REIMAGINING AN INHALED EXPERIENCE

Improving the Design of Asthma Inhalers

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Thank you to the technicians at AUT - particularly Matt, ET, Harriett, Angus, and Glenn - for helping me to visualise my ideas through the countless renditions of prototypes and experimentations.

And lastly, thank you to the respondents who participated in this research, I hope that my outcomes proved to advocate for understanding your experiences and that your contribution was invaluable.

ABSTRACT

People with asthma must learn to manage their condition throughout their lives by using inhalers routinely, as asthma is a chronic illness. Existing literature has predominantly focused on inhaler use techniques, misuse and lack of use, with minimal attempt to address the deep-rooted stigma associated with inhaler devices. This project aimed to improve the product design of inhalers. A human-centred design approach within an action research methodology was used to ensure that users were at the forefront of the development process instead of being evidence-based, which drives medical research. The findings showed a clear need for a more intuitive and modern inhaler design. An opportunity was identified to consider its form and function and the relationship between asthmatics and healthcare providers. Design outcomes include a smart inhaler concept at the centre of a proposed asthma-care eco-system to motivate consistent use, having explored aesthetics, usability, and interaction. This project highlighted the complexity of asthma treatment and revealed that more collaborative engagement with asthmatics is encouraged as part of the further research required into user experiences. However, it sets a precedent for future design research in asthma and potentially for other respiratory illness product development.

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GLOSSARY

Asthma exacerbations
Athma attacks.

Atomisation
The breakup of a liquid stream into fine particles such as a spray (Jacobs, 2014).

Bronchioles
Small tubes connecting the lower airways to the lungs (Stein et al., 2014).

Nebulisers
Devices that atomise liquid medicine (by turning it into a mist) allowing the medication to flow into the lungs like breathing in oxygen so users can breathe “normally” through the attached mask (Asthma UK, 2021c).

INTRODUCTION

Positioning the Researcher

My earliest memory of asthma was around the age of three, when I found myself unable to breathe and was admitted to a hospital in Indonesia. I was diagnosed with asthma and started being prescribed inhalers. I recall countless consultations with doctors to change my dosage, learn new techniques, and was given various spacers while growing up. Despite this, I struggled to use my inhalers routinely, and I particularly disliked having to bring my inhaler and bulky spacer wherever I went. Past my adolescent years, I decided that the hassle of using a spacer outweighed the benefits, and I began to use the inhaler by itself. I still avoided using my inhalers in public and would excuse myself to the bathroom if I needed my medication. I went to some lengths to avoid attracting unwanted attention, feeling awkward, or getting questions about my health. It was an intriguing thought to have an inhaler that I could be comfortable using regardless of my situation. I became interested in finding out if other asthmatics had similar experiences to mine.

Before deciding to study design, I studied Chemical and Materials Engineering. Though I enjoyed most subject areas and engineering thinking allowed a certain extent of creativity, I missed being more imaginative and exploring design elements that are not so constrained. My journey in designing for health began during my undergraduate semester in Industrial Design, where I gained exposure to the design field. I selected a ‘design for health’ project in one of the courses. Before this, I had not considered healthcare to be a sector that required design intervention, and this project opened my mind to the possibility of being able to contribute in this area.

Once I began looking into the possibility of a project focused on asthma metered-dose inhalers (MDI), I was surprised how little dose was delivered into the lungs without the spacer. Given my experiences with asthma, I was excited for a design research opportunity that let me utilise my engineering and industrial design backgrounds to redesign the asthma inhaler in consideration of its form and function to help improve the experiences of people with asthma.

CONTEXTUAL REVIEW

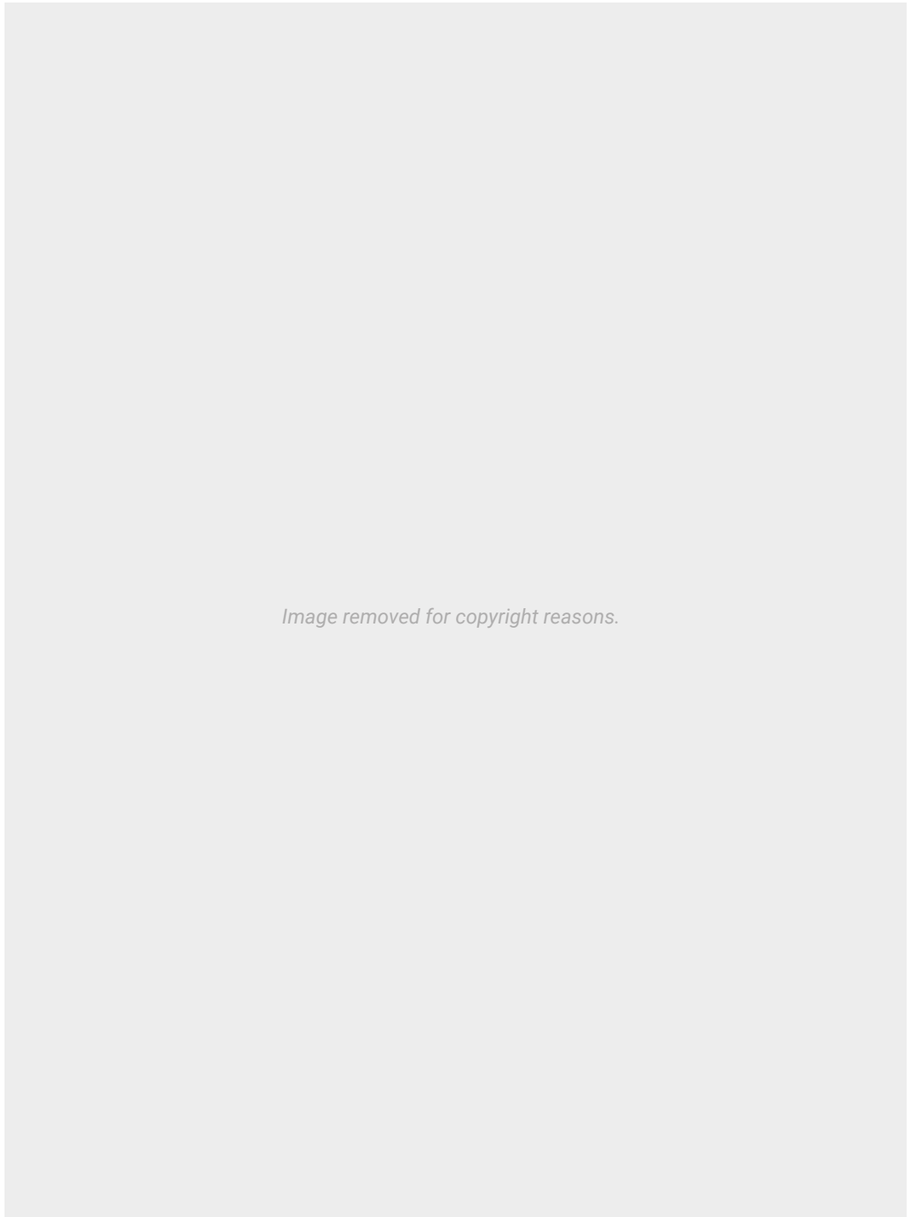

Figure 1 – Overview of New Zealand Healthcare System (Ministry of Health NZ, 2016).

Healthcare in New Zealand

Overview

The New Zealand public healthcare system covers citizens, permanent residents, and certain visa holders, ensuring free or low-cost health and disability services as the government subsidises the health system through general taxation (New Zealand Immigration, 2022; Southern DHB & WellSouth, 2022). Those eligible for public healthcare are entitled to, for example, free in-patient and outpatient hospital treatments, hospital care for accidents, oral healthcare for children, maternity care, and disability support services (New Zealand Government, 2022). The first point of contact for health services usually is primary health care, which includes general practitioner (GP) consultations, dentists, and pharmacists. These services incur a cost for patients, though many are subsidised, including many prescriptions for medication. Specialist care, also known as secondary health care, may be free for eligible patients, but private consultations incur a considerable cost (Southern DHB & WellSouth, 2022). However, non-profit organisations may also provide patients with free or low-cost specialist care, such as Asthma NZ and Asthma Foundation NZ (Asthma Foundation NZ, 2021b).

What is Asthma?

Asthma

As with all living things, humans need to breathe to supply oxygen to the body and remove carbon dioxide as waste gas. All the cells in the body require oxygen to convert consumed food into energy (Brabandere, 2019; British Lung Foundation, 2015). Generally, most people do not often think about breathing and take this natural process for granted. During inhalation, the air flows through the trachea (windpipe) and then down the bronchi tubes (airways), where they split into different pathways of bronchioles, called generations [Fig. 2]. These airways expand under healthy environmental conditions and contract when exposed to cold air or allergens, making it difficult for air to flow through (Nucleus Medical Media, 2012).

Asthma is a chronic respiratory condition where the oversensitive airways become inflamed from specific triggers, and the smooth muscles become tightened, leading to airway restriction [Fig. 3] (Asthma Foundation NZ, 2022a; Asthma New Zealand, 2021). People diagnosed with asthma have more trouble breathing than non-asthmatics due to their contracting airways. Excess phlegm is also produced, further obstructing airflow into the lungs (Yoshida et al., 2020). Reports indicate that the fourth and fifth generations of the bronchioles are most affected during acute asthma exacerbations (Jiang et al., 2018). Asthma symptoms include wheezing, shortness of breath, coughing, breathing difficulty, and chest tightening (Mayo Foundation for Medical Education and Research, 2021).

Its high prevalence within developed countries such as the United Kingdom, the United States, New Zealand, and Australia, suggest genetics, environment, diet, and allergens as likely contributing triggers, but specific causes are unknown (Asthma Foundation NZ, 2021a; Mitchell, 1985; E. Wang et al., 2020). Poor housing conditions such as minimal insulation and visible mould have also been attributed as a factor causing high asthma rates. In New Zealand, 35-46% of houses were reported to contain mould, likely caused by dampness indoors, lack of insulation, and lack of heating (Bornehag et al., 2001; Telfar-Barnard et al., 2019). Although housing conditions appear to be a primary concern, these issues have been prominent for several decades as many houses were inadequately constructed for the New Zealand climate, causing concern for more than asthmatics (Howden-Chapman et al., 2008, p.; Howden-Chapman & Pierse, 2020).

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Figure 2 – Diagram showing the inside of the lungs from the mouth to the system of airways (Themes, 2019).

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Figure 3 – Comparison between normal airway, asthmatic airway, and airway during asthma exacerbation (Ophea, 2021).

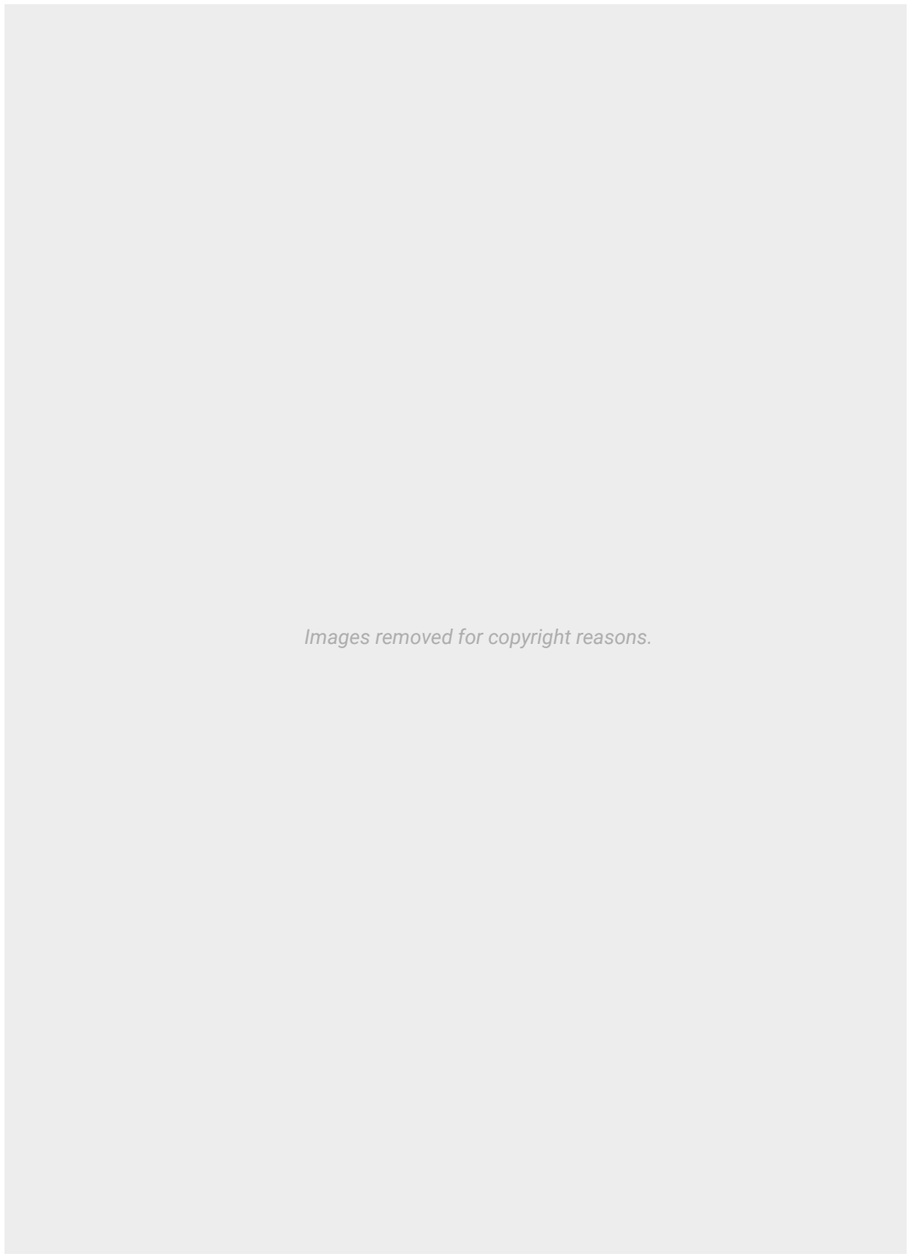

Figure 4 – Asthma inhalers available in New Zealand (Ponen, 2021).

Asthma Treatment

Asthma is a chronic illness, and can only be managed by treating the symptoms depending on the severity and need for long or short-term management (Ponen, 2021). Medications are prescribed based on the patient's symptoms, age, dosage requirement, and availability. There are three common types of asthma medication: relievers, preventers, and combinations. Preventer medications are long-acting treatments that can help prevent asthma symptoms and exacerbations by reducing inflammation in the airways (Asthma Foundation NZ, 2022b). Although preventer medication contains low steroid medicine, it is considered safe, beneficial to lung function, and improves airway responsiveness when used daily (Asthma Foundation NZ, 2022b; Ye et al., 2017). Reliever medications are short-acting bronchodilators that quickly relieve asthma symptoms by relaxing the tight airway muscles. However, the effects of these treatments wear off within hours. Therefore, they must be used with preventer inhalers for improved long-term results.
Side effects from excessive use of reliever inhalers may include mild shaking, hyperactivity, headaches, increased heart rate, nervousness, and restlessness (Asthma Foundation NZ, 2022c; NHS, 2018). Combination inhalers combine corticosteroid (preventer) and bronchodilator (reliever) medication, eliminating the need for two devices. This approach also encourages reduced reliance on relievers and allows people to take their preventer medication (Asthma UK, 2021b).

All medication options can be administered using various devices, including metered-dose inhalers (MDIs), dry-powder inhalers (DPIs), and soft-mist inhalers (SMIs). Inhalers are the most commonly prescribed devices for asthma. Other less common forms of treatment include nebulisers, pills, liquids, and in rare cases, injections (DerSarkissian, 2021). Until the recent decade, MDIs were most widely-prescribed in NZ (Pharmac, 2019) due to their simplistic mechanism and affordability (Hodder & Price, 2009).

The devices have different colours associated with each type of medication (produced by various pharmaceutical companies) for easier differentiation between medicines (Jayakrishnan & Al-Rawas, 2010) as shown in [Fig. 4]. For example, reliever inhalers are blue, preventers tend to warm tones, and combination inhalers are purple or red (Ponen, 2021).

