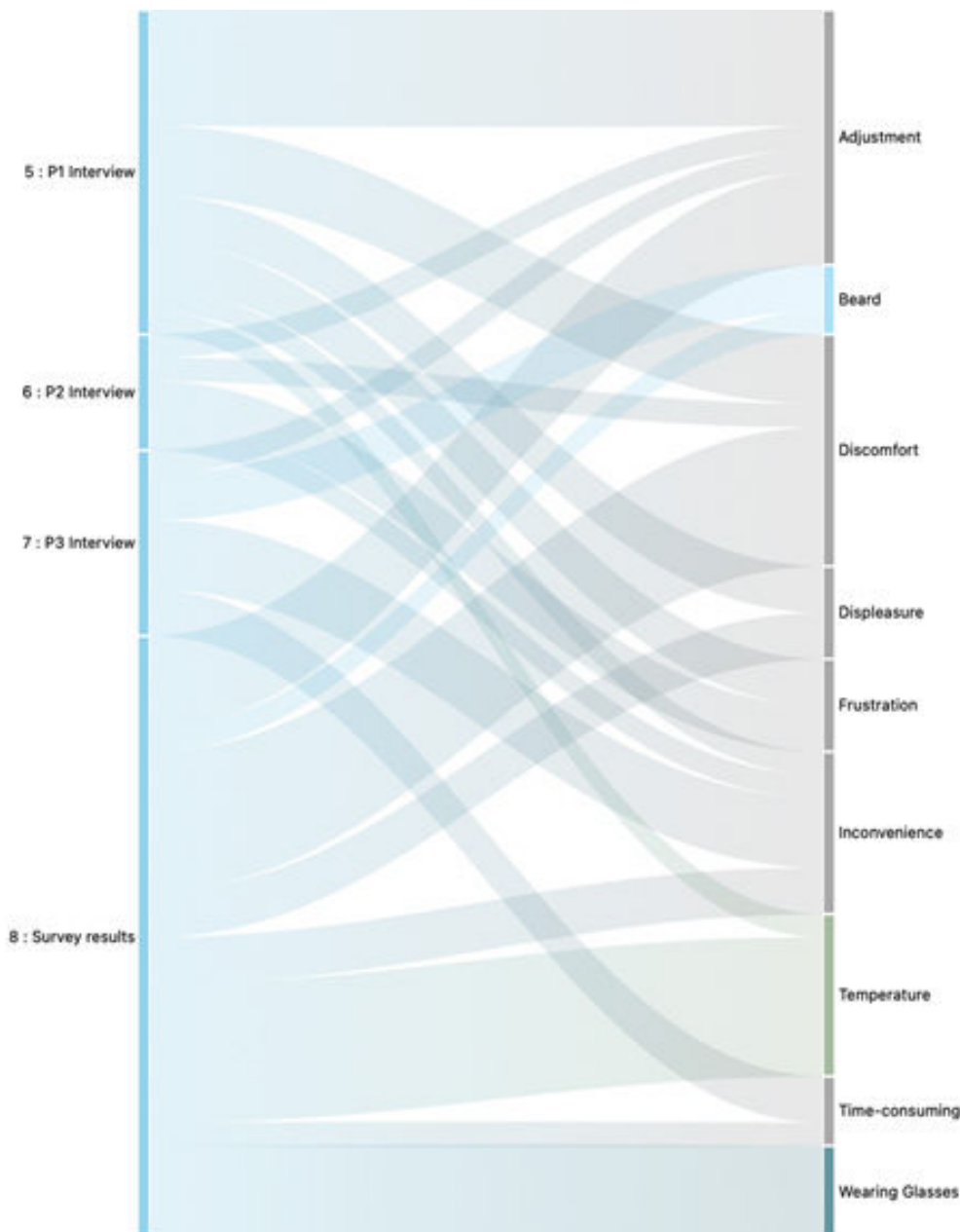


Figure 10, Sankey diagram comparing survey and interview coded data.

Using a Sankey diagram all quantifiable spoken data was categorised and linked to the respective data collection methods this allowed for easy visualisation of the data source and weighting. This method of visualisation shows equal weighting between 3 interviewees compared to 26 survey results, resulting in an unfair comparison. Also showing that in a semi structured setting, a user may talk more about a specific problem and therefore result in more coded analysis in their dialogue. Observational notes were excluded from this comparison which will further be talked about in the discussion. However, observational data can still be useful to inform design decisions in the design phase.

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Findings from Primary research

Discomfort

Adjustment

Temperature

Convenience

88.5% of the survey agreeing that they are aware of the effects of silica dust on their health. 76.9% of the survey results reported wearing a mask when not required.

Survey further found 61.5% of the participants experience a 'tolerable' comfort when wearing their mask. Could this be because they have not found a comfortable

DISCUSSION

INTRODUCTION

Based on identified gaps in the literature report, primary research was conducted to understand how despite being preventable, silicosis is affecting 584,000 Australians (ACTU,2022). Primary and secondary research support the statement that the safest mask is the mask the user chooses to wear. Survey results show that despite 88.5% of the 26 responses, are aware of the effects of silica dust on the lungs, 76.9% of participants do not wear respirators when not required, see Appendix A. As outlined in the survey and observation, the user group experienced discomfort, adjustment issues, temperature issues and inconvenience when applying, wearing, and taking off personal respirators. Through this report it is believed that these factors contribute to the reason why construction workers are not wearing respirators. It was identified that there are two key users' groups in the study. Those who are considered high risk, high exposure which included workers that are cutting or drilling high concentration silica materials such as artificial stone bench tops on a regular basis. As well as a second user group who can be considered low risk, low exposure accounting for workers who are cutting or drilling low to medium silica concentration materials such as concrete and natural stone on a semi regular basis.

HIGH RISK, HIGH EXPOSURE

These conditions are common for tunnel boring workers, stone masons and kitchen fitters. Workers in confined spaces using ill-fitting protective equipment and repeating these tasks daily or weekly are considered high exposure. For these workers, there are current masks and other PPE on the market to reduce exposure to harmful dust such as positive airflow full face respirators and HEPA systems. Risk control in these environments can be managed with education interventions and financial offset to reduce the expense of protective equipment.

LOW RISK, LOW EXPOSURE

This user group includes concreters, electricians, and earth movers. In these situations, workers are often actively moving through construction sites in confined or open spaces. These workers are more susceptible to low risk, long exposure issues such as a gradual build of silica will damage the lungs over the extended period of a long career. As participant

2 mentioned in their interview, "like everybody just, hold[s] [their] breath... all the tradies say that". Despite the data showing majority of people understanding the consequences of silica exposure, workers seem to believe the task they are performing does not warrant the inconvenience of putting on safety equipment. As a result, many of the construction workers will likely see declining lung performance over their career if not protecting themselves. Survey results and interview data found a gap for a respirator designed to be convenient to take on and off.

GAP: NO REPORTS ON PERSONALISED MASK FITMENT WITHIN CONSTRUCTION INDUSTRY

Market and literature research found that there is a supply of generically sized, off the shelf, respirators that often result in pressure points and seal gaps, decreasing the effectiveness of the mask (Lei et al., 2010). This research is supported by user experience and survey results that found discomfort when wearing face masks is common. Through design intervention it is possible to use advanced manufacturing techniques to create affordable custom fitted respirators. Allowing equal distribution of pressure and therefore improved comfort and seal. Technological advancements from military pilot oxygen masks, and the medical industry during COVID-19 lead to an increase in the commercial viability of more diverse and appropriate products. Other design interventions could also improve inconvenience, strap design and temperature issues. Virtual fit tests in the manufacturing of personalised respirators may forego the need for in person respirator fit tests resulting in time and money savings to construction companies. Changes to current regulations and policies would need to be backed by research to support virtual fit tests.

GAP: NO MENTION OF FACIAL HAIR IMPEDING THE SEAL OF MASK

In Queensland having facial hair that is under the seal of the mask is deemed unpassable when conducting a tight respirator fit test (WorkSafe, 2021). Reports fail to test, mention or design for participants with facial hair and the effect this may have on the seal or user wearability. Participant 3 of the interview and observation was aware that the beard created an imperfect seal and accepted the risks however mentioned that there was no issue with comfort. People who experience harsh skin conditions such as severe pseudo folliculitis barbae or ingrown hairs may

need to keep facial hair as shaving irritates the skin causing pain. Alternative solutions for those with facial hair including wearing a full-face respirator shield with neck cover which may interfere with their work duties in confined spaces.

LIMITATIONS

Limited sample size gave insufficient power to perform statistical analysis and draw conclusions about the population at large. The survey was deployed via social media and in person recruiting to ask any workers in the construction industry to answer a broad range of questions to gauge their general thoughts and experiences wearing respirators. A total of 26 participants and 12 separate industries completed the survey. Furthermore 3 participants agreed to a 10-minute semi structured interview and observation. Given a larger sample size, data could be further extrapolated to increase accuracy however it did capture a diverse range of mask users.

EXCLUDING OBSERVATIONAL NOTES

The observational data collected during the interview was excluded from the data analysis in order to ensure good data collection methods. During the interviews users were asked to talk through the process of the four tasks designed to find pain points in current mask interaction. The observational notes taken by the interviewer were too closely linked to the user's dialogue. This would lead to potential doubling of data therefore skewing the results. To keep statistical accuracy, the observational notes were excluded from the analysis. However, these notes can still be used to inform the design interventions and development of the respirator.

05

CHAPTER 05

DESIGN INTERVENTIONS + CONCLUSION

CONCEPT 1-5

CONCLUSION

REFERENCES

APPENDIX

CONCEPT 1

Design mounted on nose or forehead

Airflow

Room for eyewear



Uses air to create invisible shield.

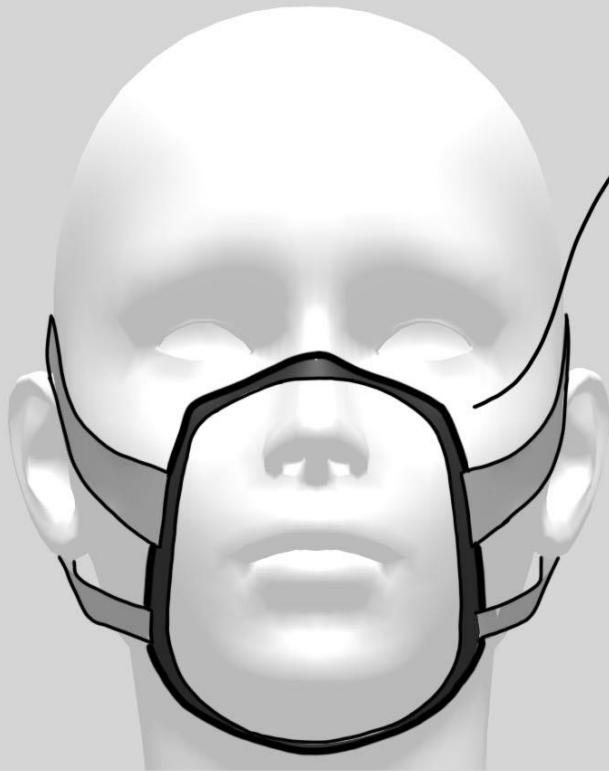
Solves temperature issues

Potential car and safety glasses integrated



minimal face
contact and
open design
allows for easy
communication

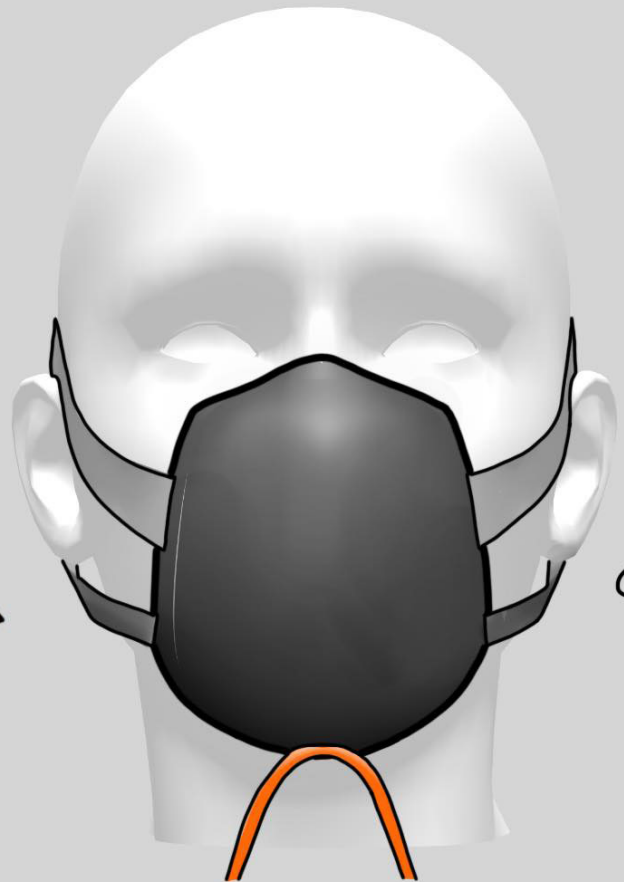
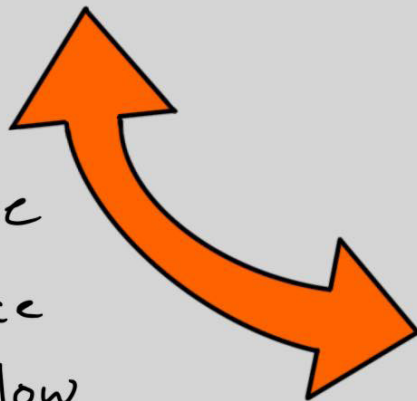
CONCEPT 2