Inhalers

History

English physician John Mudge invented the first inhaler in 1778 that medicated the catarrhous cough by modifying a tankard for the user to inhale opium vapour (Mudge, 1782). In 1956, the first MDI was designed by George Maison and his team at Riker Laboratories in the United States. His daughter, Susie, asked why her medication could not be delivered more like a hairspray instead of her “awkward squeeze-bulb nebuliser”. This inquiry led to the rapid development of a device that delivered exact volumes of vapour through a metering valve (Vaughan, 2020).

At the time, the pressurised canister included a small quantity of alcohol and chlorofluorocarbon (CFC) propellant-medication mixture (Melling, 2017). Since the phase-out of CFC-containing products from 1993 until 2010 due to its harmful effects on the atmosphere’s ozone layer, hydrofluoroalkane (HFA) was selected as the more environmentally-friendly alternative propellant (Velsor-Friedrich et al., 2009). Many HFA-based MDIs still contain approximately 10mg of alcohol, in the form of ethanol, per puff. However, studies show this amount to be minimal for human consumption and would therefore not have any pharmacological effect. Patients concerned with alcohol intake may be prescribed alcohol-free HFA inhalers (Alrasbi & Sheikh, 2008; Bruce et al., 2009; Medsafe, 2018).

Figure 5 – Historical timeline of inhalers (MDI specifically).

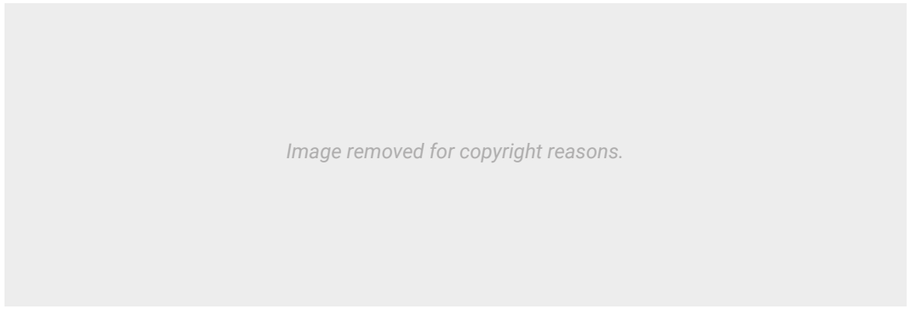

Figure 6 – MDI's product design and mechanism (Khan et al., 2013).

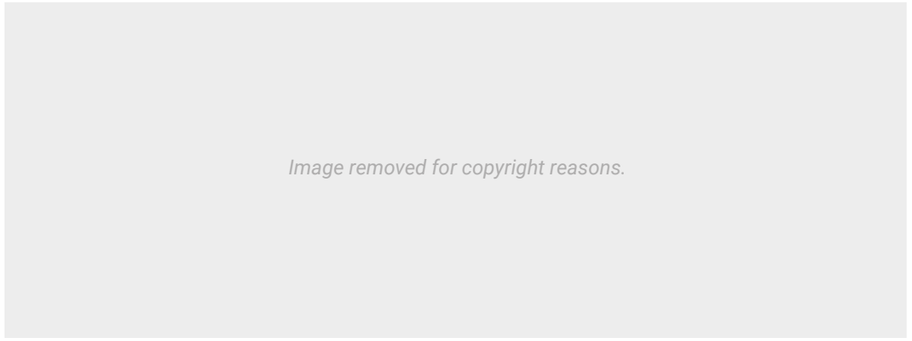

Figure 7 – Laminar flow velocity profile with spacer. Circled are evident dead spaces around the edges (Kleinstreuer et al., 2007).

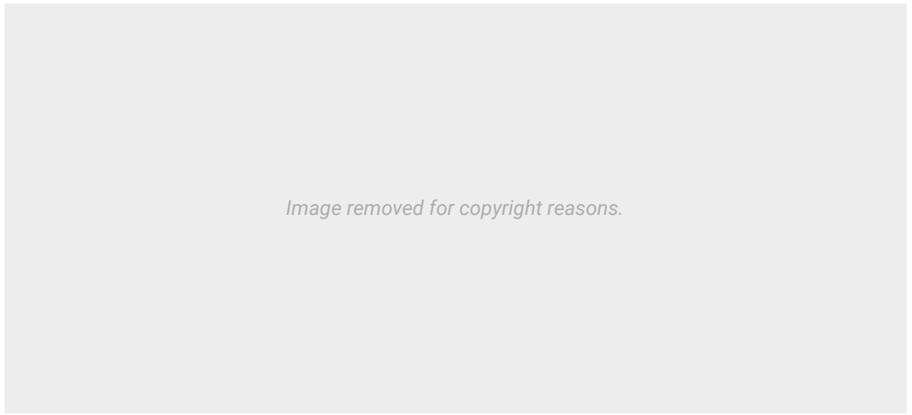

Figure 8 – Simulation of particle deposition from MDI a) with spacer b) without a spacer (Kleinstreuer et al., 2007).

Metered-Dose Inhaler (MDI)

The MDI consists of several separate components, as shown in [Fig. 6]. The medication is housed inside the canister with a hydrofluoroalkane gas (HFA) to propel the medication when sprayed. Once the medicine is released, the fine particles travel into the bronchioles (Stein et al., 2014). However, only 10-20% of the dose is generally deposited in the lungs, where the medication is meant to help relax the surrounding muscles (Newman & Clarke, 1992). This is mainly attributed to the nature of aerosol sprays inducing high velocity and pressure necessary for dispersal, causing turbulent flow and difficulty pushing the canister down while simultaneously inhaling (hand-breath coordination) (Newman et al., 1981). Small particles less than 5um in diameter are more likely to deposit in the lung. However, those less than 0.5um are usually exhaled as they have less chance of travelling past the trachea due to their random movement, also known as Brownian diffusion (Heyder & Svartengren, 2002; Labiris & Dolovich, 2003; Yu & Taulbee, 1975).

A spacer device attachment was developed in 1957 (Nikander et al., 2014) to improve drug delivery into the airways and lungs by up to 50% compared to using the inhaler by itself (Ammari et al., 2020; Ministry of Health NZ, 2021). Several reasons achieve this increased efficacy. The first reason is that a spacer eliminates hand-breath coordination, so the user can inhale the medication when they are ready. Secondly, using a spacer results in more favourable conditions for the flow of medicine by reducing the aerosol velocity, thereby transforming the flow from turbulent to laminar [Fig. 7] (Labiris & Dolovich, 2003). Using a spacer makes the flow more directional and can reach the airways better, as particles are less likely to collide with the roof of the mouth, tongue, or back of the throat [Fig. 8] (Roller et al., 2007). Despite this, increased efficacy is still only up to 50% (Vincken et al., 2018). As shown in [Fig. 7], the geometry of the current spacer design promotes 'dead spaces' where particles agglomerate in the corners, thereby reducing the number of particles inhaled into the lungs, despite the desired laminar flow conditions (Kleinstreuer et al., 2007).

Dry-Powder Inhaler (DPI)

DPIs were designed to eliminate the need for the user to coordinate inhalation and actuation while retaining a compact size (Crompton, 1982; Lavorini et al., 2008; Newman & Busse, 2002). DPIs are also considered more environmentally friendly as these combination medications have a lower carbon footprint than the MDI's HFA propellant (Asthma Foundation NZ, 2021c).

Early dry-powder inhaler (DPI) designs had capsule medication that required pressure to be applied by the user to pierce a capsule. The medication was mixed with a lactose carrier-based formulation contained in gelatin capsules (Clark, 1995). Multidose reservoir inhalers were popularised around the 1990s using the exact drug formulations, such as the Turbuhaler in [Fig. 9]. These were designed to dispense 'per dose' medication by the user. Some mechanisms used to measure single doses included dose cavities (e.g. Accuhaler and Ellipta [Fig. 9]), slides, shafts, and cylinders. The multi-dose or refillable design of DPIs supported cheaper manufacturing processes, making them viable alternatives to MDIs (de Boer et al., 2017).

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Figure 9 – DPIs available in New Zealand and their respective mechanisms – top to bottom: Turbuhaler (Basheti et al., 2013), Accuhaler (Musso, 2009), and Ellipta (GSK, 2021b; Ponen, 2021).

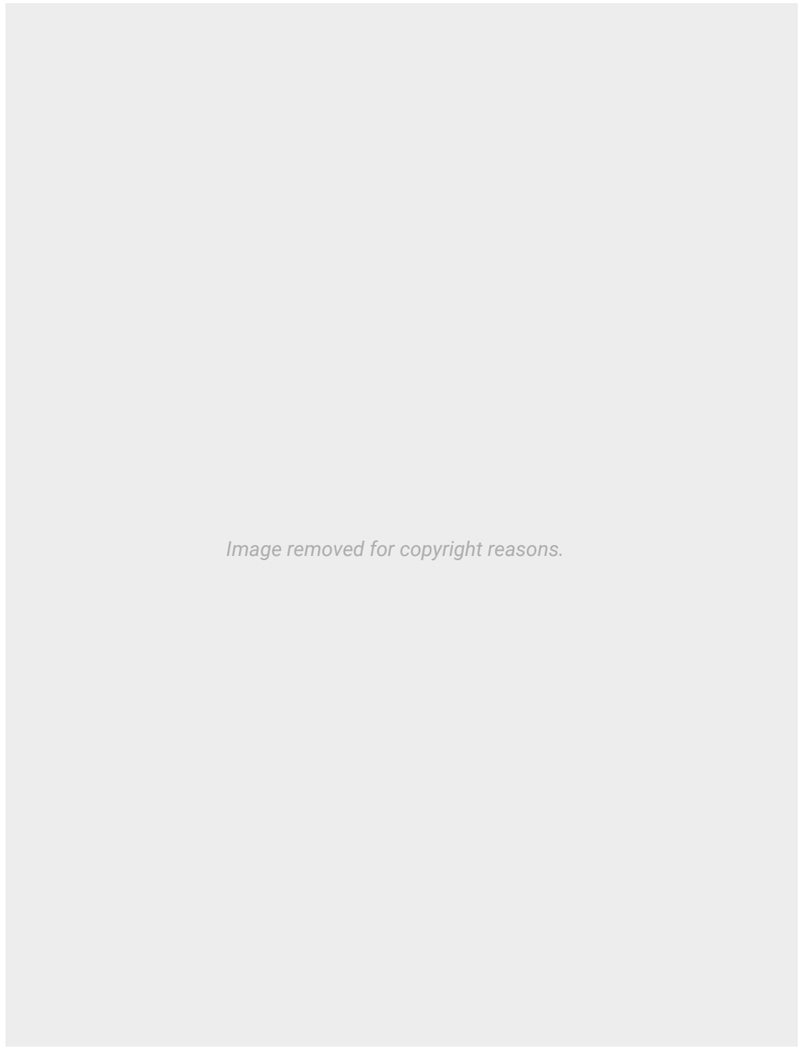


Figure 10 – Respimat inhaler components (Boehringer Ingelheim Ireland Limited, 2020).

Soft-Mist Inhaler (SMI)

The first known SMI was introduced in 2004 as an alternative to MDIs and DPIs by the pharmaceutical company, Respimat (Dreher et al., 2021). When pressure is applied to the canister, a mist is sprayed through a nozzle. Unlike MDIs, the velocity of the spray is much slower, allowing the user to inhale more naturally. Consequently, a higher percentage of the medication is deposited into the lungs than the MDI (Newman, 2006). However, like with MDI, the user must inhale while simultaneously pressing a button to release the medication (Boehringer Ingelheim Ireland Limited, 2020).

Despite its higher efficacy, SMIs seem more commonly prescribed for COPD patients and asthmatic patients who struggle to use MDIs and DPIs (Asthma New Zealand, personal communication, 2021; Navaie et al., 2020). While relatively simple to use, reports show common usage mistakes that result in less medication being delivered into the lungs. These errors include not completely exhaling all the breath before use, holding in breath for less than the required time, inhaling too lightly, not holding the inhaler upright, and not turning the base sufficiently (Navaie et al., 2020).

User Experience

Living with Asthma

People with asthma experience symptoms that can often impact their psychological, physical, social, and emotional well-being. For children, this may mean being unable to participate in fitness activities (Rydström et al., 2005; Stridsman et al., 2017; van den Bemt et al., 2010), higher school absence rates (Bonilla et al., 2005; Moonie et al., 2006; Silverstein et al., 2001; Washington State Department of Health, 2013), peer exclusion or bullying as a result of inhaler use or being unable to control their asthma symptoms in class (e.g. coughing), or missed school days (Naman et al., 2019; van den Bemt et al., 2010). Children have reported difficulty accessing inhalers during school hours due to restricted access or otherwise risking theft or loss (Naman et al., 2019). Staff, notably nurses and teachers, have been known to "gatekeep" inhalers by giving permission or denying students access to their inhalers, where their decisions were based on their own experiences of asthma (Clark, 2012; Naman et al., 2019). As a result, students wanted school staff to be more considerate and involved with their asthma care and provide better support based on their individual needs (Naman et al., 2019). Schooling may further be impacted due to asthma symptoms disrupting sleep and concentration, particularly for those with more severe asthma (CDC, 2018; van den Bemt et al., 2010).

Adolescents and young adults have also reported asthma's effects on their personal and social lives. participants from Cole et al.'s (2013, p3) study expressed their eagerness of "wanting to be like the rest." Concerns included being excluded from team activities, needing to be selective of clothing (tighter fit may restrict breathing), and reliance on inhaler medication when going out. Although most asthma exacerbations occur during childhood due to poorer management (Zahran et al., 2015), many people diagnosed earlier in life are known to "outgrow" asthma around their second decade. However, some asthmatics may relapse with worsening symptoms later in life or continue to suffer from symptoms causing significant burdens on their quality of life (Bronnimann & Burrows, 1986; Trivedi & Denton, 2019; Warke et al., 2002).

In the UK, approximately four million sick days were taken in 2019 in relation to asthma (Asthma UK, 2020), and the direct cost burden of asthma on health services including prescriptions, GP consultations, and hospital care was estimated at $1.1GBP billion (Asthma UK, 2021a). In New Zealand, the costs due to asthma were estimated at $1NZD billion per year (Barnard & Zhang, 2021). The United States' asthma-related medical cost per person per year was estimated at $3226USD (Inserro, 2018). Moreover, asthmatics may be subject to anxiety and depressive disorders due to their reduced quality of life (Hamilton, 1959; Vermeulen et al., 2017).

Even with modern-day advances in medical care and improved medication adherence strategies, unsatisfactory outcomes for asthmatics continue despite a better understanding of asthma. There is limited research regarding people's personal asthmatic experiences. Most literature was focused on the more medical aspects of asthma (Holley et al., 2017; Pickles et al., 2018; Ring et al., 2011). Within a New Zealand context, statistics continuously show how Māori, Pacific peoples, and those from lower socio-economic communities have higher asthma prevalence and hospitalisation rates (Barnard & Zhang, 2021; Pattemore et al., 2004; Sheridan et al., 2011). Despite this, there seemed to be no appropriate changes made to consider this reality, as published surveys present repeated statistics year after year. From the literature reviewed thus far, it seems that healthcare professionals tend to focus on asthma symptoms, triggers, and medication, while people living with chronic conditions are more interested in the necessary changes they may have to make, and the effects on their lifestyle such as exercise, diets, fatigue, and sleeping habits (Chung et al., 2014; Ring et al., 2011).

Asthmatic Identity

It was evident from qualitative studies that personal identity may be connected to an individual's health condition. Van den Bemt et al. (2010) found that asthmatic children were worried about feeling different from their peers who did not have asthma and were concerned about being teased when medicating at school (Walker & Reznik, 2014). The fear of social exclusion drives self-consciousness around peers, especially during adolescence, where comparative behaviour is most prevalent (Eccles, 1999; Lycett et al., 2018). People respond to living with asthma differently, which, in turn, affects their treatment management. Adams et al. (1997) discuss three groups that correspond to the most apparent attitudes – deniers/distancers, accepters, and pragmatics.

Deniers/distancers

Respondents who perceived asthma negatively and rejected asthma as part of their identity seemed to manage their asthma through denial. They claimed they did not have asthma or stated that they did not have "proper asthma" (Adams et al., 1997; Al-kalemji et al., 2014; Taylor et al., 2014). Despite the claims of minimal impacts from asthma, the participants' lifestyles were undeniably affected. As a result, they had formed subconscious strategies to prevent triggering symptoms or showing symptoms, even going as far as making extensive attempts to ensure that their condition was not evident to others. External support can also play an essential role in one's identity (Baggott et al., 2020). Those whose friends and family do not adequately understand asthma may feel embarrassed about their symptoms and avoid necessary use of inhalers, particularly in public.

Deniers/distancers tend to view their symptoms as an acute illness, preferring to accept asthma as a temporary sickness rather than identifying with having a chronic condition (Adams et al., 1997). This perception was evident concerning their medication regime and being selective about medication, noting several reasons as follows (Adams et al., 1997; Bidad et al., 2018; Health Experiences Research Group, 2015b). Firstly, the action itself of taking medication every day meant recognising that their asthma is a chronic condition (Adams et al., 1997). Secondly, and most commonly seen in adolescents and young adults, reliever inhalers were perceived as a "quick fix"' tool to allow denier asthmatics to continue their daily routines. In Diette et al.'s (1999) study, the emotional and social issues were more evident in people who tend to overuse reliever medications. Favouring one medication over another and overusing reliever medication can result in worse symptoms and poor asthma control (Kansra et al., 2021). Thirdly, since preventer medications are steroid-based, people feared its potential side effects and having to depend on daily medication. To avoid reliance on medication, denier asthmatics have admitted attempting to cope without inhalers (Bidad et al., 2018; Price, 1994).

Goffman (1961) and Charmaz (1983) argued that a detachment from the identity as someone who suffers from chronic illness and the behaviours affiliated with the condition could result in identity confusion, loss of self, or a diminished identity. Furthermore, deniers/distancers were more concerned about their social identities, believing that others knowing their asthmatic condition would minimise their self-identity (Adams et al., 1997). On the other hand, the perception of asthma may also be influenced by distrust in the advice of healthcare professionals, especially if such advice is conflicting or misinformed (Bidad et al., 2018; Newcomb et al., 2010).

Accepters

In contrast, many asthmatics accept asthma as being part of themselves. Fletcher and Hiles (2013) found that self-managing their condition meant learning to take their medication regularly and not allowing their condition to hinder them from doing their daily activities. Upon diagnosis, however, accepters may initially react negatively and not instantly accept being an “asthmatic” as part of their identity (Adams et al., 1997).

The main difference between accepters and deniers/distancers was their attitude, which led to a seemingly more secure sense of self (Adams et al., 1997). Although they may be equally interested in wanting to live normally as deniers/distancers, accepters displayed more motivated adherence to their prescriptions and willingly accessed healthcare resources or partnered with clinicians to improve their self-management (Adams et al., 1997; Baggott et al., 2020; Mancuso et al., 2010). In Adams et al.’s (1997) study, accepters expressed an open attitude about their condition; although they identified as “asthmatic”, they did not feel impaired. The confidence in self-managing asthma seemed to stem from personal experiences as opposed to receiving formal education. For example, this may result from past successful outcomes in their treatment, identifying triggers of symptoms and risk of exacerbations, receiving positive social support, and accessing adequate medical care (Mancuso et al., 2010; Sloand et al., 2021). The preference to self-manage worsening symptoms by increasing or decreasing their medication dosage instead of consulting with their physicians may be correlated to past interactions with healthcare professionals (Bidad et al., 2018; Mancuso et al., 2010; Partridge et al., 2006). Having to routinise using preventer inhalers was found to be generally disliked. However, accepters recognised the need to rely on these treatments to manage their condition (Adams et al., 1997).

Pragmatics

The third group of asthmatics had neither a strong negative nor positive outlook of asthma, as their views on treatment depended on individual situations (Adams et al., 1997). Pragmatics may try to accept the “asthmatic” label in society but view asthma as an acute rather than a chronic condition. In Adam et al.’s (1997) study, respondents believed their medication was like antibiotics and would only be required upon diagnosis or impending exacerbations. Similar to deniers/distancers, pragmatics were shown to deny parts of their condition or minimise its effects (Al-kalemji et al., 2014; Taylor et al., 2014). Adherence to taking preventer medication was higher when people deemed themselves at higher risk of exacerbations, such as during colder seasons or when fatigued (Bidad et al., 2018). A pragmatic approach seemed to be strategic and carefully considering whom asthmatics would disclose their condition. Pragmatics generally told family and close friends about their asthma but were more hesitant towards co-workers, especially when they feared their employment might be threatened (Baggott et al., 2020; Health Experiences Research Group, 2019; Janson & Becker, 1998). This was particularly the case regarding the public use of inhalers (e.g., using inhalers in the office may “undermine [their] managerial authority” (Adams et al., 1997, p198). These perceptions may result in identity concerns, as pragmatics found it difficult to integrate their condition with other social identities (Adams et al., 1997).

The Stigma Attached to Inhalers

Taking medical treatments in social environments can cause people to feel stigmatised and separated from their peers. As described in previous sections, this may reduce a person's quality of life and affect their adherence to a medication regimen (Kansra et al., 2021). Portrayals of stigmatised differences may have predominantly stemmed from the media and the entertainment industry. Even in films directed toward children, inhalers have been tied to asthma (Prout, 1996). Asthmatics characters using inhalers were often taunted and depicted as being under stress. This results in a complicated tension, where an inhaler cancels out or corrects breathlessness, yet it can make breathlessness more visible (Clark, 2012). Depictions of asthmatics in media also generally ignore the spacer device (De Simoni et al., 2017). A survey by the Asthma Society of Ireland reported that 48% of people with asthma did not use a spacer device within one year, with many having never used one (Asthma Society of Ireland, 2018). Asthmatics have expressed concern regarding the inhaler's design and how embarrassed they had to take out an inhaler to use it, especially in new environments (Al-kalemji et al., 2014; De Simoni et al., 2017; Health Experiences Research Group, 2015b).

Different age groups described various accounts of stigma experienced throughout their lives. When children felt they required their medication during school, they often asked to be excused from their lessons to use their inhalers in private, attracting attention from their peers and emphasising their self-identity as being 'different' (Clark, 2012; Monaghan & Gabe, 2019). As mentioned earlier, using inhalers at school has also led to teasing and bullying. Kansra et al. (2021) discussed that children may have stopped using inhalers at school to avoid the potentially associated stigma.

The fear of stigma seems to continue into adulthood, with adults voicing strong opinions about asthma. This indicated that their stigmas may have been ingrained from a young age when asthmatics were learning to accustom themselves to the "social hierarchies of value and moral worth" (Monaghan & Gabe, 2019). Adults also viewed inhalers as "an admission of weakness." Consequently, many people go to great lengths to avoid or manage asthma-related stigma for reasons such as "embarrassment," "discretion," and "privacy" (Adams et al., 1997; Health Experiences Research Group, 2015b). Tactics include hiding inhalers from public view, refraining from participating in physical activities that may provoke breathing difficulties (Adams et al., 1997; Cole et al., 2013), and denying and showing "animosity toward the inhaler" (Monaghan & Gabe, 2019). As a way of normalisation and to avoid disclosing their condition to others, people may also evade treatment (Kansra et al., 2021).

Images removed for copyright reasons.

Figure 11 - Examples of asthma tropes in film and television: Eddie Kasbrak (IT), 12 | Carl Wheezy (The Adventures of Jimmy Neutron, Boy Genius), 13 | Albert Brennaman (Hitch), 14 | Mikey Walsh (The Goonies), 15 | Milhouse van Houten (The Simpsons), 16 | Leonard Hofstadter (The Big Bang Theory), 17 | Shannon Rutherford (Lost).

Medical Device Use and Misuse

Aside from the inhaler design, the other prominent factors impacting adherence are inhaler use techniques and the education on those techniques (Price et al., 2013). Without adequate health education and practice for good inhaler techniques, a patient cannot receive the maximum benefits of treatment (Lavorini et al., 2008). Studies showed that frequent misuse of MDIs was strongly correlated to poor asthma control (Abegaz et al., 2020; Giraud & Roche, 2002; Griffith et al., 2019; Kebede et al., 2019; Lenney et al., 2000; Price et al., 2013). DPIs are can be a preferable alternative to MDIs, mainly due to their ease of use (Ramadan & Sarkis, 2017; Svedsater et al., 2013). However, despite DPIs' higher efficacy in dispensing medicine and being easier to use, studies have shown relatively high percentages of users practice incorrect techniques (Carrión Valero et al., 2000; Girodet et al., 2003; Haro Estarriol et al., 2002; Molimard et al., 2003; Nimmo et al., 1993; van der Palen et al., 1994, 1995). Although DPIs eliminate the need for hand-breath coordination some of the DPIs' mechanisms were described as relatively confusing, according to patient assessment and feedback (Lenney et al., 2000; van Beerendonk et al., 1998). From the literature reviewed, all authors concluded that inhaler technique and health education should be revised and improved to improve asthma statistics.

The initial responsibility of educating the patient on the correct inhaler technique is entrusted to primary care physicians and healthcare professionals (e.g. a GP) during diagnosis (Leung et al., 2015). From the patient perspective, some have expressed not feeling heard by their healthcare professionals or have received conflicting or insufficient information (Health Experiences Research Group, 2015a; Hussein & Partridge, 2002; Munro et al., 1996; Speck et al., 2014). There were suggestions that stigma held by healthcare professionals influenced their healthcare practices (Nyblade et al., 2019) based on their own experiences with treatments and symptoms (Kansra et al., 2021). Not involving patients in decision-making regarding their treatment becomes an issue when the individual's lived experience is not considered. This can negatively impact treatment to be successful (De Simoni et al., 2017; Loignon et al., 2009). Time restrictions and the availability or choice of many different inhaler types are cited as reasons for the lack of training for the professionals. These result in a significantly low proportion of patients who receive proper inhaler education (Basheti et al., 2005).

Unfortunately, people are also likely to become complacent. Those taught and practiced correct techniques may eventually become complacent with their medical routines (Bosnic-Anticevich et al., 2010). Comprehensive asthma action plans are beneficial, but without a sufficient understanding of their condition, asthmatics may still exhibit poor control for treatment adherence (Griffith et al., 2019). Recently, the focus has changed to engagement rather than adherence, with the purpose of patient care to be more person-centred. This presents the opportunity for design to understand why people may not do certain practices or what may help them do those practices better.

Although there is an evident need to re-evaluate inhaler technique and asthma education, inhaler mechanics currently limit the efficacy. Sanchis and Pederson's (2016) systematic review found that incorrect inhaler use has not improved over the last 40 years. This highlights that new approaches should explore more effective methods of drug delivery. While asthma management and symptoms may improve with better health education and inhaler competency, the stagnating design of inhalers appears to be a factor that contributes to a lack of significant improvement of asthma statistics.

Design Considerations

Product Design in Healthcare

Healthcare is a risk-averse field (Evans et al., 2021). The establishment of evidence-based medicine (EBM) means medical research relies on scientific evidence as a foundation for medical progression (Masic et al., 2008). Consequently, the consideration of human factors and user experiences has often been dismissed in favour of clinical studies, available resources and prioritising manufacturing considerations (Privitera et al., 2017; Tran & Yin, 2020). Only more recently have medical researchers considered actively involving patients within the research as stakeholders using design principles (Ku & Lupton, 2020). The following examples depicted currently available and conceptual medical device designs.

Figure 18 – Top: Two-pack of Mylan EpiPens (Wilts, 2021)
Bottom: Components of EpiPen and instructions (EpiClub, 2019).

Medical-Based vs. User-Based Design

EpiPen

A well-known example of poor medical device design is the Mylan EpiPen. The cap must first be removed to use the device. However, the needle is ejected on the opposite end, contrary to common sense (Lee, 2016b). As a result of this mechanism, there were more than 15,000 cases of accidental injections between 1994 and 2007 (Simons et al., 2010). A bright orange label was added on the needle end in 2009 to reduce the number of unintentional injections (Lee, 2016b, 2016a). The Auvi-Q rivalled Mylan in the autoinjector market due to its needle placement, more compact shape, and step-by-step voice instructions (Umasunthar et al., 2015), but unfortunately was recalled in 2016 from dosage issues (Sanofi US, 2015). With little competition, the price of EpiPens hiked up to over $600 a pair in some countries, including the United States (Celia, 2016; Groeger, 2016). Doctor and designer, Joyce Lee, expressed how DIY healthcare solutions have become more popular alternatives as they are significantly cheaper (Lee, 2016b). The emergency services in Washington state, for example, cannot afford bulk loads of EpiPens, so instead, they created their own injectors for $20 per kit (Taylor, 2016). This reflects an account from Asthma NZ (personal communication, 2021) of a parent who was disappointed with a DPI's design causing difficulties for her child to inhale the required dose of medication. Instead of purchasing a newer, smaller model, she simply stuck a straw into the opening, solving her dilemma at almost no cost and her child was able to take her required medicine sufficiently.

The EpiPen example reinforces the idea that medical devices, such as inhalers, should be intuitive to use and not rely on signs or instructions for the user to understand in order to use them properly. Early in the project, I made a conscious decision to avoid signs and labels indicating touchpoints of interaction, as I believed the device itself should depict natural handling (Groeger, 2016). This also raised concerns about the politics involved with pharmaceutical companies controlling available medication in the current markets and the near monopolisation of medical products (Popken, 2016).

Drop

In contrast to the EpiPen example, the following recent medical device concepts were designed to focus primarily on being more user-centred.

Moorman's (2019) project was based on the issue of adherence to medication for glaucoma patients. Causes for poor adherence included difficulty aligning the bottle with the eyes, elderly patients requiring help from family or friends to administer medication, inconsistency of drop size during administration, and worsening symptoms due to insufficient treatment routines. The design solution helped ensure easier medicine administration, more uniform drops precisely into the eyes, and a "dignified" design that encourages users to be more actively involved in their treatment. The device used a simple squeezing mechanism that does not require much force for actuation. The accompanying dock design recognises the complex system of the manual repeat prescription process. It simplifies it into an automated process, using sensors to track usage and serve as a reminder to renew prescriptions, making users more likely to follow a regime.

Like asthma medication (inhalers), glaucoma medication requires a set routine. Difficulty administering medication, receiving inconsistent doses, and not adhering to the medication regime leads to worsening symptoms and poor management of the patient's health. The modern yet simplistic and intuitive design response helped to encourage adherence and therefore produces a better patient experience.

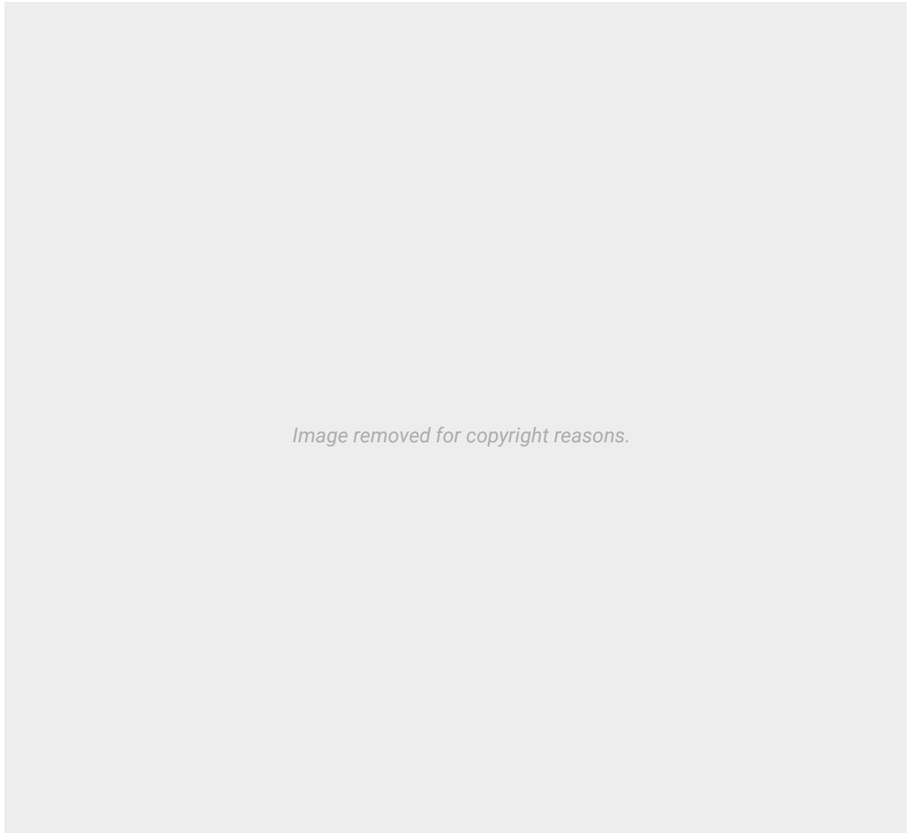


Figure 19 – Drop: glaucoma treatment device (Moorman, 2019).