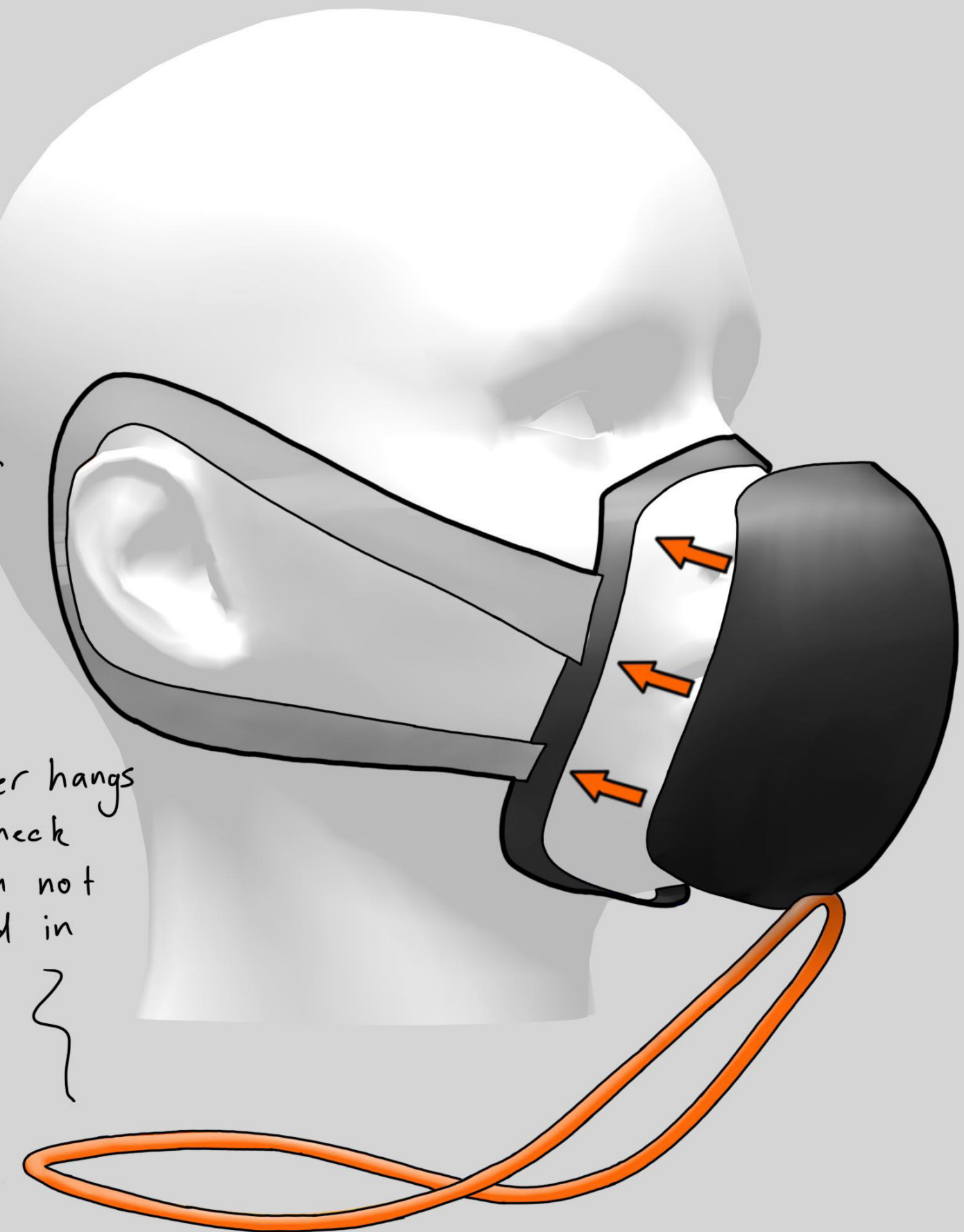
filter magnetise
to face mask

Minimal strap
design. cloth
combats heat

Removeable
filter on face
mask to allow
quick relief when
needed

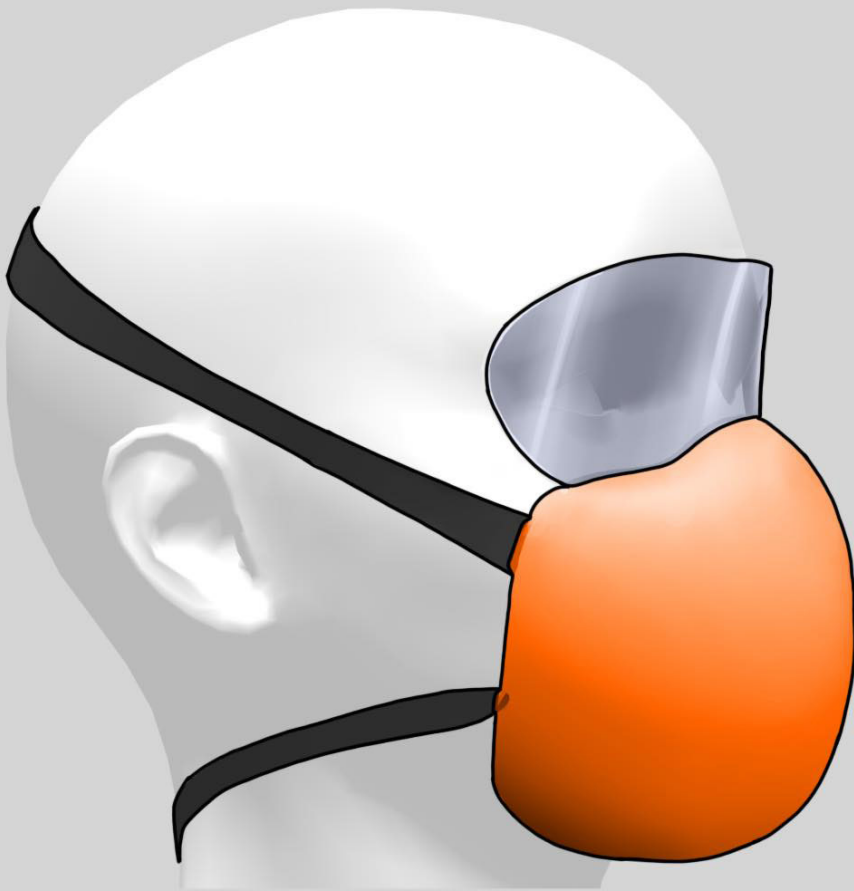


filter
of
when
clipped

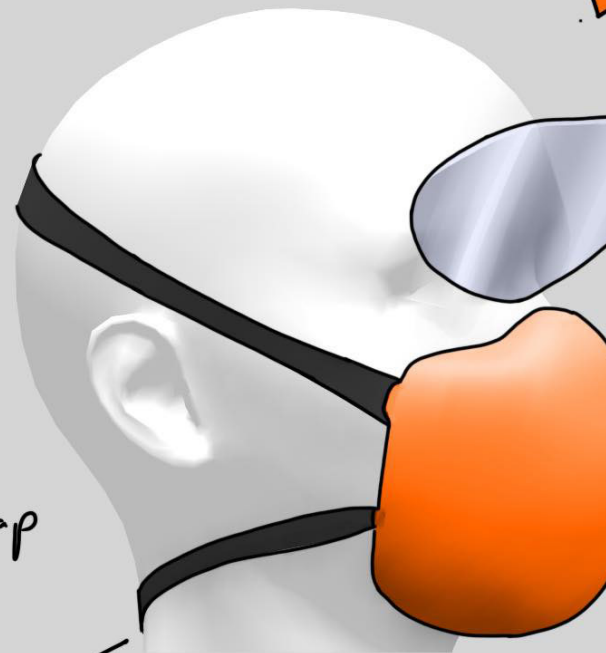


er hangs
neck
n not
d in
}

CONCEPT 3

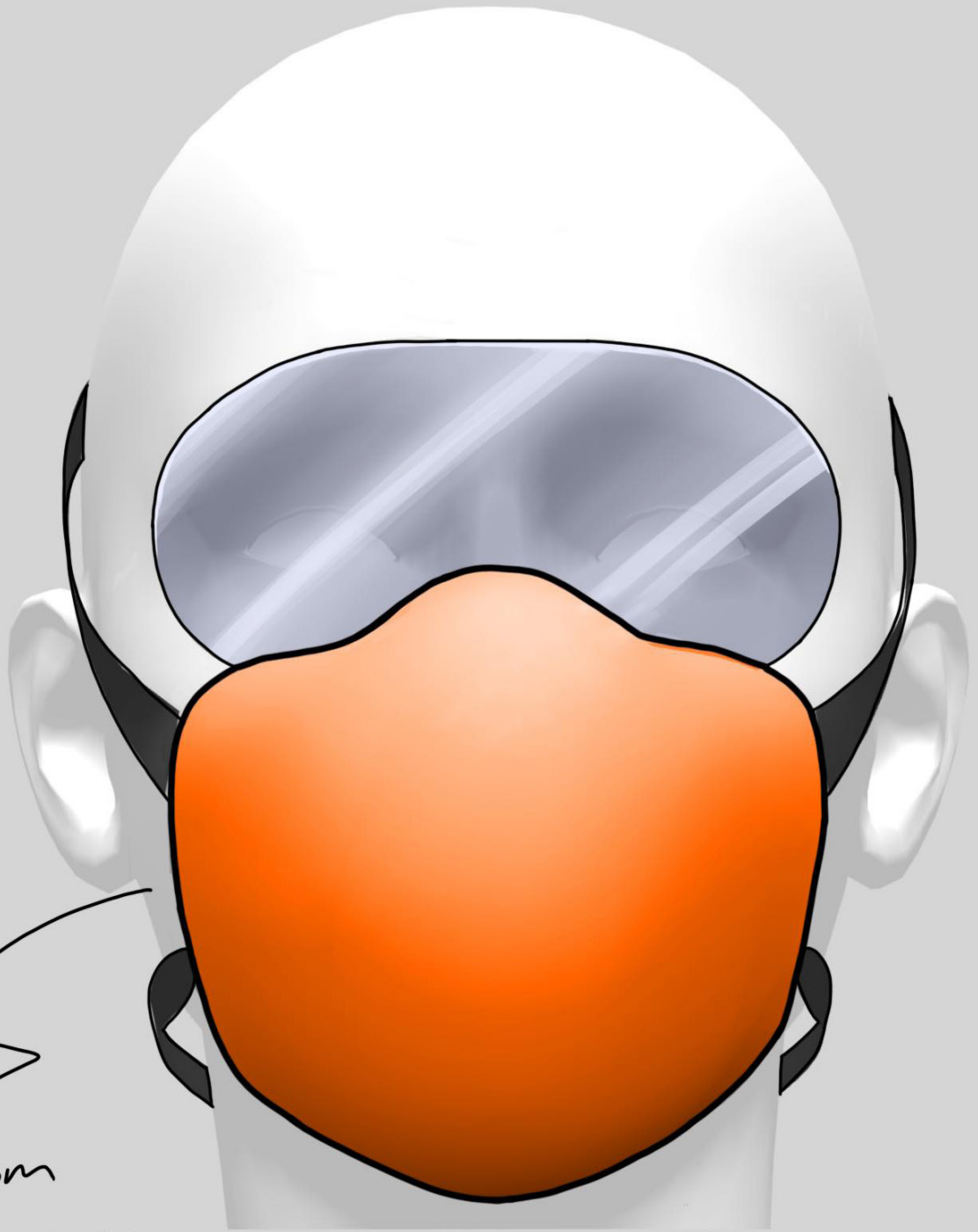


Modular mask
User can tailor
to their needs
and preferences



'traditional' strap
design.