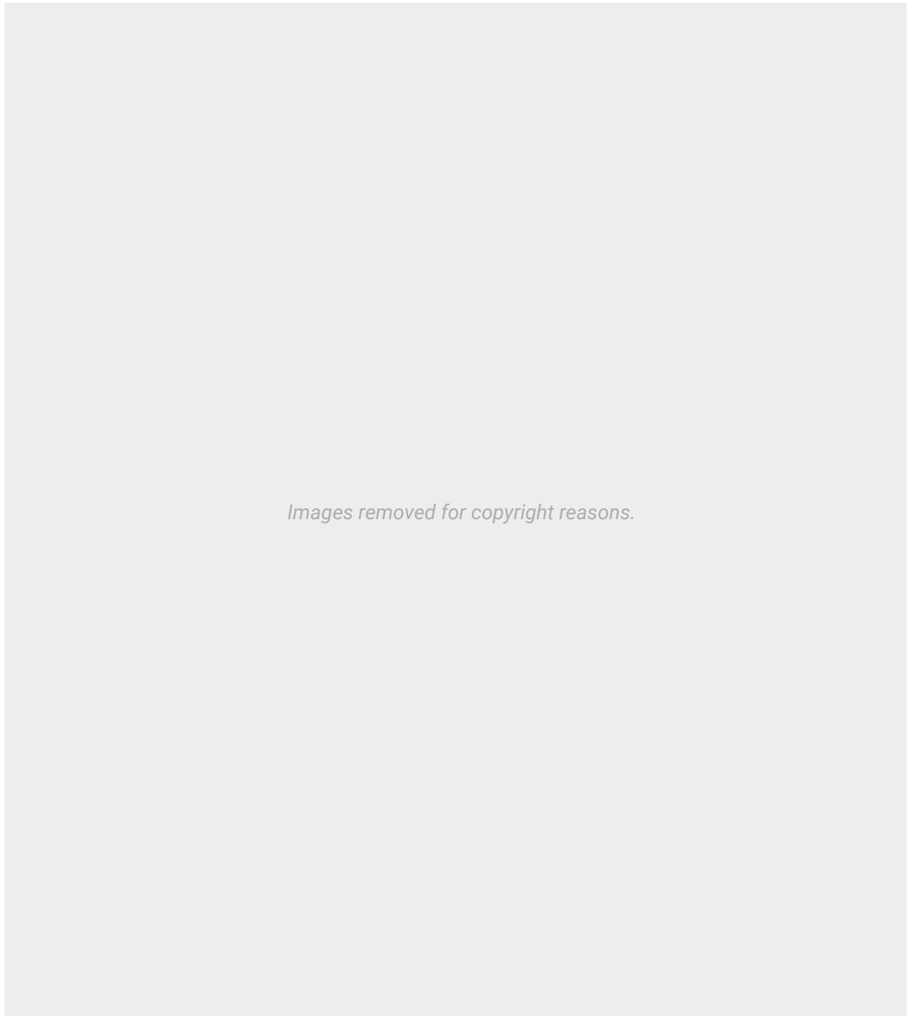


Figure 20 – Top: traditional behind-the-ear hearing aid (Sounds Good Hearing Aids, 2022), Bottom: Turner's "Amplify" hearing aid and bluetooth connection to a mobile app (Turner, 2020).

Amplify

Hearing loss affected approximately 10% of the world's population in 2010 (Bento & Penteado, 2010). Kochkin (2000) reported that the most prominent reasons for reluctance to wear hearing aids included increased background noise, poor fit, adverse side effects of hearing aids, cost, inability to adjust volume controls, increased audio feedback, and stigma. "Premium" hearing aids are often advertised as having extra technological features compared to "basic" hearing aids. However, Cox et al. (2016) argued that there was little to no evidence indicating that such premium technologies allowed users to receive superior or more noticeable benefits.

Turner (2020) designed a hearing aid that utilises "bone conduction technology to provide the user with a comfortable and high-quality audio experience". Instead of creating a device that aims to be hidden from sight, she shifted the narrative to make the hearing aid a fashion statement, much like the evolution of eyewear (Pullin, 2009). Where many hearing aids require the devices to be inserted into the ear canal and may feel uncomfortable (Kochkin, 2000), Turner's design allows the user to slot the device around the concha. Additionally, the Bluetooth sensors implemented in the hearing aids allow users to adjust the sound settings according to personal preference. Amplify aimed to challenge the hearing aid status quo. Commonly hearing aids are intended to be discreet. However, with Amplify, they become a fashion statement, encouraging users to be more transparent about their condition while benefitting from improved audiology technology. With respect to asthma inhalers, I used this example to explore how modern fashion trends can influence the design of medical devices.

Reflection

Amplify and Drop both present the positive outcomes of technological implementation in medical devices and how technology can be embedded in artefacts centred on improving user experiences. Smart devices are controversial, including whether technology is justifiable for their increased cost (Thimbleby, 2013). This, to some extent, will depend on the features included and whether such features are essential additions or serve only as accessories. Human-centred design (HCD) does not necessarily need to include technological advancements. Literature and case studies suggest that the problem often lies within the design itself, not with the patient, as "patients often do not understand when to use the device, how to use it, often forget it, [and] allow it to expire" (Sicherer, 2001, p597). Everyday objects can be confusing to use (Norman, 2013), and making them "smart" may cause further complications if basic human behaviours are not regarded.

Consumer Product Design

Most medical devices are not designed to account for user experiences at its core. Consumer products' developments depend on individuals purchasing for themselves, compared to medical products, which are usually based on the healthcare system's purchasing dynamics in the health market. At the centre of consumer-based development is urgency, as trends quickly change or are otherwise fickle so market opportunities can be very brief (Kirsh, 2019). The appeal of consumer products can be linked to the features and physical forms, although it may also be influenced by personal experiences that, in turn, affect people's perceptions (Blijlevens et al., 2013; Bloch, 1995). Kumar et al. (2015) suggested that social and emotional values can make a more significant impression on consumers' devotion to brands than economic or functional value. Additionally, designs that are considered attractive by consumers can be the result of being communicated well to the intended audience and adding value to the experiences in their lives through the use of the product (Bloch, 1995). The following examples showed how the products' features result in their success among consumers. This is to help draw attention to the contrast often observed in medical devices that seem to hold stigma (albeit with good intentions to improve health outcomes). The products selected are pocketable, handheld, and can be brought closer to the face, exhibiting similar user actions as inhalers.

E-Cigarettes (Vapes)

Small-sized products have become increasingly popular in product design, particularly with electronic devices that can perform just as well as their regular-sized counterpart. Compact products are easily accessible and save space (MAKO Design, 2020; Pelley, 2015). Vapes, for example, were initially designed as a "healthier" alternative to cigarettes, as a mist is produced instead of smoke (Brueck, 2019; Choucair, 2022). The trend of e-cigarettes started rising when vaping companies marketed their products to a younger audience, with the guarantee of modern technology and being highly addictive (Belluz, 2018).

Despite their controversial use, lack of understanding the adverse effects on the lungs from long-term use, and heightening addiction statistics (Douglass et al., 2020; Laucks & Salzman, 2020; Marques et al., 2021), vapes present an interesting contradiction: *how do vapes appear more socially acceptable and less awkward than inhalers meant to aid an individual to breathe normally?* With the popularity of vapes, adolescent and teenage asthmatics were also reported to be using vapes, despite the consequences of triggering symptoms and exacerbations (Chatziparasidis & Kantar, 2022; Reinberg, 2018). The shape of modern vapes is small and can easily fit in a hand's palm, like the Juul design by James Monsees and Adam Bowen (Belluz, 2018). Marketing and advertising also strongly come into play for the popularity of vapes. In stores, vapes are displayed like high-end technology brands, while online platforms promote vapes through trends on Instagram and Tik Tok. Concerning identity, the culture surrounding vapes is socially "badass, rebellious, and cool" (Lee, 2020), which strongly contrasts with the stigma associated with inhalers. Furthermore, the nicotine in vaping is highly addictive and makes it difficult to stop using due to nicotine withdrawal symptoms (CDC, 2022). These reasons combined create an enticing nature for vapes, particularly for young people, all of which inhalers do not feature.

Images removed for copyright reasons.

Figure 21 – Examples of modern e-cigarettes (vapes).

Images removed for copyright reasons.

Figure 22 – Examples of Zippo lighters.

Zippo Lighters

In contrast, albeit having basic components and function, Zippo lighters were considered a ‘cult’ classic. They were the most common item carried around by US soldiers during the Vietnam War, as their durability meant soldiers could use them in almost any situation (Fratus, 2020). The minimalistic design, fuel capacity, lifetime warranty, inexpensive cost, and distinct “click” sound from the lid made Zippo lighters a staple product. After the Vietnam War, the seemingly indestructible lighters were portrayed in pop culture as tools used by both hero and anti-hero characters, such as John McClane in Die Hard (Cohen, 2010; Muzquiz, 2018). As discussed earlier, the media portrayal can serve as a blueprint for how consumers and users perceive products. The emotional connection humans have to fire creates the enigma that Zippos could become a statement of fashion (Gallagher, 2018). Although inhalers could be argued to have a comparatively distinct design (namely the L-shaped MDI), there remains a stigma that cannot seem to be disassociated with more negative perceptions.

Project Direction

Potential for Design Intervention

The contexts directly and indirectly related to asthma depict this respiratory condition's complexity. These include living with asthma, identity, stigma, and consumer and medical product design comparisons. From reviewing the literature surrounding these contexts, there was a clear opportunity to consider the role of product design within a healthcare setting, with the potential for design intervention to improve the experience of inhaler use:

How might a human-centred design approach improve the experiences of people with asthma using inhalers?

The project objectives were framed as follows:

Form

Much of the literature focuses on the mechanics of the inhaler or comparisons between inhalers for individual suitability. Only recently have studies explored users' experiences with inhalers, with issues prominently brought to light by young adults and adolescents. There has been a lack of consideration for asthma-related stigma, undoubtedly contributing to reduced device usage. Aesthetics appear to be rarely considered in terms of medical products, despite this being one of the more prominent reasons people have stated why they hesitate to use their inhalers.

Function

With the strong markets currently in place, there is an excellent opportunity to regard more natural human behaviour within product development processes. Asthmatics seem to struggle to receive adequate medication from a single dose, often credited to their inability to use the inhaler correctly, despite functional inhaler mechanics being identified as a core issue. Ease of use should be at the forefront of any new solution. Users should be able to actuate the inhaler effectively and receive adequate treatment.

METHODOLOGY AND METHODS

Epistemology

Positivism and Social Constructivism

An epistemology is a philosophy a researcher may choose to view their project through and base their approach upon (Ward et al., 2015). For this project, I adopted social constructivism and positivism epistemological perspectives.

A social constructivist perceives knowledge as constructed through experiences, interactions, and relationships with others (Ward et al., 2015). As a human-centred design project, the driving factors were a collaboration with the asthma community and empathy towards asthmatics. Although I am an asthmatic, I was limited to my assumptions and personal healthcare experiences. My own experiences do not reflect others' experiences of living with asthma., Thus my research required a human-centred approach to improve my understanding of asthma and its surrounding contexts. An action research methodology aligns well with the social constructivism perspective, paving the way for collaborative methods by engaging with clinicians and asthmatics.

On the other hand, a positivist perspective is usually correlated with scientific research using quantitative methods to verify hypotheses and determine relationships by analysis (Park et al., 2020). Positivists perceive reality through an objective lens and believe that knowledge is quantifiable by using resources separate from the researcher and presenting the uncovered data practically (Antwi & Hamza, 2015). With a background in engineering, it was natural to fall back on a more analytical perspective and desire to design a tangible and "correct" solution. Early in the project, I realised that it would be possible to adopt a positivist approach when designing a new mechanical system to dispense the medication. However, the focus on the inhaler's mechanics of the inhaler had to be limited, as the product's function is only part of the user's experience. Without gaining insight from the healthcare experts and asthmatics, a possible solution could have quickly become engineering-focused and consequently may have ended up being a technical response that did not consider people's behaviours and experiences.

Methodological Approaches and Framework

Action Research

Action research (AR) is a qualitative-based methodology that allows for collaboration between the researchers and a community to solve a problem. AR can be useful when the scenarios are complicated, involve experimental approaches, and may result in more ambiguous outcomes. It is an iterative process following a cyclic process of planning, analysing, synthesising, executing, and evaluating (Swann, 2002). The primary purpose of AR is to develop a better understanding of the social situation presented (DeVries, 2007; Koshy et al., 2011; Swann, 2002; Unger et al., 2020). According to the findings, the stages are flexible to adapt a researcher's methods (Gray, 2004; Swann, 2002). In action research, the researcher may be perceived as a research coordinator rather than an "expert" in the situation (Gray, 2004).

In design for healthcare, with a strong focus on human-centred design and user experiences, researchers often use an action research process to advocate and support stakeholders to be involved throughout the research phases, endorsing "equal partnerships" between the researcher and participants (Gustavsson & Andersson, 2019; Hughes, 2008; Waterman et al., 2001). This flexible approach supported me in better understanding the users' experiences of asthma treatment and developing concepts according to the provided insights throughout the research.

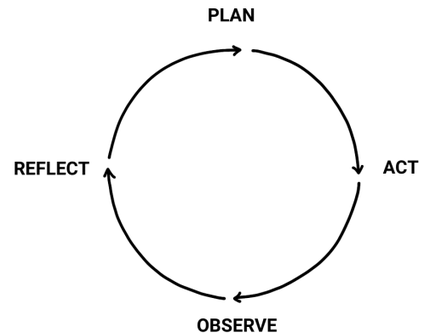


Figure 23 – Action research cycle (Swann, 2002).

Human-Centred Design (HCD)

An HCD approach helps designers frame a problem to improve the well-being of a community of users. While more traditional engineering and design research may have been primarily driven by technology or aesthetic considerations respectively, product development with an HCD approach highlights the necessity to understand the problem context of how users interact with products. From this, designers can apply the insights to produce future concepts (Boradkar, 2010; Ku & Lupton, 2020). A "good design" should allow a user to naturally understand the product is handled (Norman, 2013). HCD promotes inclusion and collaboration between users and designers. The users are experts in the problem context based on their personal experiences and actively participate in the design process (Ku & Lupton, 2020). HCD methods are aimed to allow designers to empathise with users' experiences and ultimately identify underlying issues that may not be apparent to the stakeholders, along with the users' expressed and unexpressed needs (Boradkar, 2010; Ku & Lupton, 2020).

Initially, as part of a human-centred approach, I planned to utilise co-design as a collaborative method with users. Stakeholders would include young adults in the asthma community and clinicians who have worked closely with asthmatic patients. Involving users in the design process throughout the project would encourage me to actively pursue insight from users who have first-hand experiences living with their chronic conditions (Ku & Lupton, 2020). However, due to the impacts of COVID (including a four-month lockdown in 2021), co-design was not possible, and the engagement with users was limited to an online survey and interviews. Having limited direct collaboration with users, other design research methods such as roleplay, and the creation of journey maps and personas helped me empathise with the asthma community.

Ethical Considerations

Human-centred research requires engagement and involvement from stakeholders, such as users, to help develop a deeper understanding of human behaviour, values, aspirations, and motivations (Melles et al., 2020). Involving stakeholders meant collaborating with both healthcare professionals and asthmatics. Clinicians who worked directly with asthma patients were able to share their opinions regarding asthmatic patients' asthma management, patients' behaviours and routines with their devices, and possible issues with the product's design. On the other hand, asthmatics served as the 'users' group in this research, allowing them to share their experiences of living with asthma, thereby shaping the direction of the research outcomes through their insights. In doing so, to ensure that the privacy and safety of participants would be protected, ethical conduct had to be considered and upheld (Gray, 2004).

Consultation with Asthma NZ was undertaken to determine the primary issues with asthma inhalers and treatment, thus establishing the gap in knowledge in this research. Initially, I considered the user participant age range to be 18-30 for focus groups or workshops. However, it was countered during the consultation that inhaler routines become relatively fixed around adolescence, so encouraging people to change such habits after this age may be difficult. Complexities were discussed surrounding the involvement of children and adolescents in this study to be participants. Parental consent would have had to be obtained, which may bring about power imbalances or influence children's opinions if parents were also involved. Thus, the user age group was changed to 16-25 years.

It was planned for the interviews with clinicians to take place at the Asthma NZ building or through Zoom. Due to COVID lockdown, this option was limited to Zoom to ensure participants' health and safety were not compromised. This allowed for flexibility with their schedule since the NZ healthcare system at the time may have been under tremendous pressure, particularly in Auckland.

Respect between participants and the researcher was upheld by maintaining participant autonomy by ensuring they acted of their own free will in the research (with no pressure or coercion from the researcher). All participants were free to withdraw from the research during interviews until the data analysis stage. The participant information sheet and consent forms made them aware of this. Participants were fully informed of the purpose and intentions of the research so that they were aware of what they were consenting to. They were allowed to contact the researcher should they have any questions or concerns regarding the research. To protect participants' information and preserve confidentiality, the data were stored digitally and accessible only by my supervision team and me, and participants were kept anonymous from other participants.

In accordance with the AUT Ethics Committee (AUTEC), an ethics proposal and research plan were outlined and approved under the 21/282 on 6th September 2021. Some amendments were subsequently made to account for the COVID situation in early 2022 and were approved on 17th February 2022.

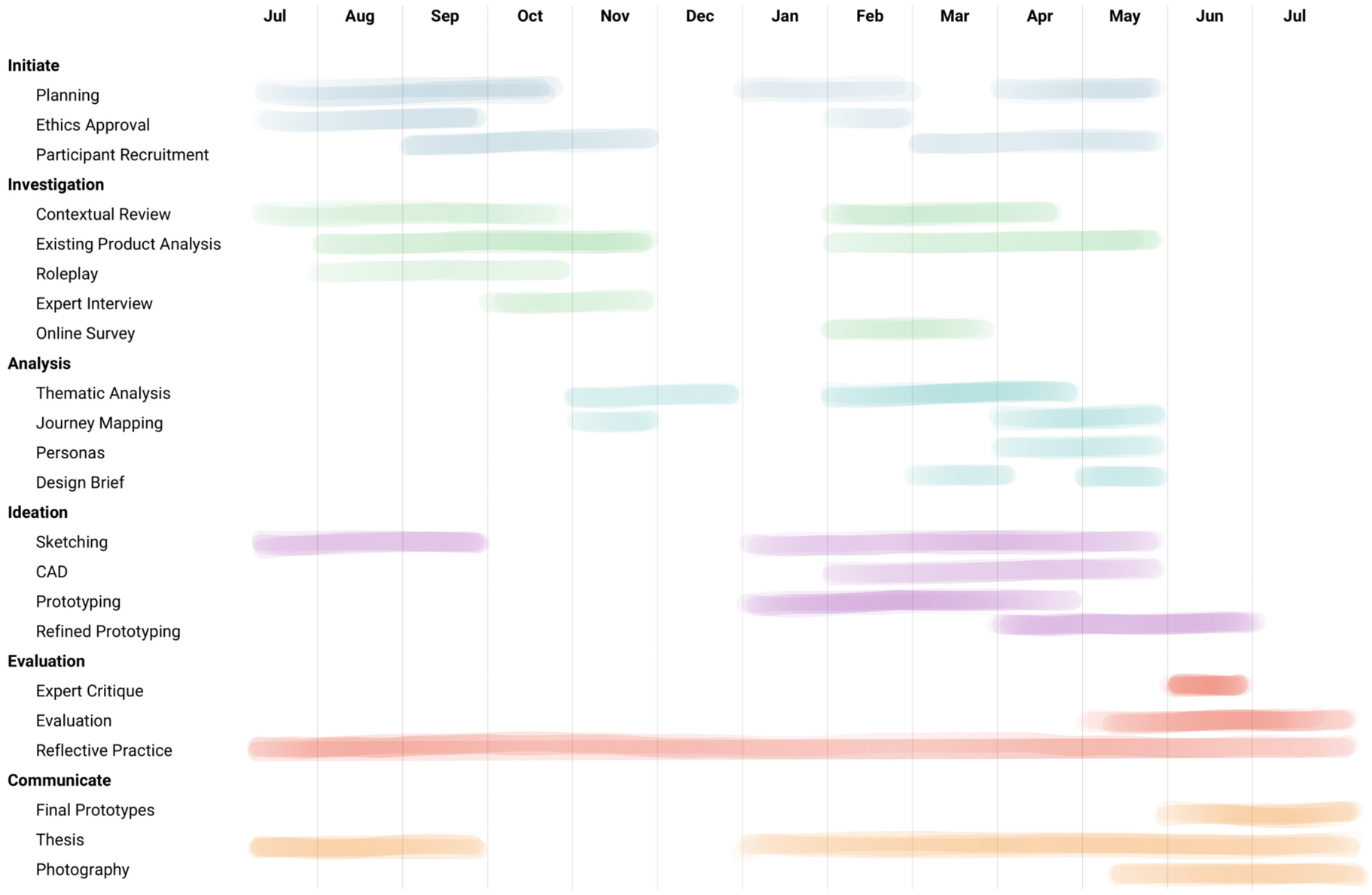


Figure 24 – Project Timeline.

Research and Creative Methods

Methods for Investigation

Contextual Review

A literature review provides a critical evaluation and summary of the available theory and previous research conducted around the chosen research topic to generate a compilation of the past and current knowledge of the area. The information gathered can then serve as evidence from expert sources to reinforce the project's stance (Collins, 2018). In creative industries, design, practices, and artefacts are often included alongside theory as part of the research. Works may be drawn from multiple disciplines and, therefore, must consider the perspectives of various disciplines. A contextual review aims to interact with industries readily, potential partnerships, the wider society, and the environment within the surrounding contexts of the problem (Barnes & Melles, 2007; Collins, 2018). Much like a traditional literature review, a contextual review can help a researcher determine a gap in the knowledge on which the research project will be based (Gray & Malins, 2004).

The contextual review in this research consisted of a wide range of topics, including the asthma condition, asthma treatment, inhaler designs and mechanics, stigma, design in healthcare, and the appeal of consumer products, to establish a context around the perspective and experiences of people with asthma. Literature was sourced primarily through the AUT library, ScienceDirect, and Google Scholar databases by narrowing down keywords as search terms, which were either directly or closely related to the project scope. Resources included journal articles, magazine articles, newspaper articles, book sections, conference proceedings, webpages, and product designs. The sources considered relevant were downloaded, and critical quotes were highlighted. Similar themes and sub-themes were extracted, forming the sections of the contextual review. Consultations held between March and July 2021 with Asthma NZ staff helped provide present-day context into their patients' experiences with asthma through the perspective of healthcare professionals, which was not readily available within existing published literature.

Existing Product Analysis

In an HCD project, the research can include the analysis of existing products to help designers learn about their features from users' perspectives. A comprehensive examination can help to determine how a user interacts with a product as well as identify a product's functions. As a result, the designer will be able to identify the required and desired areas of improvement (Hansen & Lenau, 2013; Parsons, 2009; STEM Learning, 2019).

In this project, different types of inhalers and the spacer were studied. Initially, my focus was on the MDI. Since there was a design constraint due to the aerosol canister, the spacer drew most of my attention and how it increases the efficacy of an MDI delivering medication into the lungs. The spacer was found to be one of the main issues drawn from the users's experierences through the literature review. By analysing these products, I was able to gain a better understanding from the user's perspective in terms of both its design and how they functioned. Due to my own experience with asthma, I recalled how I felt using an MDI and spacer during my childhood. This helped me to relate to the anecdotes from qualitative asthma studies conducted and explore the psychology of users to better understand the user experience and potential areas of improvements. While my focus later shifted to the dry-powder inhalers (DPI) later in the project, the aim of analysing existing inhalers remained the same. When the research shifted to smart inhalers, I analysed existing smart technologies to understand better the current market and how my concept might be feasible.

Roleplay

Researchers widely use roleplaying to study the users' experiences and relational behaviour with a product or service (Think Design Collaborative, 2018). Scenarios are re-enacted by assuming a role under realistic (or as close to reality as possible) conditions to better understand and empathise with the user (Lewis-Beck et al., 2004; Smeenk et al., 2019). Roleplaying can be used to experiment new concepts by simulating problems related to existing products or services (Ku & Lupton, 2020). Depending on the scenario, this method may involve specific locations, props, and costumes (IDEO, 2021).

As an asthmatic, my own experiences were remembered as someone with mild asthma and not a frequent inhaler user in recent years. I knew that my experience and knowledge may differ from others' experiences, especially those who use their devices daily. Considering this, roleplaying took place before conducting any methods involving users as participants. I felt it would help provide a more unfiltered experience as an inhaler user instead of having subconscious expectations or assumptions of others' experiences if I roleplayed after collaborating with users.

Roleplaying started with initial interaction with the inhaler after I obtained an empty prescription, providing an opportunity to go through the process. Although this was not a completely new experience for me, it had been a few years since I was prescribed an inhaler by the doctor. I was aware that this process had limitations, as my asthma is very mild, and I could not relate to the experiences of someone with more severe asthma. I used an empty inhaler for the roleplay and did not inhale a live drug. I use my inhalers when necessary, but as my symptoms have lessened, I did not take medicine during this roleplay as I did not need any treatment at the time.

I made mental notes during the walkthrough and wrote down my observations. I reserved my designer role through the roleplay and recognised points of concern and interest.

Expert and User Interviews

For qualitative research, interviewing is a commonly used technique that allows the researcher to better understand people's behaviour, thoughts, beliefs, and experiences by gathering open-ended and subjective data. By conducting interviews, the researcher may be able to dig deeper into more sensitive matters (Collins, 2018; DeJonckheere & Vaughn, 2019). Kvale defines research interviews as "attempts to understand the world from the subjects' point of view, to unfold the meaning of peoples' experiences, to uncover their lived world prior to scientific explanations" (Kvale, 1994). Through this definition, and with a human-centred approach in mind, the interviews with participants should be developing discussions between the researcher and participant rather than a "transactional" question-and-answer interaction (DeJonckheere & Vaughn, 2019). There are three types of interviews: structured, semi-structured, and unstructured. Semi-structured is the most frequently used type of interview, particularly in a healthcare setting (Gill et al., 2008), and can be helpful for the researcher to lead the interview with specific questions but leave room for an open discussion with the interviewee (Collins, 2018).

Experts

Addressing experts in a field focuses on the esteemed and accepted knowledge that serves as a reference frame for future works. However, this means that the knowledge can differ from authentic user experiences (Meuser & Nagel, 2009). In this project, the experts selected for interviews were those who work directly with asthmatic patients or have been involved in research regarding asthma. Clinical staff were contacted directly through their public domain email or the Good Health Design team's professional network. I was only made aware of the contact details of the Asthma NZ nurses who showed an initial interest in participating. I then directly contacted the nurses and sent them the Participant Information Sheet and consent form. A mutually appropriate meeting time was agreed upon when they confirmed their participation.

Seven semi-structured one-on-one interviews were conducted with nurses from Asthma NZ, an occupational therapist from Asthma Waikato, and a pharmacist in the Waitemata DHB. The expert interviews were held in Zoom, both as video and audio meetings. Audio and video recordings were made, and the interviews were transcribed after each session. Ten open-ended questions focused on the prevalence of asthma in New Zealand, asthma education, and the product design of the various available inhalers and spacers [see Appendix C for indicative questions]. Although the clinicians were not the target audience of this research, their insights helped me to understand better the common issues surrounding asthma aside from treatments and provided recommendations through their medical expertise. The questions asked led to lengthy discussions surrounding the underlying issues, medication choices, and poor self-management of most patients leading to severe symptoms. At the end of the interviews, the clinicians were asked to describe their version of an ideal inhaler design and the most important features to consider from a medical professional's perspective. The interviews ranged between 30-50 minutes, depending on the detail and length of the interviewees' answers.

Users

Including users in the research is the core of HCD. This project was planned for participants to be invited into focus groups to gather insight, experiences, and input from those with asthma, thereby determining a clearer idea of underlying issues related to inhalers. The participant age range was constrained to 16-25 years old. This age group are more likely able to recollect their earliest experiences of living with asthma (if applicable) while being more susceptible to changes in the inhaler designs and finding it easier to amend or better their habits. Young adults are also most exposed to new environments, including university, workplaces, and social gatherings, for which they are likely more self-conscious about using medical devices in public.

Asthma NZ identified the most appropriate potential participants within their database and invited them on my behalf. Those interested then contacted me directly and were not known to me unless they responded to the invitation with interest to participate in the research. Asthma NZ was unaware of who had chosen to participate out of those invited. The information sheet and consent form were attached to the email reply to potential participants. I had also put-up invitation posters around the AUT City campus to invite potential participants.

After the COVID lockdown, the focus group method was changed to online interviews. Unfortunately, as COVID restrictions remained in place as cases surged, I was unable to recruit participants through the university and Asthma NZ on my behalf. Therefore I was limited to the user insight obtained from respondents in the online survey.

Survey

Like interviews, surveys are used to investigate the respondents' underlying behaviours, attitudes, opinions, beliefs, and values. With its generally anonymous nature and if given no time restrictions, people may feel more reassured to answer honestly, voicing their opinions and concerns without feeling embarrassed. Furthermore, data collected through surveys can present more in-depth and extensive views of the user's behaviour compared to statistical data (Collins, 2018; Crouch & Pearce, 2012; Kostyk et al., 2021). Since my research had a focused age range, I was still interested in understanding the perspectives of those outside 16-25 years of age. Older respondents may have very different experiences and recollections of inhalers than those who, for example, have only recently started using an inhaler. Publishing a survey allowed me to broaden the target audience for more generalised knowledge of asthma inhaler usage and gather the data quickly (Walter, 2010) while providing convenience to the respondent.

To gather respondents for the anonymous online survey, Asthma NZ posted a survey link on their social media platforms and included an invitation poster that I had designed [Appendix B]. This form of recruitment was entirely anonymous for both myself and Asthma NZ, as respondents were not given the option of including any personal details in the survey besides indicating their age bracket.

There were over 110 responses between February and March 2021. A single anonymous survey created on Qualtrics was published. There was a list of 15 questions of varying open and closed-ended types with three main topics: living with asthma, inhaler (and spacer) techniques, and inhaler designs [Appendix D]. Although the introduction encouraged respondents to answer each question, they had the option of skipping through questions if desired. The last question asked respondents to describe or draw in the provided space their ideal inhaler design. An information sheet outlining the survey was included before respondents gave their consent to continue with the survey, so they could be prepared for the questions and not feel rushed. It was noted at the start of the survey that it may take up to 20 minutes to complete.

Research Probes

In design research, probes are tools designers can use to support their collaborative methods with participants to elicit expressions, interpretations, imagination, and inspiration to inform the design's situation within the problem context. As a result, researchers can actively engage with participants, explore what people consider personally meaningful, and become more empathetic towards users (Mattelmäki, 2008; Wallace et al., 2013).

Probes were used in the form of prototypes, sketches, and renders during the online interviews as feedback and critique sessions with Asthma NZ clinicians to gauge their opinions and inform me on components and features that could be changed to improve the asthmatic user experiences.

Figure 25 – Examples of some research probes used in interviews and feedback sessions.

Methods for Analysis

Thematic Analysis

Thematic analysis is a qualitative method used by researchers to identify patterns from collected data. The analysis is the fundamental idea. The themes extracted are not simply summaries of the data but rather interpreted from the data to determine “underlying ideas, assumptions, conceptualisations, and ideologies” (Braun & Clarke, 2006, p84). Clarke and Braun (2006) referred to this as a latent type of theme, extending past logical analysis and more toward interpretive analysis . In a design context, this type of analysis can be used to drive the research process, as the designer should additionally consider outside of what was explicitly discussed with the user or consumer during data collection.