Research shows
Strap design causes
neck pain

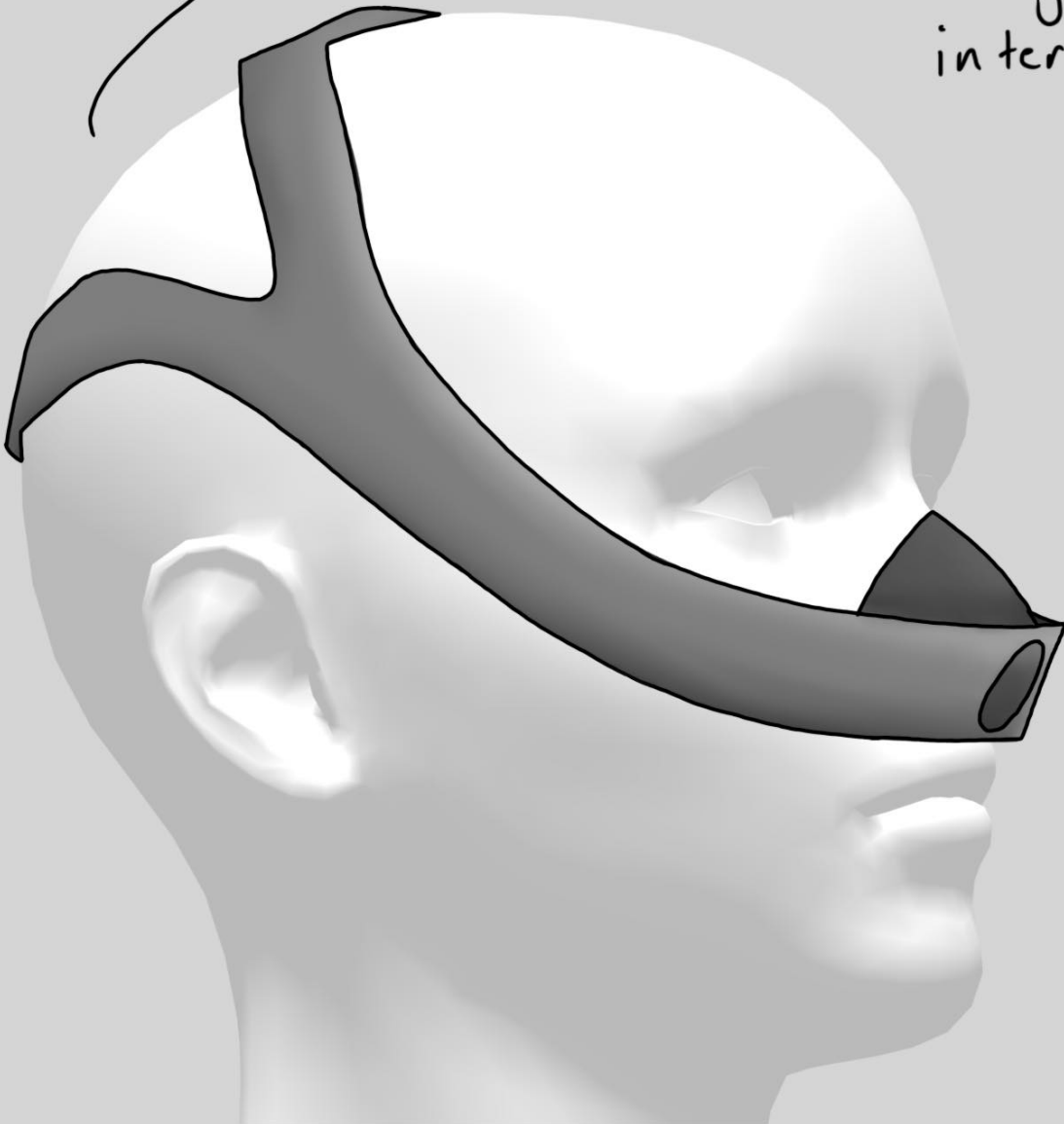


Custom
fit to users
face using 3D
Scanning technology

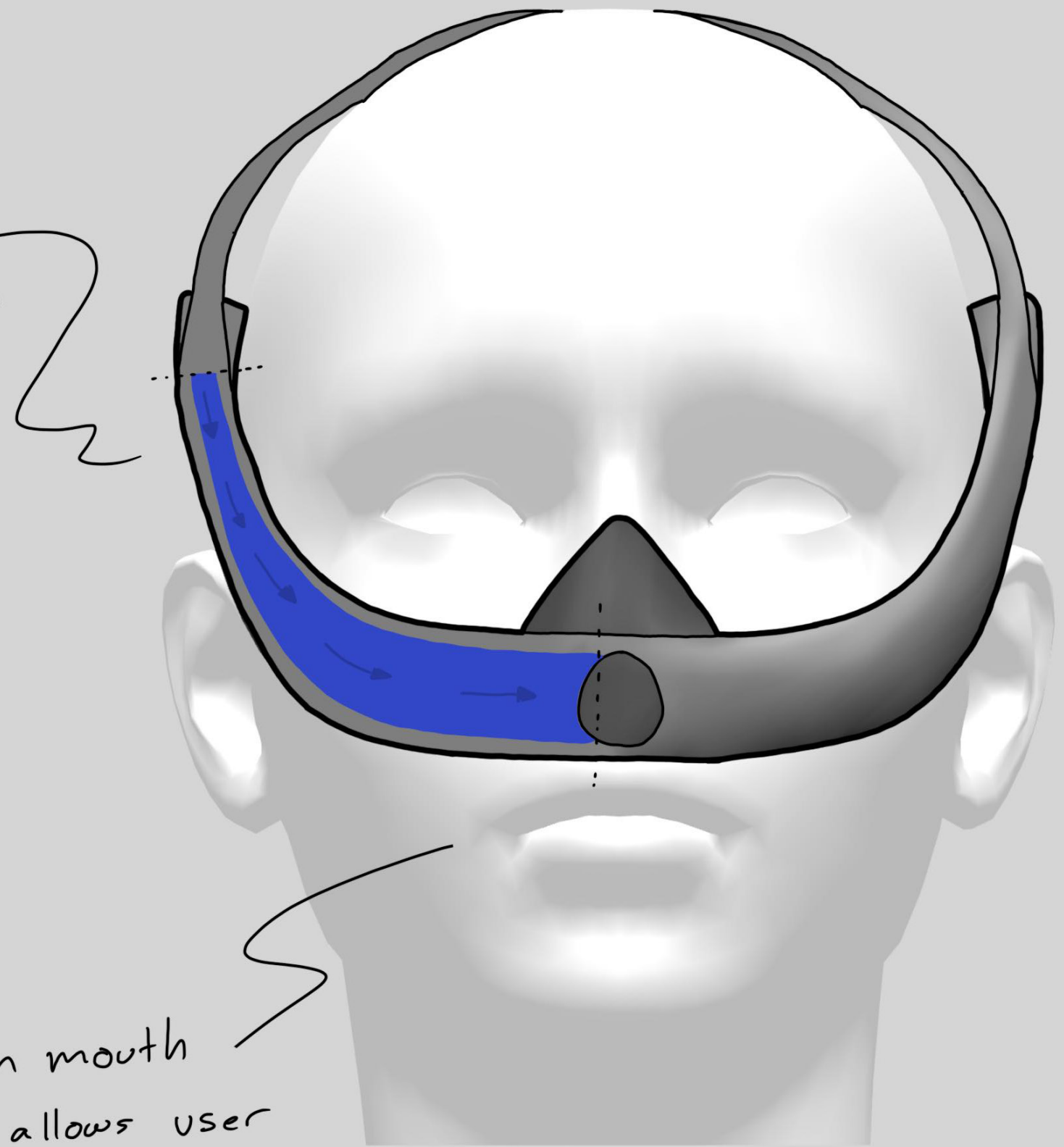
CONCEPT 4

Straps distribute
weight evenly and
holds head to
prevent slippage

Air intake
along tubing with
internal filter

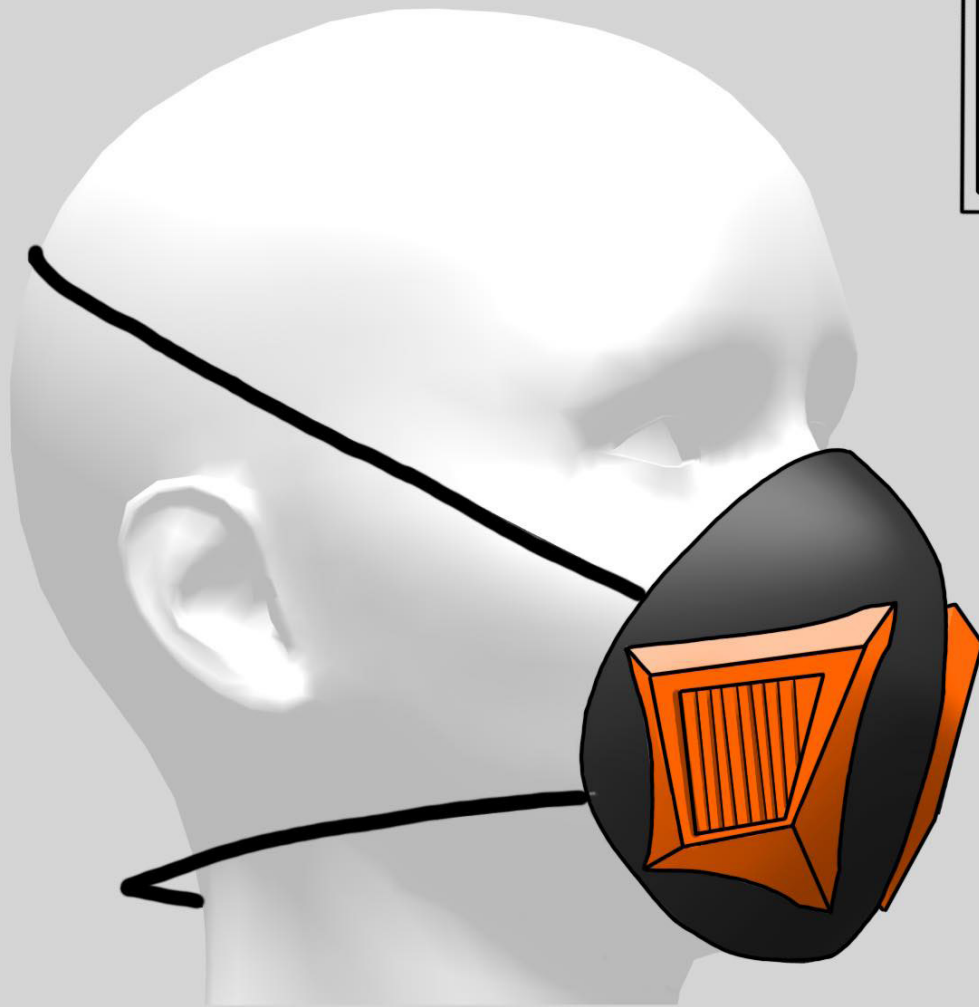


Open
design
to stay
breathing

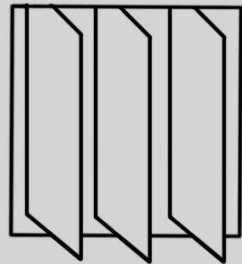


n mouth
allows user
protected by
through nose

CONCEPT 5



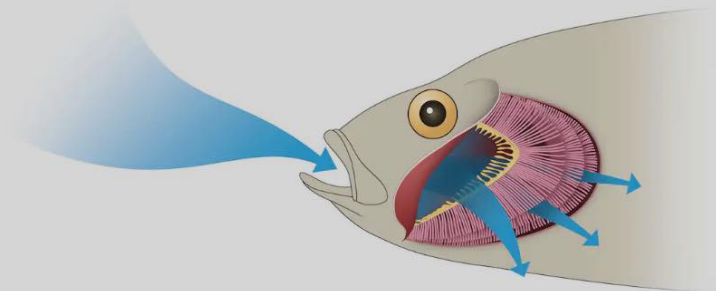
open



closed



Design a
for open
when
be
need



1



allows
when breathing
is safe, can
be closed when
needed

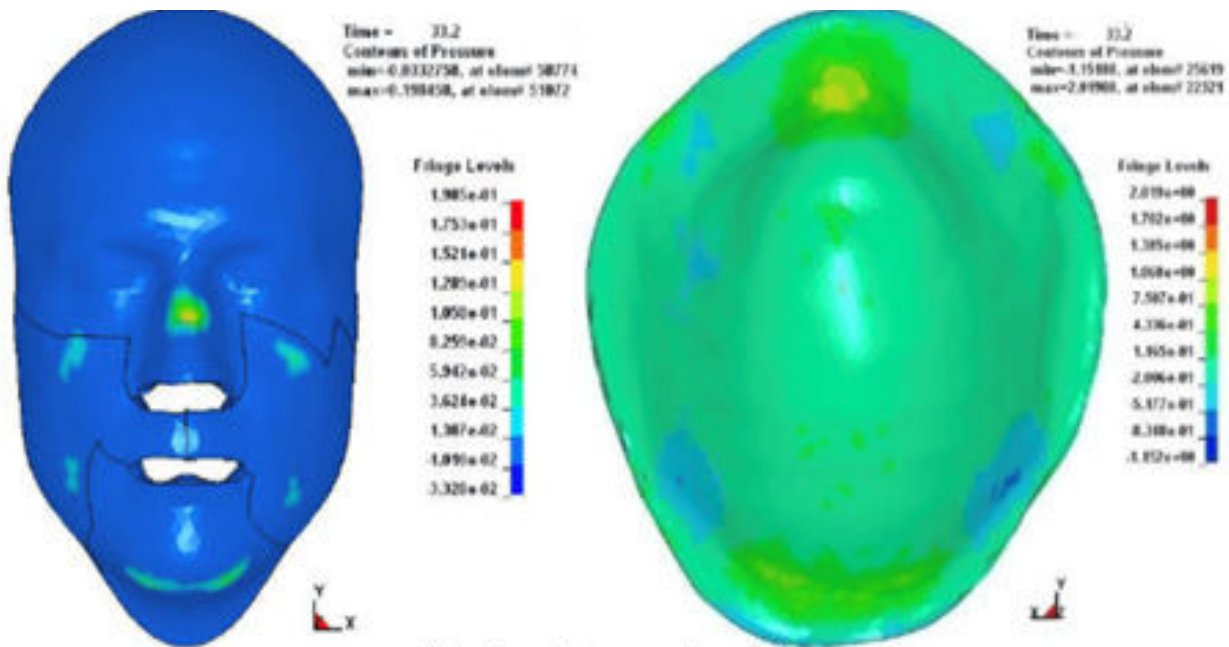


Figure 11, Lei & Yang (2010), *Contact Pressure Study of N95 Filtering Face-piece Respirators Using Finite Element Method*

DESIGN INTERVENTIONS

The five design concepts explore using different technology and techniques to create the most comfort and protection for the user. The design outcome should solve the four main issues identified in the research of this report being adjustment, inconvenience, discomfort, and temperature. All design concepts use 3D scanning technology to create a perfect seal for each user. Lei and Yang (2010) found that correctly sized masks create a better seal and equally distribute the pressure more effectively. The report identified on virtual patients that wearing incorrectly sized masks further increase gaps in the face mask seal. This could be solved by using 3D scanning technologies in a virtual fit test environment.

CONCEPT 1

Concept one explores the idea of continuous air flow to blow dust particles away from the face. As identified in the research, mask users currently experience heat discomfort and irritation with the mask pressing onto the face, trapping sweat and increasing temperature. This design aims to create a cool breeze on the face of user whilst keeping the user safe from airborne particles and dust. However, it is unsure how users will feel about wearing such design due to its unconventional and futuristic

design. A design approach like this may need to take smaller steps to make the product feel socially acceptable to the user. The design could be developed into a wearable neck and shoulder device, integrated into a helmet, or worn on the bridge of the nose.

CONCEPT 2

Concept 2 aims to solve temperature and inconvenience issues by creating a mask that can be easily taken on and off. Inspired by American NFL players who attach their mouth guards to the inside of the face. This allows the user to have quick access to safety without compromising convenience or communication. The design uses 3D scanned gasket and attachable face filters to allow the user control of when they are protected. The design could be developed into a mass customisation product allowing the user to install different filters of varying protective levels to suit their working conditions.

CONCEPT 3

Concept 3 leans into the modular design, allowing snap on protection when required. Ideally the design would allow for ear and eye protection in various forms. Allowing the user to customise their protection for their needs. The design aims

to improve user convenience by changing strap designs. Survey results identified that users struggled with putting on and off 3 forms of PPE. This design could be developed into an all-in-one personal protection unit that is easy to take on and off.

CONCEPT 4

Concept 4 is a conceptual design based on CPAP masks where the user's mouth is not protected. Pushing the boundaries of work site safety regulations this design allows the user to freely breath through their mouth, allowing their lips to act as a natural seal to avoid inhalation of dust. This would reduce mask surface area and sweat build up and allow a continuous supply of oxygen to the nose. This device would target low risk, low exposure audience and be intended to be worn all day on site. This design could be developed into various forms, straps design and mounting solutions utilising laptop fan cooling technology to draw in oxygen to the nose.

CONCEPT 5

Inspired by fish gills this concept uses technology to detected dust concentration in the air to automatically close the vents. This would allow the user to stay protected throughout the day, but when safe could relieve some negative mask effects such as temperature. The design could be developed by changing facial interaction, allowing the user the ability to grow facial hair without the need of impeding mask seal. The underlying theme of this design is to have protection when in a hazardous environment but change mask properties when in a safe environment.

CONCLUSION

The purpose of this report is to understand key issues construction workers face with wearing respirators and understand why workers are not wearing respirators. Desktop research in the form of a literature review found that there is a lack of academic papers on respirator leakage and facial hair interference with the seal specifically in the construction industry. The primary research was developed to explore these gaps and a survey and interviews were conducted. Using quantitative data from the survey about current respirators found discomfort, temperature, adjustability, and inconvenience were key factors for why workers are not wearing respirators. This was supported by qualitative data that was analysed using thematic analysis techniques to uncover key themes in the interviews. The primary and secondary research established that design interventions could improve wearability and effectiveness of masks using technologies such as 3D scanning. Moving forward the respirator will be designed to target key issues facing construction workers using advanced manufacturing techniques.

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APPENDIX A

Survey consent, questions & results

PARTICIPANT INFORMATION FOR CAPSTONE RESEARCH PROJECT – Interview / Observations –
Occupational Lung Disease Prevention Methods

Research team

Principal Researcher:	Darcy Duckworth	Undergraduate
Unit Coordinators:	Rafael Gomez	Co-Coordinator
	Tim Williams	Co-Coordinator

School of Design/Faculty of Creative Industries, Education and Social Justice
Queensland University of Technology (QUT)

Why is the study being conducted?