I conducted a thematic analysis after completing my data collection from clinician interviews and an online survey. Notes were taken during the interviews (clinician interviews). After all the responses (user survey) had been collected and summarised, I highlighted similar ideas, concerns, and insights as codes from the respective data sets. Once placed together in a brainstorm format and having analysed the data, I extracted and categorised the codes into themes that reflected the underlying ideas in the data. These themes eventually formed the basis of my initial design brief.

Journey mapping

Journey maps are tools used in design research to visualise a user’s experience, usually through a service they are receiving or a product they are using, by tracking and analysing a user’s journey. It compels the designer to pay close attention to the interactions and experiences, allowing designers to recognise users’ unexpressed needs (Dalton & Kahute, 2016; Liedtka, 2018; Micheli et al., 2019). Mapping experiences may help depict areas that may need improvement or increased attention. Journey mapping can also aid in creating a layered outline of a problem through analysis of the surrounding contexts and helping to develop a greater empathetic understanding of a user’s experiences over time (Ku & Lupton, 2020; Micheli et al., 2019).

I created a map of the asthmatic patient journey from diagnosis to current stages. Once the patient was diagnosed with asthma and prescribed medication, they would ideally be able to treat their condition and see the results as a decrease in symptoms. According to the clinicians’ insight and survey responses, a straightforward treatment process was not a realistic journey for most patients, so I added the more common tangents to my patient journey map.

A second journey map was created to visualize my research journey and the changes that occurred throughout the year, which resulted in me considering alternative methods or adapting to the situation.

Personas

Creating personas is a method where a designer creates a fictional character(s) with a simulated scenario to represent a user and help evoke empathy from the persona's perspective (Ku & Lupton, 2020; Nielsen, 2019). Personas can form a structured outlook of the context and help to ensure accurate portrayals of the users throughout the development of the solution, without constraints by stereotypes. They can be used to point out the driving factors, dissatisfactions, and likeness of people (Ku & Lupton, 2020; Micheli et al., 2019).

As my research had limited input from participants, I created two personas to represent two groups: young adults with asthma and clinicians who work directly with asthmatic patients. I based these personas on the data collected through clinician interviews and survey responses and ensured they reflected the insights from the respective groups. The personas were used in the research as a foundation on which I based my more refined developments.

Design Brief

A design brief is used to help frame a problem scenario (Mamata et al., 2017). In doing so, the designer defines the project aim, target audience, user requirements, constraints, and supplementary "technical/legal/ethical/environmental" aspects (Mamata et al., 2017; Schön, 1988). This project underwent several design brief developments as new stakeholder insights were shared and constructed, and new information was learned from related contexts. My initial design brief was defined from the contextual review, expert interviews and survey as a result of the thematic analysis, highlighting the key potential areas of improvement. I outlined a refined brief that was updated from adjustments made throughout the research and design process, focusing on the underlying ideas after further reflection.

Methods for Ideation

Brainstorming

Brainstorming encourages creative exploration and generating ideas related to the problem context. Brainstorming promotes integrating inquiry and insight by supporting a person to examine a broad range of ideas. These ideas can be created from requirements, thoughts, assumptions, needs and desires (Canva, 2022), then later narrowed down to develop further. The key intention is to be able to experiment openly without analysing single ideas in-depth (Micheli et al., 2019; Wilson, 2013). The first use of brainstorming in this project was collecting resources for the contextual review to help determine which topics may be worth exploring further. Throughout my research, brainstorming mainly took the form of sketching and was used to extract the key themes in my thematic analysis.

Mood Boards

Mood boards are design research tools that can help researchers visualise inspiration in the form of imagery to express ideas and convey emotion as part of developing design solutions. Drawing inspiration from the mood board presents opportunities for strong engagement between the researcher and their work while provoking awareness and understanding of “more ephemeral phenomena” such as colour, material, texture, and form (Garner & McDonagh-Philp, 2001, p63). The researcher can then reflect on their reasonings behind choosing specific images (Cassidy, 2011; Garner & McDonagh-Philp, 2001; Tiemann, 2018). I searched for inspiration from Behance projects (Behance.net), Google images (Google.com), Unsplash (Unsplash.com), and Pinterest (Pinterest.com) that I could use to help express my stylistic intentions and ideals. Search terms included “modern product design,” “medical device design,” “minimalist product design,” “calming products,” “attractive product design,” “natural product design,” and “healthcare product design.”

Sketching

Sketching is a visual form of thinking (Ku & Lupton, 2020) and is an efficient method for “capturing” ideas on the spot (Utterback et al., 2006). Schön (1994) described sketching as a preliminary process that encourages subjective immersion in the area of interest, which is then captured through drawings. Sketching can also be defined as a continuation of mental visualisation that a designer uses to uncover and make sense of new understandings (Goldschmidt, 2003). Drawings allow designers to visualise and communicate scale, materials, surfaces, mechanics, and details of concepts as they develop (Koskinen et al., 2011; Ku & Lupton, 2020).

Sketches were made throughout the project. Sketching out concepts gives a designer “permission to fail” (Keinonen, 2006, p25). I reminded myself that sketches did not have to be perfect, nor did the concepts drawn have to be all usable. Initial concepts were sketched out on paper and digitally, based on my personal experiences and contextual reviews of current products. As my ideas developed and I worked towards refining concepts, my sketches included more detail to visualise my final concept better, which was later translated into CAD models. Sketches were also presented during expert critiques conducted through Zoom to help the clinician picture my concepts since we were unable to meet in person. This helped gauge their opinions and attitudes towards the ideas and helped them to provide me with more specific critiques and feedback.

Figure 26 – Examples of draft and refined sketches from this research.

Prototyping

Prototypes can play various roles in a design research process. They can be used as physical forms for exploring ideas and research models and as a method of investigation (Wensveen & Matthews, 2014). Like Keinonen's (2006) perspective on conceptual design, prototyping can inspire drafting failures in the early stages of development. Prototypes also help designers to envision solutions and allow them to communicate their ideas to others (Micheli et al., 2019). Scale, texture, and material can also be explored through prototypes, as having physical forms can aid designers envision how people may feel and interact with the product concepts (Koskinen et al., 2011). Prototypes can aid in communicating the solutions to participants within a study to provide feedback to researchers (Ku & Lupton, 2020).

Following the ideation stage and initial sketches, low-fidelity prototypes were first made from cardboard, gold foam, and clay to understand size constraints and rough form models. Once I narrowed down which forms could be developed further, I drew models using computer-aided design (CAD) software such as Rhino and SolidWorks to 3D print and give more rigidity to the physical concepts. Since my interviews could not be held in-person, 3D prints were the best forms to show through video, though unfortunately, participants could not experience the objects firsthand. Fused-deposition modelling (FDM) printers were used with polylactic acid (PLA) filaments for prototypes throughout the development and refinement stages.

Figure 27 - Blue foam model prototypes.

Computer-Aided Design (CAD) and Flow Simulations

In contrast to sketching, solid models present more precise portrayals of a product and can therefore be viewed through a more objective lens (Utterback et al., 2006; Veisz et al., 2012). CAD tools are increasingly being used to model objects for the duration of the product development process. Additionally, modelling on CAD software can also exhibit the designer's intentions of the object's functions, creating variable concepts using similar characteristics and thereby allowing the designer to assess promising (Veisz et al., 2012).

In this project, Rhino and SolidWorks were primarily used to create the 3D models from my sketches. Keyshot was used to render the more refined concepts, and better visualize the device's finer details and materials. As the inhaler's inner mechanics for medication dispensation were planned to be improved within this research, the fluid dynamics of the inhaler were briefly modelled in its most simple form using the Solidworks Computational Fluid Dynamics (CFD) package (SolidWorks, 2022). This was done with the help of the Biomedical Engineering department at AUT. I was aware that I could not focus too much on the mechanics, particularly fluid dynamics, as it may lead to complex calculations and would therefore be outside of the project scope, hence only creating basic fluid flow models [Appendix E].

Methods for Evaluation

Evaluation Matrices

Due to limited participation from people with asthma in this research (as a result of COVID), I had to carefully consider what would be shown to participants in interviews to avoid overwhelming them. I used evaluation matrices to narrow down concepts that would be best for further development, which were created through the criteria in the design brief. Each concept was rated between 1-10 in terms of satisfying the criteria (Service Design Tools, 2021; Stevanovic et al., 2015), which was identified from the final design brief constructed. From this, I determined the highest totals as successful concepts to develop further and refine to eventually design a single final concept.

Expert Critique

With design solutions involving human factors, critique should be sought out from experts to help refine the design and reduce errors that may have been missed by the design team (Silverman & Mehzer, 1992). Experts are also the end-users as they will interact with the final product and should be consulted for feedback (Gray, 2018). I had planned to recruit young adult asthmatics to critique my refined concepts, but after all the COVID-related delays, I could only meet with a clinician. Understanding the healthcare professional input is vital to exploring my concepts' feasibility, particularly in a medical context. I presented my concept designs in the form of sketches and prototypes to gauge their opinions on successful elements, what may need to be improved, and advice on medical device specifications.

Reflective practice

Reflective practice is the form of thinking throughout an activity. According to Schön (1994; 1988), those working in professional design roles reflect and administer tacit knowledge amid their practice instead of disconnecting from their work. Being critically reflexive does not mean the designer is necessarily "thinking about thinking, but [rather] thinking about self from a subjective perspective" (Cunliffe, 2004, p418). Throughout the research, I reflected on my methods as there were situations that compelled me to consider how potential New Zealand participants may feel during times of uncertainty and stress. I documented my reflections to determine areas of success, what could be done better, and what my next steps could be as the research progressed. While collecting data and after completing a thematic analysis, reflecting helped me consider what elements to include in my concepts. Furthermore, I felt that my reflections may provide observations regarding my design research process that could be of interest to researchers in the future.

DOCUMENTATION OF RESEARCH

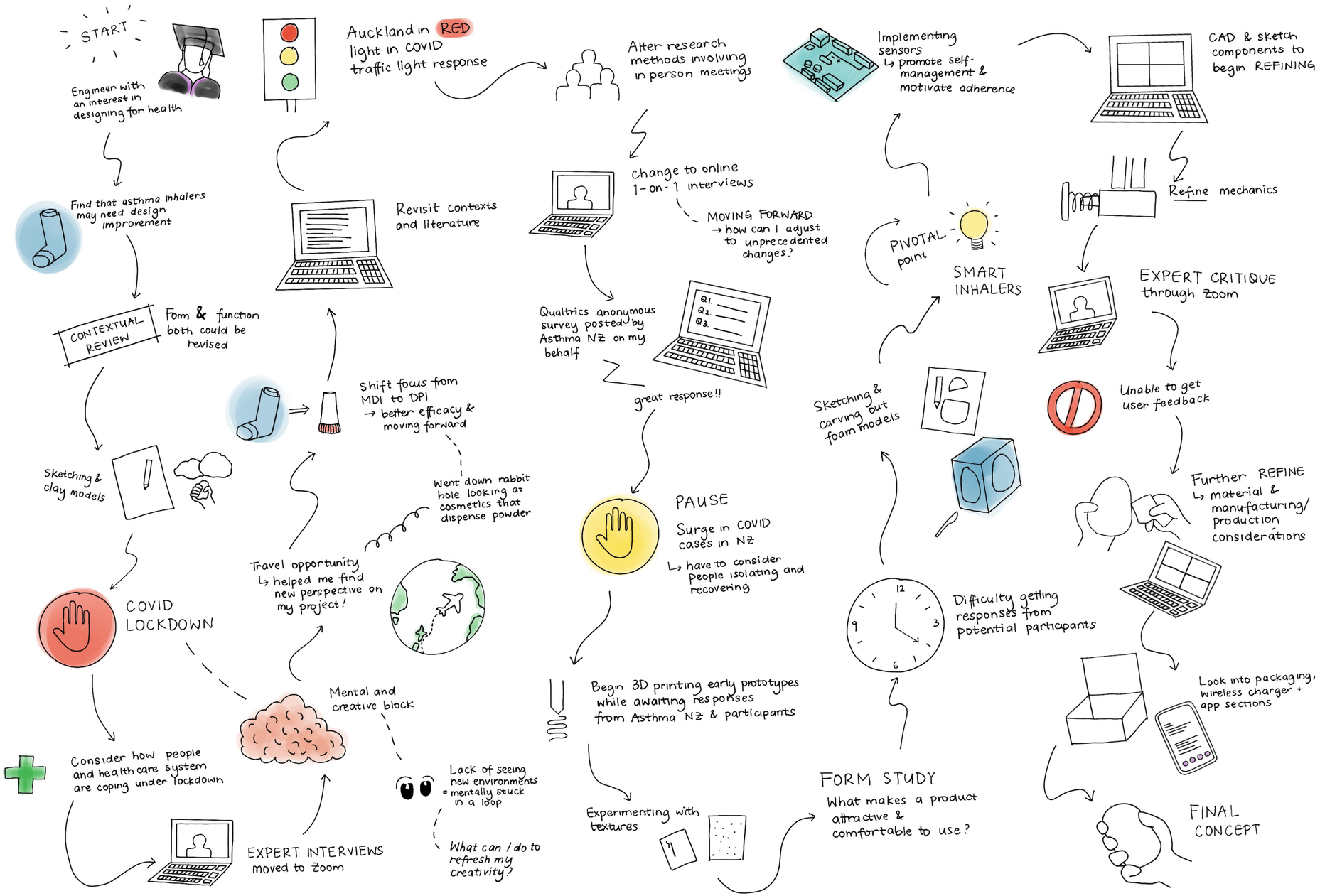


Figure 28 - Research journey map.

PHASE I: Building the Context

Existing Product Analysis

MDI

By analysing the existing MDIs, I established a sense of how users may perceive and interact with the inhalers.

Upon receiving an inhaler prescription, the first point of handling is with the packaging. There was much information on the box, including medication type, the number of doses, storage instructions, manufacturing details, the dosage for adults and children, and caution notes related to the inhaler device. The aesthetic of the packaging itself seemed to have a noticeable feel of being 'mass-manufactured,' and the box does not seem to provide great support for the device inside. Its purpose, from my perspective, was to provide a rundown of information that may have been discussed with a doctor during diagnosis and for easy distribution.

A single-sided folded set of instructions and the inhaler were found inside the box. The instructions also outline the preparation techniques before the inhaler should be used the first time, and the steps to clean the inhaler. The device was relatively light, but its sharper edges made it awkward to hold in one hand at a right angle as instructed. The grooves on the bottom of the device made it apparent for thumb placement. A rougher texture on the sides of the cap indicated where the user should place the cap between their fingers to open.

The different types of medication have different colours associated with them, as mentioned in the Contextual Review. Having grown up using inhalers, the blue colour of Ventolin [Fig. 29] gave me a sense of calmness, which fits its purpose of a reliever inhaler relieving an asthmatic's symptoms relatively quickly (Asthma NZ, personal communication, 2021). Preventer inhalers, such as Flixotide [Fig. 4], have an orange colour. Although I understand the blue colour represents serenity, I felt it would make more sense for reliever to be a warmer colour so it stands out and can be easily located during emergencies. On the other hand, combination inhalers are found in red and purple [Fig. 4], so there does not seem to be a clear colour distinction between different medication types. Without explanations from a health professional, the medication colours may seem confusing to asthmatics.