This research project is being undertaken as part of an Industrial Design Capstone project for Darcy Duckworth

The purpose of this project is to find user habits when wearing personal protective equipment in the construction industry.

You are invited to participate in this research project because you meet the requirements and needs of a respirator in the construction industry.

What does participation involve?

Your participation will involve an audio recorded / video recorded interview at z10 Kelvin Grove or other agreed location that will take approximately 10 minutes of your time.

Questions will include:

- How often do you wear a respirator?
- What do you find most time consuming about application?

Your participation in this research project is entirely voluntary. If you do agree to participate you can withdraw from the research project without comment or penalty. You can withdraw anytime during the interview. If you withdraw with 2 weeks after your interview, on request any information already obtained that can be linked to you will be destroyed. Your decision to participate or not participate will in no way impact upon your current or future relationship with QUT.

You will be able to review a transcript of your responses after the interview.

What are the possible benefits for me if I take part?

It is expected that this research project will not benefit you directly. The outcomes of the research, however, may benefit the end user in the construction industry. You can request a brief summary of the outcomes of the study by providing an email address or contact address.

What are the possible risks for me if I take part?

There are no risks beyond normal day-to-day living associated with your participation in this research project.

https://connectqut.edu-my.sharepoint.com/personal/n10482997_qut_edu_au/documents/dnb311_interview_focus_group_observation_participant_information_sheet.docx Version x

Page 1 of 2

Figure A1, *Consent form*

QUT provides for limited free psychology, family therapy or counselling services for research participants of QUT research projects who may experience discomfort or distress as a result of their participation in the research. Should you wish to access this service please call the Clinic Receptionist on **07 3138 0999** (Monday–Friday only 9am–5pm), QUT Psychology and Counselling Clinic, 44 Musk Avenue, Kelvin Grove, and indicate that you are a research participant. Alternatively, Lifeline provides access to online, phone or face-to-face support, call **13 11 14** for 24 hour telephone crisis support. If you are aged up to 25, you can also call the Kids Helpline on **1800 551 800**.

What about privacy and confidentiality?

Any data collected as part of this research project will be stored securely on personal computers or password protected cloud storage systems (not on public storage systems). Data will be deleted once the project is complete at the end of the semester.

As the research project involves an audio/video recording:

- You will have the opportunity to verify your comments and responses prior to final inclusion.
- The recording will not be used for any other purpose.
- Only the named researchers will have access to the recording.
- It is not possible to participate in the research project without being recorded.

How do I give my consent to participate?

We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate.

What if I have questions about the research project?

If you have any questions or require further information please contact one of the listed researchers:

Darcy Duckworth n10482997@qut.edu.au 0476379109

What if I have a concern or complaint regarding the conduct of the research project?

The researcher is committed to research integrity and the ethical conduct of research projects. If you wish to discuss the study with someone not directly involved, particularly in relation to matters concerning policies, information or complaints about the conduct of the study or your rights as a participant, you may contact the Unit Coordinator on email (Rafael Gomez) r.gomez@qut.edu.au or (Tim Williams) tim.williams@qut.edu.au

Figure A2, *Consent form*

By submitting you understand and agree to the following



Data Privacy and Confidentiality

All comments and responses are anonymous i.e. it will not be possible to identify you at any stage of the research, because personal identifying information is not sought in any of the responses and not traceable information is collected via the server or survey tool.

Any data collected as part of this research project will be stored securely on personal computers or password protected cloud storage systems (not on public storage systems). Data will be deleted once the project is complete at the end of the semester.

Participation

Your participation in this research project is entirely voluntary. If you agree to participate you do not have to complete any question(s) you are uncomfortable answering. Your decision to not participate will in no way impact upon your current or future relationship with QUT. If you do agree to participate you can withdraw from the research project during your participation without comment or penalty. Any information already obtained that can be linked to you will be destroyed.

You will be able to review your responses before submitting and save a copy of your responses after submitting the survey. There are no risks beyond normal day-to-day living associated with your participation in this research project.

The submission or return of the completed survey is accepted as an indication of your consent to participate in this research project.

What if I have a concern or complaint regarding the conduct of the research project?

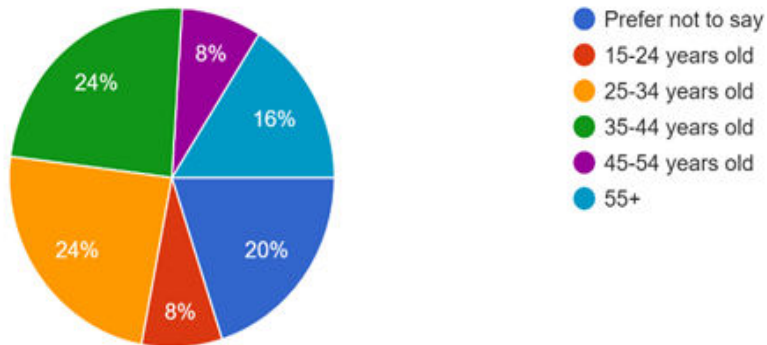
The researcher is committed to research integrity and the ethical conduct of research projects. If you wish to discuss the study with someone not directly involved, particularly in relation to matters concerning policies, information or complaints about the conduct of the study or your rights as a participant, you may contact the Unit Coordinator on email (Rafael Gomez) r.gomez@qut.edu.au or (Tim Williams) tim.williams@qut.edu.au

Thank you for helping with this research project. Please keep/print this sheet for your information.

Figure A2, *Consent form survey format*

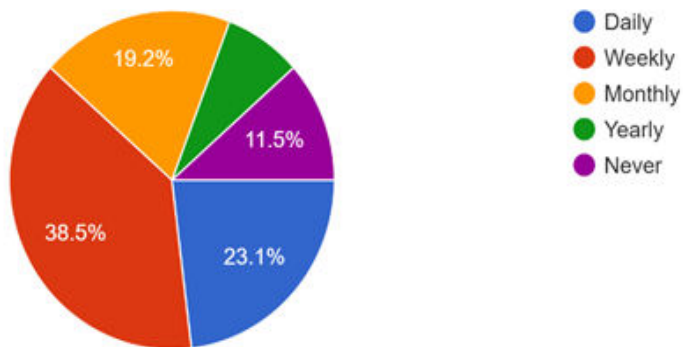
What is your age?

25 responses



How often do you wear respirators at work?

26 responses



Are you required to wear a respirator at work?

26 responses

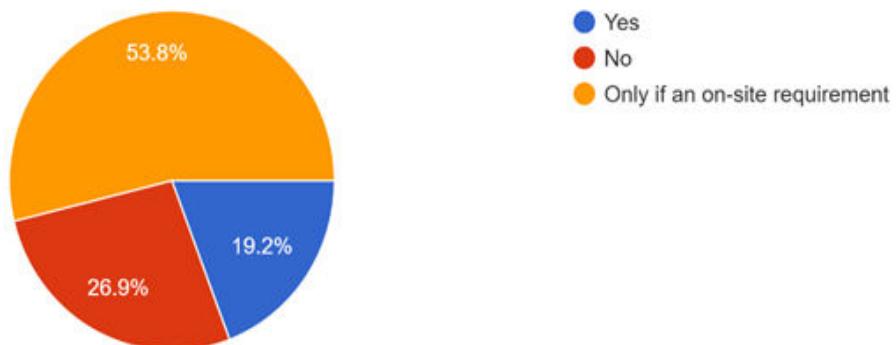
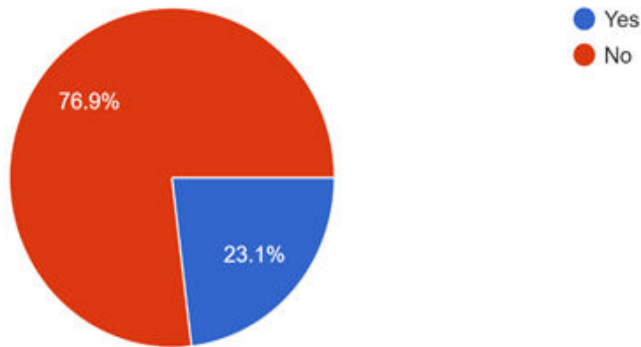


Figure A4, Survey question and responses

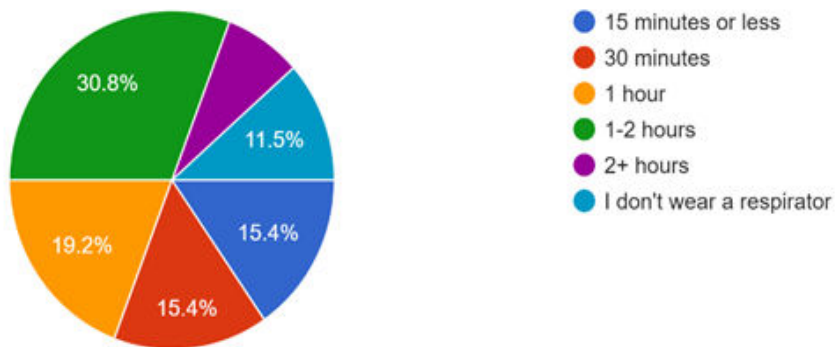
Do you wear respirators when not required at work?

26 responses



How long do you wear a respirator for?

26 responses



Rate the comfort of your respirator from 1-5

26 responses

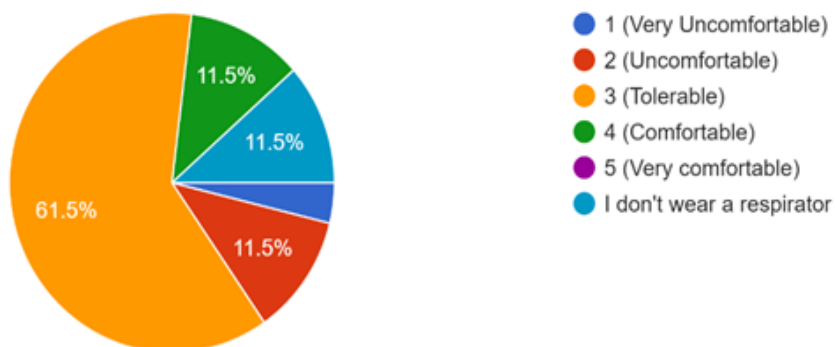
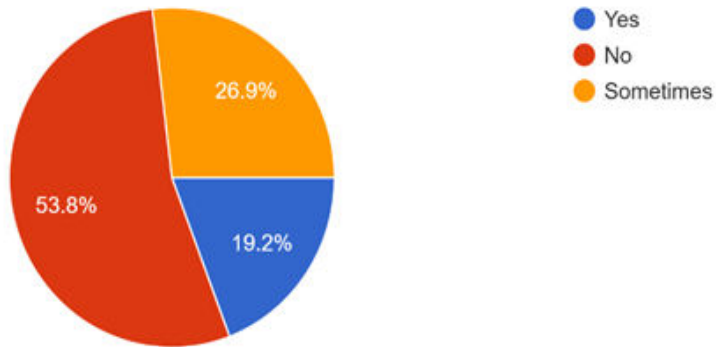


Figure A5, Survey question and responses

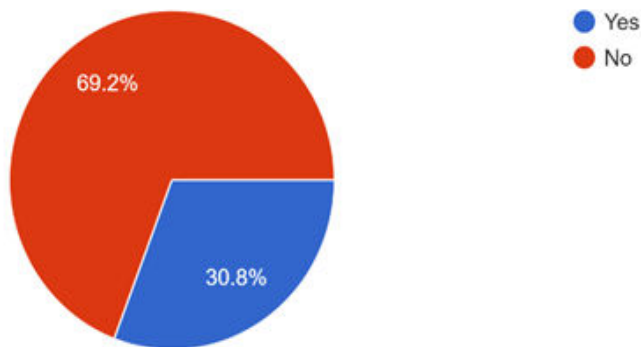
Do you have facial hair that impedes the seal of the respirator?

26 responses



Have you been required to undergo a fit-test for your respirator?

26 responses



Do you wear other head PPE while wearing a respirator? (e.g. glasses, ear protection, other)

26 responses

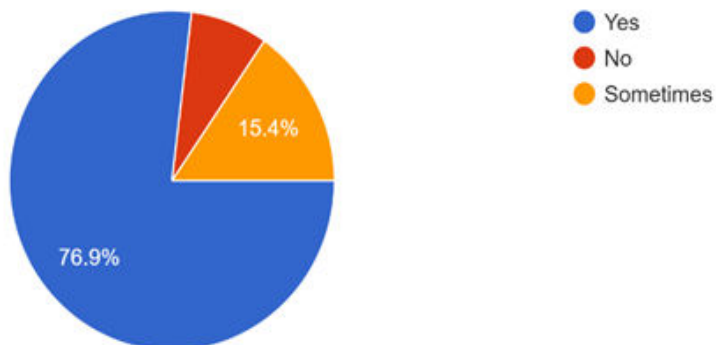
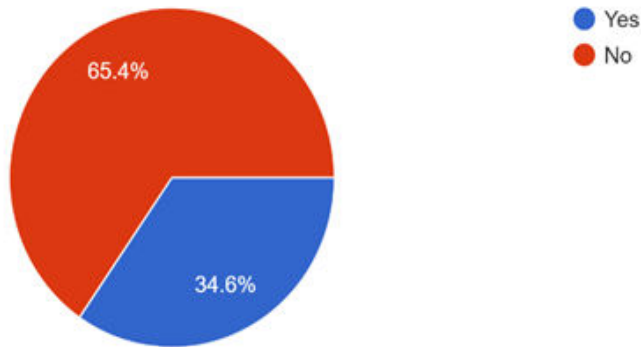


Figure A6, Survey question and responses

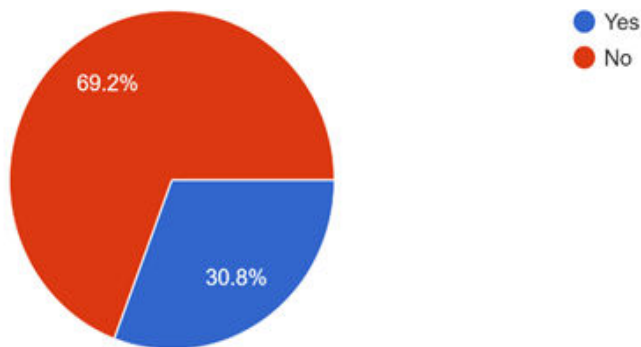
Do you wear prescription glasses?

26 responses



Do you work with hazardous materials such as asbestos?

26 responses



How often do you work with or cut concrete?

26 responses

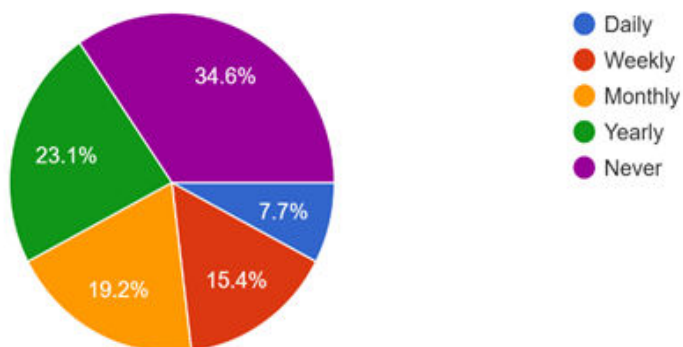
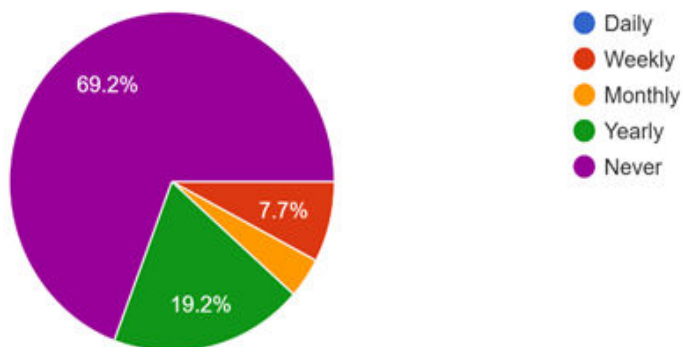


Figure A7, Survey question and responses

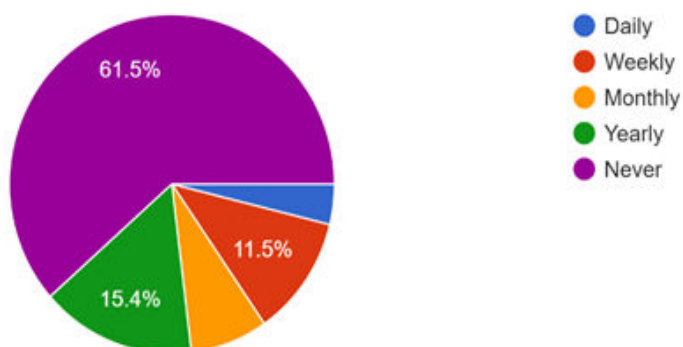
How often do you cut artificial stone? (e.g. bench tops, tiles, etc)

26 responses



How often do you work with or cut natural stone? (e.g. gravel, bench tops, earth moving, etc)

26 responses



Are you aware of the effects of silica dust on the lungs?