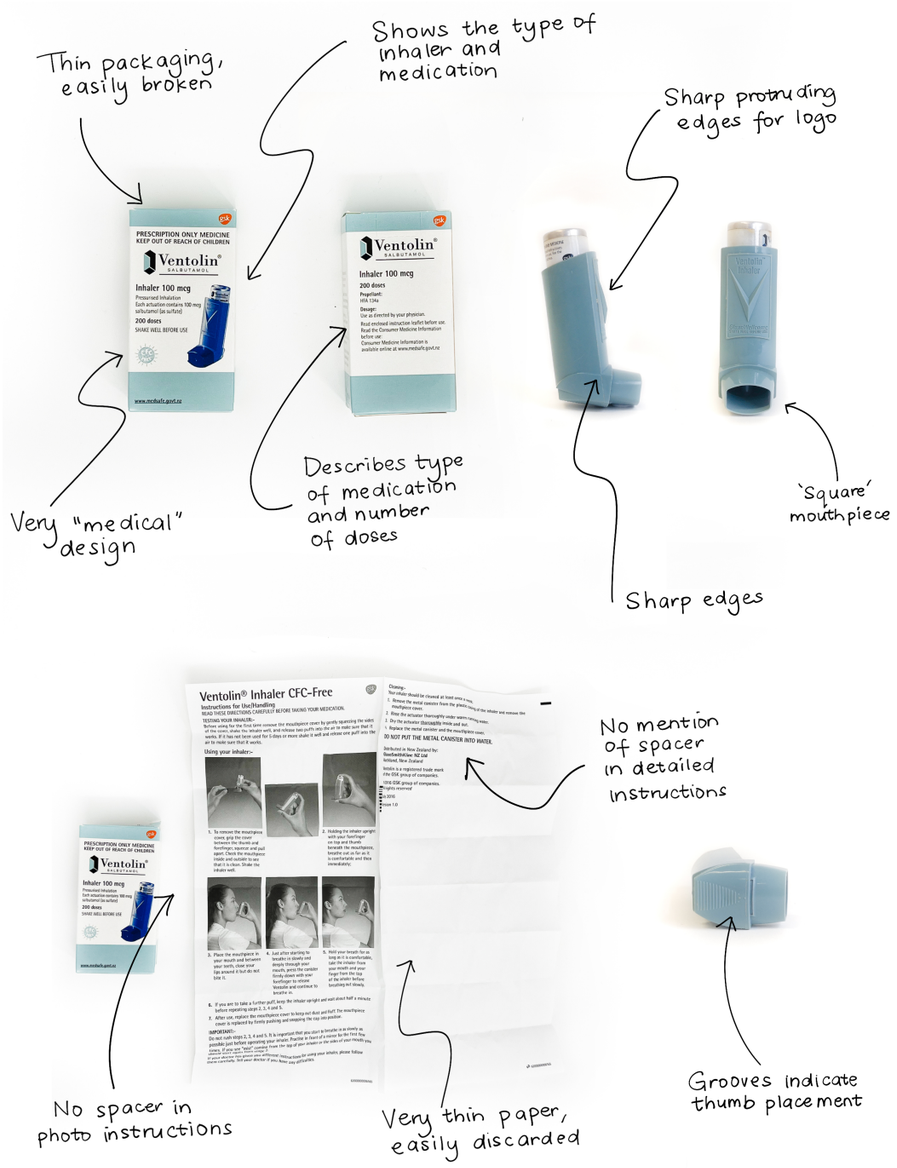


Figure 29 – MDI reliever inhaler (Ventolin) and packaging components.

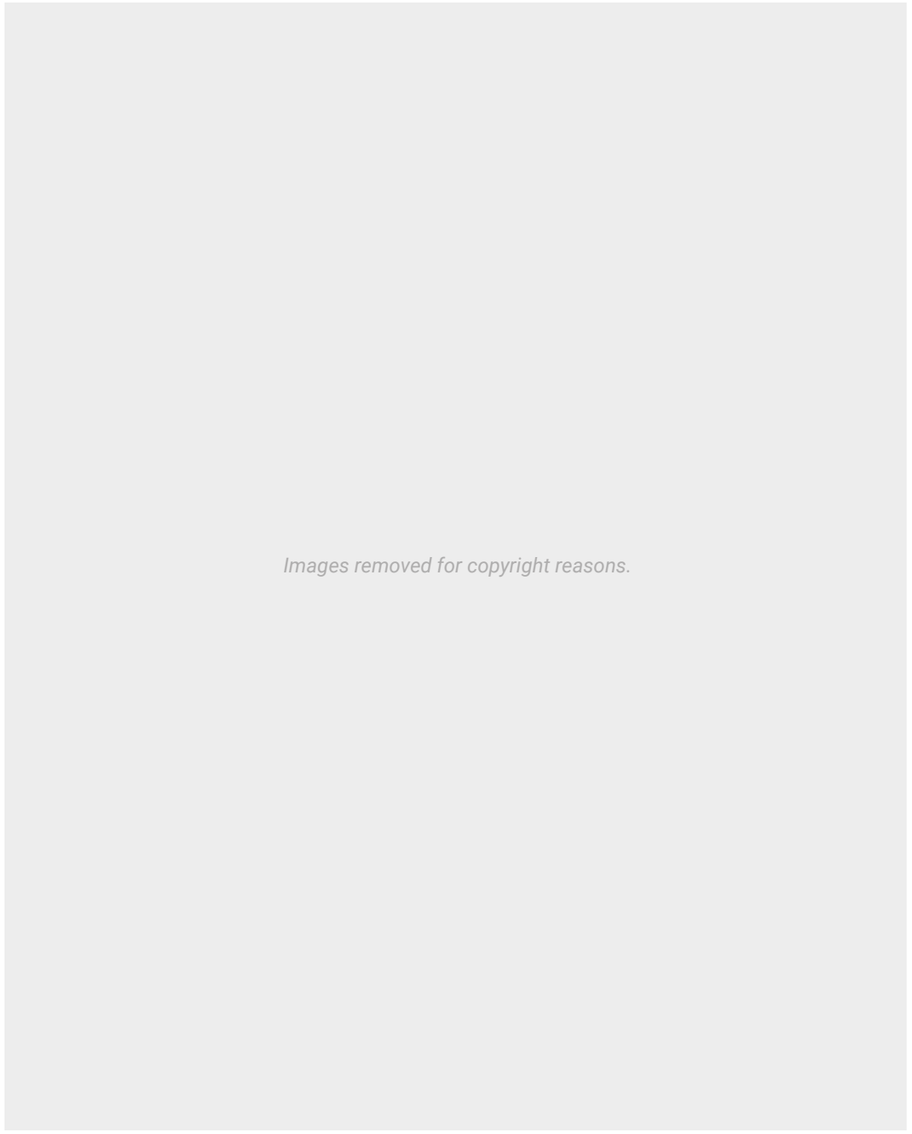


Figure 30 – MDI and spacer analysis (Hooper, 2014).

The information included on the sticker around the canister was similar to that of the prescription box. Having the expiration date in bolded letters was clear. However, I noticed there was no way of knowing how many doses might be left after use. Especially with an aluminium pressurised canister, the user would not be able to get a clear sense of how much medication is left. From memory, I could only tell that my inhaler was running out when the spray dispensed very little mist, much like a paint spray can or hairspray would. On this note, research suggests users tend to overestimate their medication and consequently inhale more propellant than medication when they feel their inhaler is running out (Conner & Buck, 2013).

Spacer

There are several spacers available in New Zealand, though the one I had was the La Petit Anti-Static spacer [Fig. 30]. It has a 220mL volume and can be held using one hand but would not fit inside clothing pockets due to its bulky shape. The silicone material allows most MDI mouthpieces to fit, and the polypropylene plastic allows for easy cleaning. Spacers are made specifically for MDIs, and cannot be attached to other types of inhalers. Its cylindrical shape means that the edges may trap some of the medication, resulting in wasted product not being delivered into the lungs.

Modern Inhaler Designs Concept (Not Commercially Available)

Flohaler

Flohaler was a concept designed by James Plimmer (Plimmer, 2019). This design focused on how the user may handle the inhaler, highlighting the key techniques used to increase efficacy. Instead of users pinching the canister to dispense the medication, the action was changed to more of a grip. Because the mouthpiece's angle and the spherical shape make it awkward to use wrongly, users would be inclined to hold it at a 90° angle. Plimmer determined that when the user tilts their head upwards, their throat is straightened, increasing the airflow of medication into the lungs (Griffiths, 2019). The prescription packaging of the inhaler was also considered. He discussed the importance of the pamphlets being secured in the current boxes, yet most people would discard them immediately after opening. Users' attention would be immediately drawn to the necessary information by including the instructions inside the packaging.

Although the new spherical form makes it easier for people to grip the inhaler, the mechanism and functions remain unchanged. Essentially, the efficacy of drug delivery into the lungs is only about 10-20% maximum without a spacer, and thus the use of a spacer is highly recommended. Furthermore, the design closely resembles the current MDIs, making it slightly bulkier and less portable.

I believe Plimmer's design addressed several critical issues with the MDI, namely correcting the inhaler technique and showing how information can be communicated with existing components. The addition of a dose counter was also a positive feature added, as many asthmatics in literature have commented on this feature as being key to their treatment.

Figure 31 – Flohaler by James Plimmer (Plimmer, 2019).

Images removed for copyright reasons.

Figure 32 - Top to bottom Aria inhaler designs: Youth, Contemporary, Heritage, and Active with associated mechanism (Aria Therapeutic Vapor Inhaler, 2017).

Aria Inhaler

Design studio THRIVE designed four inhaler concepts to suit various groups of people depending on activity, age, and preference. They took the mechanics of vape technology and combined it with inhalers based on three flaws with the current design: (negatively) recognisable and obvious appearance, required hand-breath coordination, and lack of sustainability considerations (Red Dot, 2016). Technology was also incorporated into the concepts, allowing users to link their inhalers to their personal devices so they would be able to keep track of climate conditions that can affect their breathing, expiration dates, and product use (Aria Therapeutic Vapor Inhaler, 2017). This project aimed to bring the outdated inhaler design into the modern era, allowing the design to appeal to users and make them feel more comfortable using it in public. Ideally, users would be able to select the style they feel suits their personality best, instead of having a single design for the general public.

The design strongly considered sustainability, as this concept would be refillable and reduce disposal rates. My greatest concern regarding Aria was the apparent minimal attention to the real-life applicability due to the focus on the aesthetic. Despite the innovative product combination approach with vape technology, medication cannot be heated up from a liquid state to a mist as the chemical compounds are broken, resulting in decomposition or new but unwanted compounds. Hence the recommended storage temperatures for prescription medications (Shomon, 2020).

Reflection

It was interesting that the instructions for the MDI did not include the spacer device attachment, despite the knowledge of its importance for better efficacy (De Simoni et al., 2017; GSK, 2021a). Unless recommended by a health professional, the individual using the MDI without a spacer becomes immediately disadvantaged by taking a low percentage of medication. Although the information on the box and the set of instructions use a simple and explicit language, those with lower literacy and English levels may not be able to comprehend or misunderstand such instructions properly. I believe that although there could be better ways of associating colours with medications, changing the existing colours would be even more confusing to asthmatics.

Upon reviewing modern concept designs, I noticed that neither example focused on practicality. Although Plimmer's design incorporated the intentionality of tilting the user's head to straighten their throat to increase airflow into the lungs, as recommended in research, an individual having all correct techniques still only results in a maximum of 20% medicine deposition in the lungs (without a spacer). The design also made the current MDI bulkier, which would make it more difficult to carry around. I admired the packaging concept and thought it would be a useful point to explore the idea of combining the presentation of important information onto the package itself in a way that will make people inclined to read the instructions when opening the inhaler.

I respected the idea of modernising inhalers and considering designs that may be more appealing to various age groups. However, I immediately queried whether this concept would work in real life with the heating up of medication like a vape. I made a mental note that for my own project that I needed to be relatively attentive to medical knowledge as best as possible, knowing that I am not a medical expert. I had to keep on top of the current research and basic scientific principles to avoid designing a product that may concentrate too much on form or aesthetic and not enough on practicality.

Roleplaying

As mentioned in the Methodology and Methods chapter, I had to be aware that roleplaying as a mild-severe asthmatic would have its limitations and not have an adequately represented experience. Since all patients are prescribed and given directions by doctors according to their medical needs, my walkthrough of using inhalers would not be accurate with all asthmatics. I recalled the advice given to me from past doctor's consultations.

I roleplayed a day in the life of an asthmatic, simulating the use of both reliever and preventer inhalers to gain insight into the potential physical and emotional circumstances that asthmatics may feel. For both inhalers, I first sat up straight to not constrict my lungs so I could inhale as much medication as possible. I then shook my inhaler vertically for 10 seconds to ensure the medication and propellant were mixed correctly before use. I took the cap off and placed the mouthpiece inside my mouth. The mouthpiece felt unnatural to place between my lips. Although I used MDIs many times until my late teenage years, being conscious of the experience made me unsure if the mouthpiece should sit between my top and bottom teeth or just in front of my teeth. Either way, it felt awkward with its geometry, size and sharper edges. I was also unsure where to place my tongue around the mouthpiece to ensure it would not block the flow of medication.

To dispense the medication, it took considerable force to push down on the canister. I had to use my index and middle finger instead of just the index finger. Administering the medicine and breathing in simultaneously was difficult, and I knew I could not breathe in the same time as the medication was sprayed out. I held my breath for 10 seconds to avoid letting the 'medication' escape as much as possible. After this, I gargled water as suggested to prevent the risk of an oral thrush infection around the inside of the mouth. With a spacer attached, the two devices together felt relatively heavy to hold just between the lips, even for several minutes. Having a spacer meant I did not have to simultaneously press the canister and inhale instead of allowing me time to breathe in when I was ready.

Preventer inhalers are to be used once in the morning and once at night, while the reliever should only be used if symptoms are felt. During the day, I felt nervous about having to roleplay using the reliever (Ventolin) inhaler while out in public. When I took out the inhaler, I felt self-conscious and looked around to see if anyone was looking at me. My first instinct was to find a more secluded area to use the inhaler in private; this is not an uncommon inclination according to literature. I worried about what people walking past might be thinking and having to remember the list of steps to use my inhaler correctly. I fumbled taking the spacer out of my bag, worsening my already nervous state. Using the inhaler without a spacer could be relatively hidden if I tried to, particularly since vaping has been more common these last few years. Attaching the inhaler to the spacer in public made me feel like I was exposing my medical condition more prominently, almost like I was making a show of using the inhaler.

Since I could not simulate an acute exacerbation, I surmised that an attack would have made the experience even more nerve-racking, terrifying, and uncomfortable. People who did walk past only quickly looked at me with concern or did not glance too long. Although this comforted me knowing my fears may be exaggerated in my head, I also noted that I did not exhibit any symptoms, so there was no genuine concern.

Reflection

When simulating the use of inhalers, I was aware there were several constraints. As the preventer inhaler is recommended to be used in the morning and night, I did not feel too self-conscious about using the inhaler. Most of my family had used inhalers before at home, so it was the norm. My experiences do not reflect all experiences of asthmatics, and I feel it would be discomforting for someone whose family or other household members do not understand asthma and the need for using inhalers daily. Having to use a reliever inhaler in public was uncomfortable. Since I did not simulate asthma symptoms, I could only reflect on my childhood experiences of suffering from an exacerbation, remembering how discomforted and unsettled I felt. I understood that people's lives with asthma would vary depending on their asthma severity, state of health, peer and family support, and personal life experiences, all of which can contribute to an individual's identity and attitude towards asthma.

As Ku and Lupton (2020) described, the designer may perceive and analyse their roleplay through personal biases and in their current state of health. Therefore, the user may not be accurately represented, as those accessing health services or using medical devices are more likely to be experiencing negative emotions. The roleplay helped me gain insight into the user's possible interactions with inhalers, the emotional struggle from not being able to breathe properly and the reliance on inhalers with the stigma attached.