26 responses

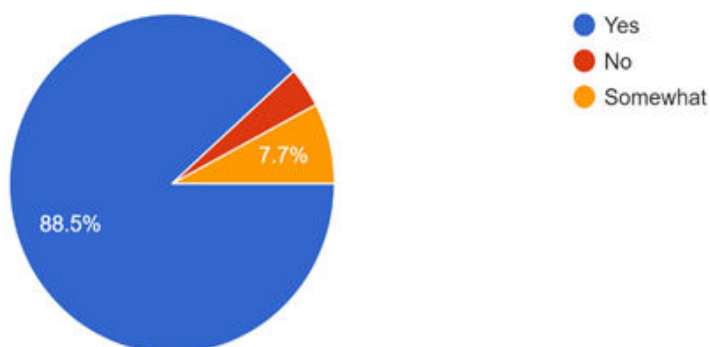
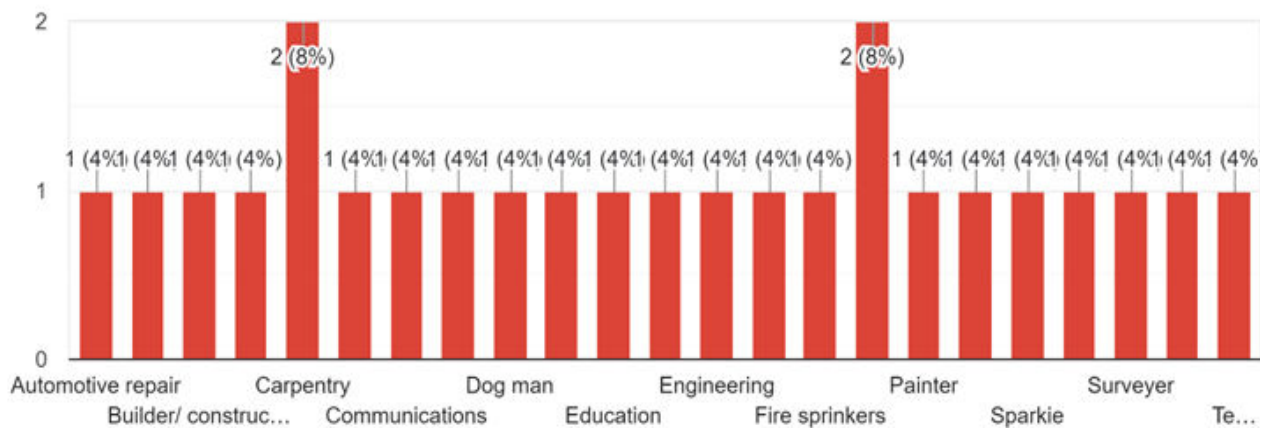


Figure A8, Survey question and responses

State your primary industry (e.g. carpentry, boilermaker, earth-moving)

25 responses



Is there any aspect of wearing a respirator that you find uncomfortable or irritating?

22 responses

- Sweat
- Hard to where eye protection, lung protection and hearing protection at the same time as it becomes very uncomfortable. Taking all protective gear off is very time consuming too.
- tightening the straps, straps cut above the ears
- hot, sweaty, itchy, P2 masks ear loops suck after a while, full face respirators are hard to keep fog free and scratch free and in BA applications to keep a good seal the mask puts a lot of pressure on the face and jaw, causing discomfort and pressure injury's
- Fogging of eyewear, seal around nose is never adequate, pressure from straps on head
- Band going behind my ears.
- Tight fit along with wearing glasses and hearing protection
- Getting caught in my hair (head hair/pony tail). And pinching my ears.

Figure A9, Survey question and responses

Is there any aspect of wearing a respirator that you find uncomfortable or irritating?

22 responses

- Yes I have a big nose
- doesn't fit well with a beard
- Difficult to breathe normally
- Straps, nose fitting, eara
- Straps, glasses, sweat,
- Sweat, straps cut in above ears
- Pressure, breathing hot air
- Temperature of the day
- Safety glasses fogging is frustrating

Figure A10, *Survey question and responses*

APPENDIX B

Interview & Observation, questions, results, transcripts

Semi Structured Questions for Interview & Observation

Feelings (qualitative) <ul style="list-style-type: none"> - Stress levels? - Vision impairment? - Pressure points? - Gaps? - Facial hair around seal? - Comfort / discomfort? - Weight? - Material feeling? - When would you feel the need to wear a mask? 	Metrics (quantitative) <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: - Inconvenience 0 convenient, 5 inconvenient:
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Task observations – Participant 1

Date: 14/09/2023

Put on mask (How they put on mask? Hands required? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 1 - Inconvenience 0 convenient, 5 inconvenient: 3 - Comfort 0 comfortable, 5 uncomfortable: 3
Qualitative notes Not sure how straps connect around back of neck on first setup. Hard to reach around back of head. No trouble tightening. Multiple re-adjustments to get right fit. Hard to hear when user has mask on. Can't tilt head up, pulls on back of neck, pull mask, pressing on chin. Not tight around the nose No pain in straps above ears. heavy on face Not too bad breathing Stuffy Dexterity issues tightening straps.

Momentarily taking off mask between jobs (How they take off equipment? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 4 - Inconvenience 0 convenient, 5 inconvenient: 3
Qualitative notes Not sure when to put it when taking it off. Head strap off, hanging on chest.

Put on mask + PPE + glasses + hard hat (Order of equipment, hands needed? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 3 - Inconvenience 0 convenient, 5 inconvenient: 3 - Comfort 0 comfortable, 5 uncomfortable: 3
Qualitative notes Hard hat issues with safety glasses interaction. Ponytail getting in the way. Helmet not on head properly. Good vision. Pressure on nose after 5 mins. Deeper breathes. Neck sore Hard to look up, uncomfortable on neck.

Taking off mask (Struggles? How they took off mask?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 2 (hair)
Qualitative notes Taking off mask was quick. Wearing mask for 7 minutes began to feel pain in nose bridge. Neck strap pulls on nose and neck, tighter neck strap would not have sealed. Hair consideration

Table B1, Participant 1 observation notes

Task observations – Participant 2

Date: 14/09/2023

Put on mask (How they put on mask? Hands required? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 2 - Inconvenience 0 convenient, 5 inconvenient: 2 - Comfort 0 comfortable, 5 uncomfortable: 3
Qualitative notes Struggling to put on neck strap. tight around nose. User concerns over long term use Restricted breathing with nose bridge Possible hay fever/issues sneezing (user suffering from hay fever at time of observation) User notes "distance from chin to nose fit to small, pulling on <u>skin</u> " User notes "seals pretty good" User notes "some gaps on nose bridge" User notes "Straps are good, good split strap design, not slipping, good strap <u>placement</u> "

Put on mask + PPE + glasses + hard hat (Order of equipment, hands needed? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 2 - Inconvenience 0 convenient, 5 inconvenient: 2 - Comfort 0 comfortable, 5 uncomfortable: 3
Qualitative notes User notes "Glasses don't <u>fogging</u> because nose seal is good". Cannot wear over <u>ear</u> Uncomfortable 15 minutes of exposure, hold your breath.

Momentarily taking off mask between jobs (How they take off equipment? Other?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 1 - Inconvenience 0 convenient, 5 inconvenient: 2
Qualitative notes Take it completely off, sound issue. User suggests hard to communicate face to face and on phone with mask on. User suggests microphone in mask. Elastic straps stretch and lose elasticity over time.

Taking off mask (Struggles? How they took off mask?)
Quantitative notes <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 2
Qualitative notes Residual pressure over nose from mask after 8 minutes of use. User notes "Should offer XL mask option." User concern for Dust lines on face

Table B2, Participant 2 observation notes

Task observations – Participant 3

Date: 14/09/2023

<p>Put on mask (How they put on mask? Hands required? Other?)</p> <p>Quantitative notes</p> <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 1 - Inconvenience 0 convenient, 5 inconvenient: 2 - Comfort 0 comfortable, 5 uncomfortable: 4 <p>Qualitative notes</p> <ul style="list-style-type: none"> - Familiar with wearing masks with pottery. - Used this model before. - Tightening straps getting correct fit first time is a struggle. - Annoying strap fasteners - Head strap is ok. - Tight enough feels like its slipping down. - Off nose bridge. - Compressing hot spot, dragging face down.

<p>Put on mask + PPE + glasses + hard hat (Order of equipment, hands needed? Other?)</p> <p>Quantitative notes</p> <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 1 - Inconvenience 0 convenient, 5 inconvenient: 2 - Comfort 0 comfortable, 5 uncomfortable: 2 <p>Qualitative notes</p> <p>Doesn't feel any more annoying.</p>

<p>Momentarily taking off mask between jobs (How they take off equipment? Other?)</p> <p>Quantitative notes</p> <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 2 - Inconvenience 0 convenient, 5 inconvenient: 2 <p>Qualitative notes</p> <p>Takes the whole thing off.</p>
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<p>Taking off mask (Struggles? How they took off mask?)</p> <p>Quantitative notes</p> <ul style="list-style-type: none"> - Difficulty 0 easy, 5 hardest: 1 <p>Qualitative notes</p> <p>Beard is flattened, disfigured beard Not fully protected because beard</p> <p>Feel relieved when taking it off.</p> <p>Time and volume of material used and what materials they are. Should be wearing it but don't when mixing small quantities (1-2kg).</p> <p>Hard to get answers because varying jobs.</p> <p>Long time, low exposure, or high exposure short time. 2-3hrs a time sometimes.</p>

Table B3, Participant 3 observation notes

Observation dialogue

Participant 1

Darcy Duckworth

Just go ahead and put on the mask for me please and adjust the straps

Participant 1

What do you do?

Darcy Duckworth

they connect at the back around the back of your neck yes if you could tighten it to like a reasonable standard okay how do you feel? Is there any pressure points.

Participant 1

I can't really lift my head because of the neck strap. if i look to high it pulls on my face

Darcy Duckworth

pressing on chin.

Participant 1

Chin feels very tight here. Not tight around the nose bridge.

Darcy Duckworth

Okay, that is the size medium. So, they do a small medium and a large but pretty well, pretty well. Yeah. Yeah. And what about is do you feel any like do you notice the straps above your ears? No. Okay. Straps.

Participant 1

I can't feel any pressure until that point

Darcy Duckworth

Yep. Would you say it in? impairs your vision. Just seeing like having something on your face? Are there any problems with the weight or the field? Is it too heavy? on your face? Is it.

Participant 1

feels like it's falling forward curious to feel how it would feel after an hour or so.

Darcy Duckworth

Do you find it hard to breathe through the mask?

Participant 1

I've never worn one of these. It's not too bad. Like it's stuffy. It is stuffy but as far as masks go its not like the worst getting a bit hot. Moist and condensation.

Darcy Duckworth

Do you want to try and put those glasses on the hat? Hard Hat on as well? Oh, sorry. Just before you do that, difficulty to put the mask on. Zero being easiest five being hardest probably a one. A one. Being easy. Yeah. Yeah. And inconvenience. If you had to do those multiple times a day. Do you do you think that would be inconvenient?

Participant 1

It was more just I didn't look at how to do that. Clip? Yeah. It was fine. So maybe another inconvenience and convenience zero being convenient. Yeah, like All right.

Darcy Duckworth

And come comfortable, wise, do you find it uncomfortable? More comfortable, comfortable being 05 being most uncomfortable.

Participant 1

three puffy and then going to try and put the hard hat losses on as well.

Darcy Duckworth

How do you feel now?

Participant 1

Okay, it's not too bad. I noticed that I would have to have my ponytail in a very specific spot like it's the helmet is hitting my helmet hitting ponytail don't know how I would have my hair now.

Darcy Duckworth

Yeah. Yeah, yeah. Would you have would have to be almost out and flat or something. Yeah, it looks. It looks like the ponytail has too much like hair mass. For the helmet. my ponytail much lower. Yeah, the ponytail. What is it band is like right where the helmet strap is.

Participant 1

And if I go higher, then it'll be where the masks strap is. yeah, that's weird.

Darcy Duckworth

yeah. Okay. And then the helmets not sitting on your head properly.

Participant 1

Yeah, it's a bit dangerous. Yeah. still have good vision.

Darcy Duckworth

Good vision. And how are you going? You've had the mask on for five minutes. Now. How do you feel face wise? Comfort face wise is a hot

Participant 1

is a bit of pressure my nose now and I'm a bit hot. And I'm taking deeper breaths. Deep breaths. On my neck is going to strain. if you're looking down, it'd be alright but if you even look straight, it feels uncomfortable.

Darcy Duckworth

All right, you can take all that stuff off. And breathe again.

Participant 1

Yeah, wow. I don't know if I could do that. Much long.

Darcy Duckworth

Yeah, like an hour. To even if you want to take it off.

Participant 1

for a second. Like where do you put it?

Darcy Duckworth

Yeah, that's, that's great.

Participant 1

Sometimes you want to just take it off and chat. It's probably not work safe. And you want to just like rest it. Yeah, but there's nowhere.

Darcy Duckworth

Well, I'm struggling to. I'm struggling to hear you. With it on so yes, he could you do that? Yeah, you take the head strap off. Okay, that's not too bad. It's stressful. Yeah. Yeah. Yeah.

Participant 1

Pretty well. All in one go.

Darcy Duckworth

How do you find it with your hair?

Participant 1

So it's already messed Yeah, I would have to like braided it yeah, I'd have to braid my hair tied around my face and flyaway and then I'd have to flat probably flatten the strands getting back in Okay,

Darcy Duckworth

cool. And how is it taking off the mask?

Participant 1

that was quick.

Darcy Duckworth

just going back on the putting everything on how you rated the difficulty five being easiest. Sorry, zero being easiest five being hardest.

Participant 1

Maybe three

Darcy Duckworth

inconvenience wise. If you had to do those 10 times a day

Participant 1

maybe three

Darcy Duckworth

and come to ability comfort wise.

Participant 1

maybe three as well.

Darcy Duckworth

Taking off momentarily. How did you find that difficulty taking off the mask to sweet, thank you any do you have any design suggestions that you would like? Be like hey that's that needs to be redesigned that's pretty crap. No pressure,

Participant 1

then nose it's off now that's I can feel like my nose is like

Darcy Duckworth

can you still feel the seal of the mask? Not here.

Participant 1

I can't around my cheeks or anything but oh my bridge of my nose. Because the next so I can sort of feel the pressure where the nose was and the neck. But if the neck strap wasn't tight, it wouldn't have sealed.

Figure B1, *Participant 1 transcript*

Participant 2
Participant 2
yeah, it's a bit tighter on my nose or just adjusted it's actually pretty good that was pretty good but wearing this is a bit different story.

Darcy Duckworth
Yeah, how do you find your breathing?

Participant 2
yeah, pretty good a little bit restricted because of the nose pressure

Darcy Duckworth
and you have hay fever hay fever. How do you feel with that? Do you think it's going to stop the pollen or just get an itchy nose like is all?

Participant 2
yeah. okay. I don't have a very big face, but it is like it is too small.

Darcy Duckworth
Too small. Yeah. So why is that too small? Is it the fitment is too tight? Is that what you mean like

Participant 2
from my chin to my nose was too short and I've got a pretty small nose and I don't have a huge face so that's kind of weird.

Darcy Duckworth
Yeah it is a medium

Participant 2
or medium right so knowing that I'd like to get a large

Darcy Duckworth
Yeah All right cool. Anything else you starting to notice?

Participant 2
the gaps there's no gaps don't think feels pretty good seals good. I'm used to mask dust on side of nose because that's where its drawing in.

Darcy Duckworth
with the ears and coming across your face does it feel alright running along your cheekbone?

Participant 2
the straps are good. This split kind of whatever that's called is pretty good. Because often if it's not split like that it wants to slip either backwards or forwards. Not slipping the strap placements good. I haven't worn one of these before.

Darcy Duckworth
Do you want to put the PPE on the other glasses and the helmet? And just let me know how that feels then got shorter hair? How the glasses are they sitting straight?

Participant 2
wore glasses aren't fogging because which means the nose seal must be pretty good.

Unknown Speaker
so, the only thing you could run with probably the ear muffs you have to have ear buds

Darcy Duckworth
Yeah, yeah. ear Protection is it sort of like overwhelming having all that stuff on your face? Or, you know, if you had to wear that for at least half an hour? What you know

Participant 2
just the nose like the size of it would get uncomfortable but otherwise it gets a small price to pay for pesticides and dust. You I knew if I had to wear every day for eight hours. Yeah. I'd have to find something better.

Darcy Duckworth
What's, what's the lowest job that you would do to where it facemask? Like, like if you're drilling five holes in concrete if you're you know, like what your spray painting you're doing?

Participant 2
It would have to be like 15 minutes of concrete dust for me to warrant wearing the mask. Yeah, If you drill two holes on the ground, like everybody just, hold your breath. But like all the tradies say that.

Darcy Duckworth
Yeah, yeah. Okay, cool. And then do you want to take it off momentarily between jobs? So, take off the PPE and then just the mask?

Participant 2
Yeah, probably take the whole thing I usually must take it off if someone asks you a question as well to reply just because of the seal and the sound. I have that with my wife when I'm spraying pesticides. I can't talk to you now because I just don't want to go through taking off my hat. My glasses and mask. Yeah. So yeah, Bluetooth kind of thing or a phone line could be handy. Yeah, finally, because I had that on the weekend when I was spraying selective herbicide. I was wearing a mask and she wanted to talk to me about something else. I just couldn't wait to finish.

Darcy Duckworth
And how would you wear it? Participant 1 took the head strap off and let it hang. Would you do the same?

Participant 2
Probably not simply because I know that over time, these elastic straps deteriorate and lose their elasticity. And I wouldn't want to buy another one too soon. But they're 100 bucks. Yeah. Yeah. Because the outlet some of the cheaper ones that you got to throw out because the elastic straps

Darcy Duckworth
cool. And I mean, now you've got the mask completely off. How do you How did you find taking it off?

Participant 2
Yeah, taken off was easy. I just feel some residual pressure over my nose from the mask which is strange because I'm looking at

the sizes here. And it's small, medium large offered. Ah, yeah. Considering the size of my face and my nose I should probably offer an extra-large for like a big dude. Because if I don't, I don't wear a large in anything.

Darcy Duckworth

sweet and then I'll just ask some questions about like putting on the mask zero being I'll show you so maybe he's putting on the mask what how'd you find difficulty wise zero being easy five being honest.

Participant 2

They like to mainly the connector at the back is the annoying Yeah. Everything else if yeah, it's pretty well done this mask. Really? Yeah. Other ones? Definitely. Well, the other ones Yeah.

Unknown Speaker

Inconvenience 0 to five again, five being inconvenient.

Participant 2

Like yeah, two

Darcy Duckworth

and comfort. Wise, what did you think?

Participant 2

For that? three

Darcy Duckworth

Is it sort of tolerable?

Participant 2

I guess anybody putting a mask on for work knows that it's like a necessary evil. It's not like they're wholly ever going to enjoy the experience like 100%. You want to I think the important thing if they are uncomfortable and if they don't really work properly, like if you do get these dust lines on your face you're inclined to not wear one Yeah. So it has to be functional because you'll have to do it anyway.

Darcy Duckworth

Yeah What about having all the PPE on was that how do you find that scale? Probably about to difficulty inconvenience.

Participant 2

Probably 2. Wasn't that easy once you get the mask comfortable for that three, tolerable.

Figure B2, *Participant 2 transcript*

Participant 3
Darcy Duckworth
show me how you put on that mask and I'm just going to take some notes. your pretty familiar with wearing these hey, because of ceramics.

Participant 3
yeah, that's already pretty that one's a bit tight.

Darcy Duckworth
Do you have a similar model?

Participant 3
I've used them before Yeah, I think it's probably too tight and I'm not used to being too tight to bad I've never loosen one before.

Darcy Duckworth
And so, do you normally leave gaps? Like with your beard?
Can you feel the gaps? Do you notice them? Or?

Participant 3
I can't feel them. Like I thought I had this now is probably too loose. Once it is set i wont redo it

Darcy Duckworth
How do you find the top strap the head like the

Participant 3
okay, but I mean, it's like to get it tighter enough and now it's falling off. But it's sort of just It's okay. It feels like it's like slipping down. More than that, you know, usual. Okay.

Darcy Duckworth
Is irritating with your beard pushing into your face?

Participant 3
No. I'm probably happy about but it's I think I'm finding this one. particularly annoying right now is because I've got a a different brand. I don't know the brand that I've been using been using recently. This mask is just too small. This is just it feels like it's coming down. Okay. Just pull them down.

Darcy Duckworth
Any vision impairments? Do you feel comfortable wearing it?
Like visually? Do you find it annoying is it ok?

Participant 3
Yeah, as I say, like, is this still annoying right now? Like more annoying than I'm used to right now. pulling it down. So, it's pulling on my nose. On the bridge of my nose.

Darcy Duckworth
And are there any other comments on the on the fitment of the mask?

Participant 3
It sort of feels like it's compressing in or i can feel it almost dragging my face down a bit. I can almost feel tension on my eyes almost.

Darcy Duckworth

go ahead and put the glasses and helmet on to pick your order. Is this what you'd normally wear, you know, the eye protection and respirator for pottery stuff?

Participant 3
Yeah, sometimes I'll wear that but not always

Darcy Duckworth
If you're on site or something maybe.

Participant 3
yeah exactly

Darcy Duckworth
Yes, they're much better. How do you feel with that?

Participant 3
honestly doesn't feel any more. Any more annoying than that

Darcy Duckworth
cool, so there's no issue between the glasses affecting the respirator? Helmet?

Participant 3
[Inaudible]

Darcy Duckworth
Yeah, yeah. Cool. And then you're going to show me how you take it off momentarily. loop between jobs if you're just talking in a conversation.

Participant 3
probably Yeah, probably take the whole thing off. This one this one. I will take the whole thing off.

Unknown Speaker
All right, cool. Sam was under the top strap and let it hang down. But then she was like, Ah, sure annoying, because it's just like dragging.

Participant 3
Now and not loud. It's like my beard like kind of it's like sucking in

Darcy Duckworth
me. Yeah. Flattened or something.

Participant 3
Yeah, like disfigured my beard

Darcy Duckworth
beggar. Okay, cool. Do you have any comments on the design? fitment just you know, any last things before I asked you some more questions?

Participant 3
Yeah, like I said before. I've worn one every similar to this, maybe the nose part slightly different, but that felt particularly annoying on my nose.

Darcy Duckworth
Is there anything in general with masks that you don't like or

do like?

Participant 3

It's probably more the beard thing than anything like that. I know that it's not I'm not fully protected because the beard and it's annoying that it as I say, you know from having a good beard day or stuff like that. But from a comfortability perspective? Not? Not really. Yeah. I wouldn't say the beard seems to make too much of an effect on that.

Darcy Duckworth
inconvenience?

Participant 3
probably a 2.

Darcy Duckworth
Comfort?

Participant 3

This particular model right now. this particular model right now, probably a 4.

Darcy Duckworth
Momentarily taking it on and off how do you find that?

Participant 3

I guess it depends on how momentary, right, like, I mean, I like I like, taking it off is good in that. Okay, relief when it gets when it comes off. If I'd have to take it off for five seconds, I will find that annoying. Yep. I'm taking it off. For you know, whatever, half an hour lunch, rest of day, whatever. That's fine. Yeah. But having to take it on off again, multiple times in a short period of time. tend to be annoying, but at the same time having a bit of relief. Yes. I also like Yeah.

Darcy Duckworth

And lastly, what do you think would be the minimum time if you were doing some things that you thought required a respirator? Yeah, drilling concrete or doing your pottery stuff with the talc? What's the minimum time that you would want to be exposed before putting a respirator on? So, like, at what point do you justify putting the mask on

Participant 3

me it's, for me, it's a combination of time but also like volume of material used and also what materials are so some like there are times when I probably should be wearing it, but I don't if I'm mixing like very small quantities. I'm talking, you know, less, maybe less than maybe something like one or two kilograms. I'll probably not even though I probably should. And then time as well if I've got to do something with a little bit you know, it's not a huge amount for a couple of minutes. I'll probably not put on a respiratory.

Darcy Duckworth
How often are you mixing small quantities?

Participant 2

look it depends on the project what I'm doing like you know for what I'm, I can tell you for what I have been doing this project I have been working on it's probably been. It generally

would have been me having to do like a number of hours of at a time sort of thing. but in the past, there have been times when I need to do something quickly so there is the possibility of that as well. But then certainly there are times when I'll put it on I'll have to wear it for two or three hours at a time because what I'm doing.

Figure B3, *Participant 3 transcript*

APPENDIX C

Data coding

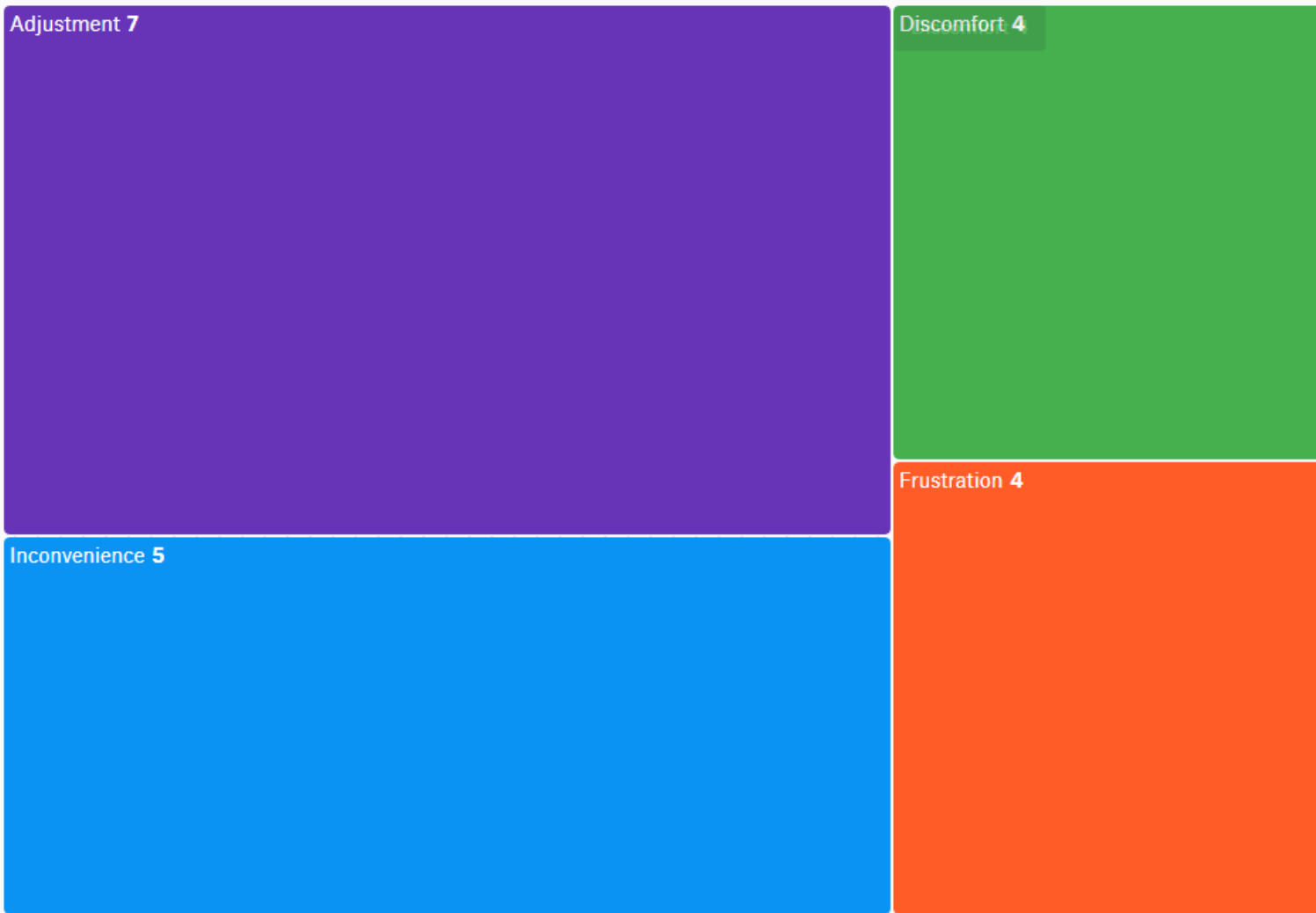


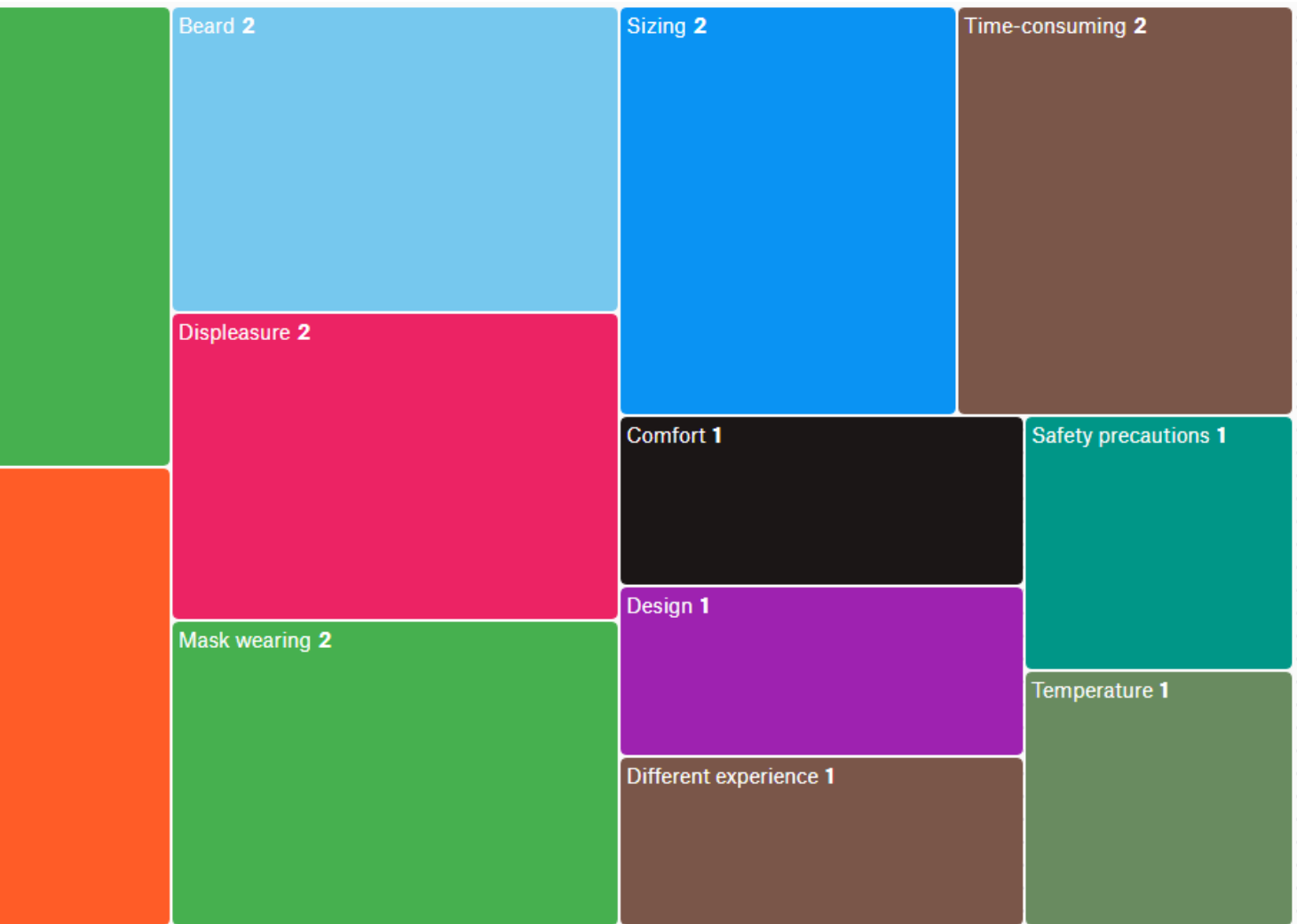
Figure C1, Sankey diagram of coded interview data

<input type="checkbox"/> Name	Document Name	Codes
<input type="checkbox"/> Like it's stuffy. It is stuffy but as far as masks go its not like the worst getting a bit hot. Moist and condensation.	P1 Interview	Temperature 7
<input type="checkbox"/> Okay, it's not too bad. I noticed that I would have to have my ponytail in a very specific spot like it's the helmet is hitting my helmet hitting ponytail don't know how I would have my hair now.	P1 Interview	Adjustment 11 Frustration 4
<input type="checkbox"/> is a bit of pressure my nose now and I'm a bit hot. And I'm taking deeper breaths. Deep breaths. On my neck is going to strain. if you're looking down, it'd be alright but if you even look straight, it feels uncomfortable.	P1 Interview	Adjustment 11 Discomfort 10
<input type="checkbox"/> Sometimes you want to just take it off and chat. It's probably not work safe. And you want to just like rest it. Yeah, but there's nowhere.	P1 Interview	
<input type="checkbox"/> I can't around my cheeks or anything but oh my bridge of my nose. Because the next so I can sort of feel the pressure where the nose was and the neck. But if the neck strap wasn't tight, it wouldn't have sealed.	P1 Interview	Adjustment 11 Discomfort 10 Displeasure 4

Figure C2, P1 coded interview data

<input type="checkbox"/> I can't really lift my head because of the neck strap. if I look up to high it pulls on my face
<input type="checkbox"/> Chin feels very tight here. Not tight around the nose bridge
<input type="checkbox"/> feels like it's falling forward curious to feel how it would feel after an hour or so.
<input type="checkbox"/> It was more just I didn't look at how to do that. Clip? Yeah. It was fine. So maybe another inconvenience and convenience zero being convenient. Yeah, like All right.
<input type="checkbox"/> yeah, it's a bit tighter on my nose or just adjusted it's actually pretty good that was pretty good but wearing that is a bit different story.
<input type="checkbox"/> the straps are good. This split kind of whatever that's

Figure C3, P2 coded interview data



ook	P1 Interview	Adjustment 11 Discomfort 10	on a respiratory.	P3 Interview	Adjustment 11
			<input type="checkbox"/> Once it is set i wont redo it	P3 Interview	Sizing 2
idge	P1 Interview	Displeasure 4	<input type="checkbox"/> This mask is just too small	P3 Interview	Inconvenience 7
	P1 Interview	Adjustment 11	<input type="checkbox"/> Yeah, sometimes I'll wear that but not always	P3 Interview	Beard 3
			<input type="checkbox"/> Yeah, like disfigured my beard	P3 Interview	Beard 3
h.	P1 Interview	Inconvenience 7 Frustration 4	<input type="checkbox"/> I know that it's not I'm not fully protected because the beard and it's annoying that it as I say, you know from having a good beard day or stuff like that	P3 Interview	Time-consuming 3 Inconvenience 7
is	P2 Interview	Adjustment 11 Different experience 1	<input type="checkbox"/> If I'd have to take it off for five seconds, I will find that annoying.	P3 Interview	Time-consuming 3 Inconvenience 7
	P2 Interview	Comfort 1 Design 1	<input type="checkbox"/> And then time as well if I've got to do something with a little bit you know, it's not a huge amount for a couple of	P3 Interview	Time-consuming 3 Inconvenience 7

Figure C4, P3 coded interview data

Discomfort 6

Adjustme

Temperature 6

Wearing C

Figure C5, Sankey diagram of coded survey data

<input type="checkbox"/> Name	Document Name	Codes
<input type="checkbox"/> Hard to where eye protection, lung protection and hearing protection at the same time as it becomes very uncomfortable. Taking all protective gear off is very time consuming too.	Survey results	Time-consuming 3 Inconvenience 7
<input type="checkbox"/> hot, sweaty, itchy, P2 masks ear loops suck after a while, full face respirators are hard to keep fog free and scratch free and in BA applications to keep a good seal the mask puts a lot of pressure on the face and jaw, causing discomfort and pressure injury's	Survey results	Displeasure 4 Temperature 7 Discomfort 10
<input type="checkbox"/> The elastic band and the sweatiness in summer. I really don't enjoy when the rubber perimeter sweats up!	Survey results	Temperature 7 Adjustment 11
<input type="checkbox"/> seal around nose is never adequate	Survey results	Discomfort 10
<input type="checkbox"/> Tight fit along with wearing glasses and hearing protection	Survey results	Wearing Glasses 4 Inconvenience 7
<input type="checkbox"/> Getting caught in my hair (head hair/pony tail). And	Survey results	Displeasure 4

Figure C6, Sankey coded survey data



<input type="checkbox"/> Getting caught in my hair (head hair/pony tail). And pinching my ears.	Survey results	Displeasure 4
<input type="checkbox"/> Fogging cup safety glasses	Survey results	Wearing Glasses 4
<input type="checkbox"/> doesn't fit well with a beard	Survey results	Beard 3
<input type="checkbox"/> Difficult to breathe normally	Survey results	Discomfort 10
<input type="checkbox"/> Straps, nose fitting, ear	Survey results	Discomfort 10 Adjustment 11
<input type="checkbox"/> Straps, glasses, sweat,	Survey results	Wearing Glasses 4 Adjustment 11 Temperature 7 Discomfort 10

Figure C7, Sankey coded survey data