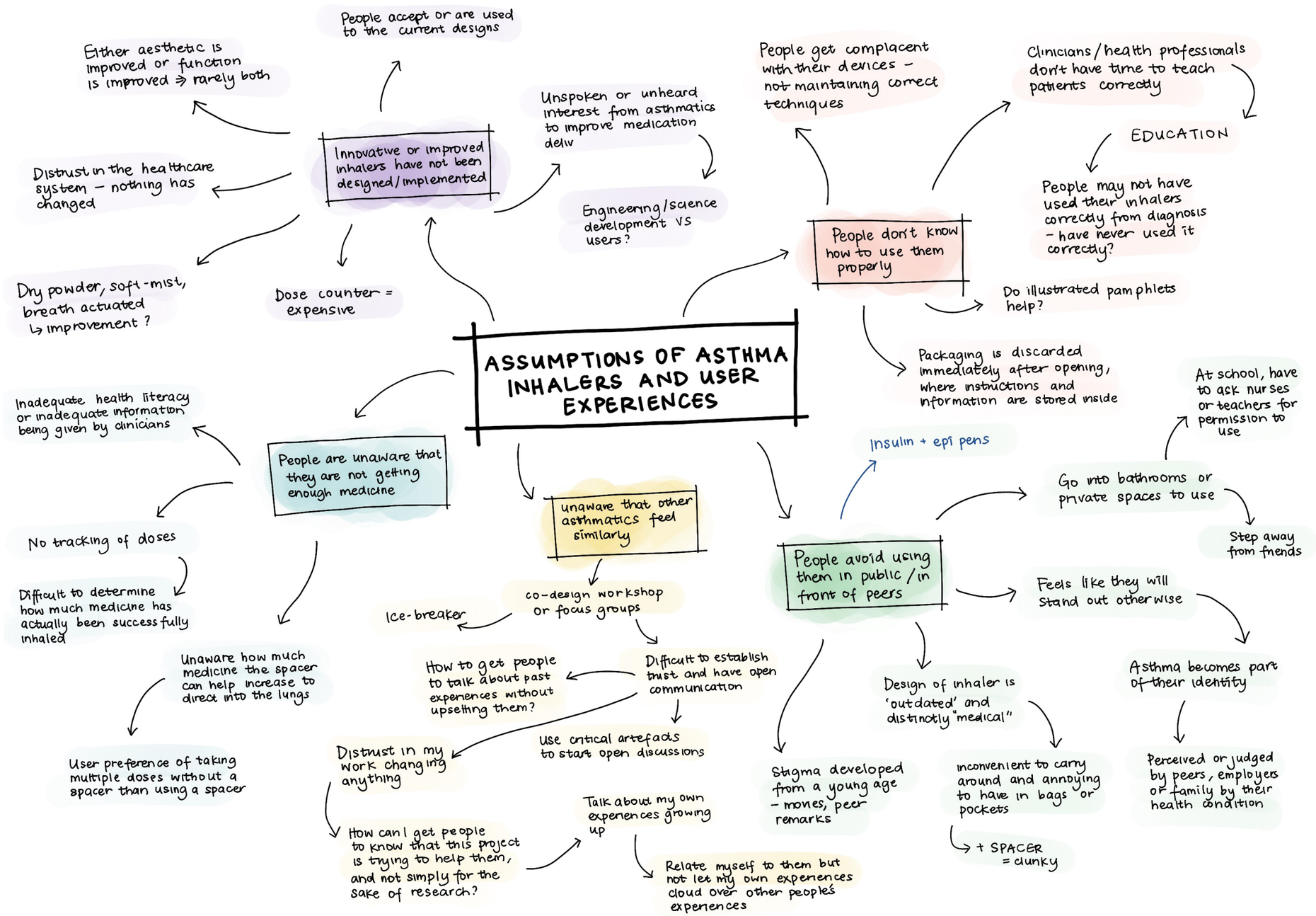


Figure 33 - Assumption brainstorm.

Upon reflecting on the initial stages of preparing the context, I created an assumption brainstorm to write out all my current assumptions. Building on the assumptions were possible contexts and methods I could explore, to help gather insight and dive further into the asthma community's experiences.

It also allowed me to be aware that these are all assumptions, and do not accurately represent all asthmatics' experiences.

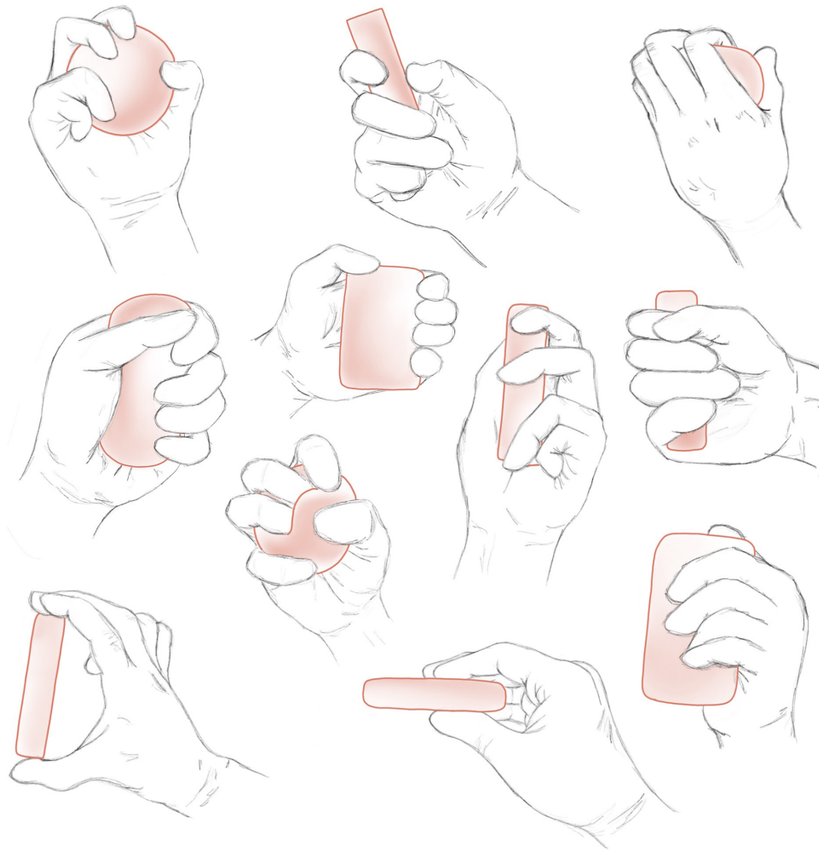


Figure 34 – Sketch exploration of handheld forms.

Ideation I - Rapid Prototyping

After conducting a contextual review, I began my creative exploration through rapid sketches and prototypes. At this early stage in the research, I was yet to collaborate with asthmatics and clinicians, so I ensured this process would only inform my research probes to show participants.

Sketching

Before designing concepts, I explored various ways a product could be held in one hand. Ideally, if I managed to improve the mechanics as part of my product, the user would not have to attach a spacer. Part of the difficulty with hand-breath coordination was the awkward feeling of gripping the inhaler while having to press down on the canister, while the spacer was often considered too bulky to carry around. I took inspiration for these handheld shapes from vapes, exercise equipment, zippo lighters, and cosmetics.

Cardboard Models

Following the sketches, I realised that many medical devices had rigid forms and looked distinctly “medical”. While my sketches gave some idea of the sizing, I hoped that creating physical models would help me visualise the scale in real life. Additionally, cardboard models allowed me to create approximate size constraints, ensuring that my future concepts would not be too small or too large for the average user to hold in one hand. I explored more abstract shapes but decided it was best that my future concepts should be relatively simple for easier and better manufacturing. The maximum size was determined to be approximately 100mm in height, 60mm in width, and 40mm in length. Higher values were either awkward to hold or too large to fit into a standard pocket.

Figure 35 - Cardboard models to determine maximum size and definite shapes to exclude from further exploration.

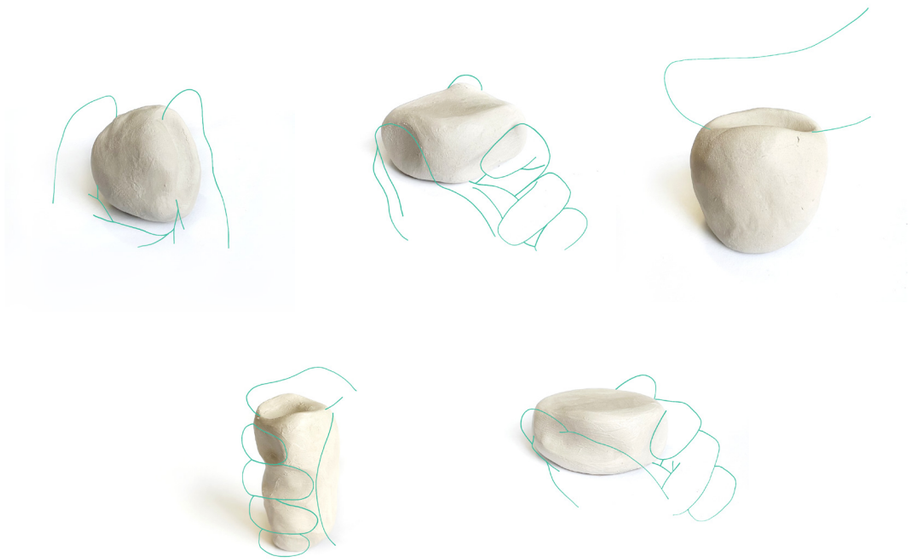


Figure 36 - Top: Clay models, Bottom: Ceramic forms.

Clay and Ceramic Forms

Initially, I decided to use clay to explore forms that would be most comfortable to hold, following the cardboard cut-out experimentations. The canister required to be placed inside the device is a constraint, so I had to account for its dimensions. I eventually tried to model clay to emphasise the pressure points of an individual interacting with a product, particularly the actions of using an inhaler, such as pushing, pressing, squeezing, or gripping [Fig. 36: Top]. I concluded that forms with softer or rounded sides were the best forms, and I would try to deter from designing sharper edges as the current MDIs have.

Reflecting on one of the completed core postgraduate courses, I recalled an activity where critical artefacts were used to instigate conversation about personal experiences. Past experiences can be by holding a particular form, and these thoughts could be shared within the group. I considered using this activity as part of the focus group session with participants, where I could use ceramic-clay models [Fig. 36: Bottom] to prompt conversation as either an ice-breaker or initiating discussions about comfortable forms to hold.

Reflection

Understanding through Literature

It was fascinating to read about qualitative studies compared to quantitative studies that I was used to in my engineering studies. Such literature was around people's experiences and opinions, so there are no right or wrong answers, and studies may never have solid solutions. I found myself agreeing with one person's opinion, yet agreed with another's opinion on the opposite side, having understood their conclusions too. Understanding different experiences and factors that influenced their perspectives cannot be categorised into 'black and white' – they are all in the 'grey' area. As a designer, I became aware that I cannot change people's past experiences or change their minds about a product because of bad experiences they might have had. Experiences also seem to be related to social environments and have a lot to do with self-identity, thinking, and perception - which in that sense, no one can change because they are what shapes each individual differently.

Creative Block and COVID

At this point, Auckland went back into a COVID lockdown for an undefined period (which ended up being four months). I had only begun to define my project based on the previous semester's feedback and reflections, continuing my contextual review and refining my research question. The first few weeks of lockdown slowed my progress, and by discussing with my peers, I found that many felt equally unmotivated. We struggled to figure out the next steps of our projects since it was uncertain when we could move forward with our research methods – especially those involving participants.

This particular lockdown was one that I found myself struggling in the most. It came as quite a shock to me because I worked well from home in the previous lockdowns. This time, however, I found it extremely difficult to motivate myself to do research, write or even draw. Every time I tried to push myself to do some work, I would be distracted by minor excuses, which consequently led me to lose hours that I felt could have been productive. It was challenging to develop new ideas; I found myself circling similar concepts. Most peers felt this concern, and we realised that being stuck in the same environment for an extended period was draining our creativity. Although we communicated through online platforms, it was a different feeling being able to bounce ideas off one another in a studio setting. Keeping in contact with my peers helped my mental state, as they felt they were in a similar position, so we were not alone in feeling this way.

Expert Interviews

Collaborating with clinicians was key in the research to gain insight into asthma treatments, their opinions on asthma education, and their own experiences from working directly with asthmatic patients. These interviews were intended to shed light on the issues, benefits, advantages and disadvantages, and potential inhalers' improvements from a medical professional's perspective. Since the healthcare systems are well-established, it was beneficial to determine possible design constraints and requirements before starting to design concepts.

I conducted interviews with asthma specialists and other clinicians who work closely with asthmatic patients. As Auckland was in lockdown, I had to consider the availability of health professionals throughout New Zealand, particularly in Auckland. I had to approach the clinicians cautiously and understand that they may not be in a position to be part of my research project until New Zealand is more stable. Revising the timeline and adjusting accordingly, ensured that the clinicians would feel more comfortable being part of my project and of a healthier mind to take part as best as they can.

Individual interviews were conducted online through Zoom, and interviewees consisted of nurses, an occupational therapist, and a pharmacist. All clinicians either specialised in asthma or worked closely with asthmatic patients. The nurses and occupational therapist strongly focused on educating and supporting their patients who had been referred to them by the hospitals after the patients have been admitted for asthma exacerbations. Nurses, on the other hand, may make home visits to patients' homes. This way, they can have as much time as needed to discuss asthma triggers, techniques for using the inhalers, and the long-term best practices to prevent asthma exacerbations. The nurses and occupational therapist interact with asthmatic patients the most, while the pharmacist had focused on research and quality improvement from an educational rather than a clinical perspective.

Health Education

It became evident that the inhaler needs to account for more natural human behaviour and require minimal demonstration once prescribed. It was a shared concern that most asthmatic patients have minimal understanding of their condition and their prescribed forms of treatment. As a result of most GPs' time restrictions and limited knowledge about asthma, patients are consequently not well-informed about how to manage their condition correctly. This includes a lack of education about the correct techniques for their inhalers, the reasoning and importance behind each step, and the adverse long-term consequences of excessive use (Baggott et al., 2020). All clinicians mentioned that the knowledge of the MDI's low efficacy without a spacer is unknown to most patients, if not all.

After the GP consultation, the responsibility of educating patients is often passed onto nurses and pharmacists. Due to the multiple device options and updated guidelines, non-specialised health professionals may not keep up with the different techniques. Several comments were made by the clinicians regarding the primary care sector's lack of knowledge of correct techniques, and worryingly so when patients have recounted being shown techniques meant for one type of inhaler compared to another. One of the nurses discussed that patients must understand the reason behind the techniques to adhere to them willingly. Naturally, people do not like being told what to do – also known as psychological reactance (Steindl et al., 2015) – and will not follow the given advice. On the other hand, patients were more likely to adhere to their treatment regimen if they were familiar with the inhaler they had been prescribed (Rogueda & Traini, 2016), hence the common preference for using MDIs. When asthmatics are admitted to the emergency department for an asthma exacerbation, only then does serious consideration seem to be taken by the healthcare system.

A few nurses mentioned cultural and regional differences within New Zealand, particularly the high prevalence, hospitalisation and mortality rates related to the asthma of Māori and Pacific peoples (Barnard & Zhang, 2021). They surmised that although general asthma triggers significantly affect their risk of severe symptoms and exacerbations, other underlying issues influence their treatment. I assumed that this may be regarding the inhaler device required to be used near the head. In many cultures, including Māori, the head is very tapu (sacred) (Victoria University of Wellington, 2020). However, the nurses understood through their working experience that Māori and Pacific peoples do not have a problem with the inhaler, but rather a general distrust of Western medicine and the New Zealand health system.

Current Market Availability

Another prominent issue is the availability of specific inhaler devices in New Zealand. The nurses were aware of other inhaler devices in other countries, especially if they had their own experiences overseas. However, many emphasised the control of pharmaceutical companies, such as Pharmac, and their focus on limiting expenditure. One part of the inhaler that all clinicians mentioned is the inclusion of a dose counter. Interestingly, all the MDI devices in Australia have mechanical dose counters, but this is not the case in New Zealand because Pharmac considers them too expensive. Dose counters can be helpful for users to keep track of their medication and provide an indication of its use. This can allow them to take more notice of their potentially excessive use, which can then be discussed with their GP. Although having a dose counter may cost slightly more, it was mentioned in the interviews that a patient admitted into the hospital can cost the healthcare system around $1000NZD for an overnight stay and tens of thousands of dollars if admitted into the intensive care unit (ICU). This is a significant drain on the health system, especially in New Zealand, where asthma is highly prevalent. It was argued, that risk of hospital admissions for asthma may be lowered with better management.

Lack of Choice

The Asthma Guideline from 2020 has been pushing health professionals to prescribe dry-powder Symbicort Turbuhaler inhalers to all asthma patients over 12 years of age. This is mainly due to its combination of reliever and preventer medicine, and the device allows more of the dose to be deposited into the lungs than the MDIs. Some of its limitations include the lactose carrier mixed with the medication (so people who are lactose intolerant or have diabetes cannot use this device) and the strong breath required to inhale the medication. Turbuhalers are thus difficult to use during acute exacerbations. The clinicians voiced their concern that doctors have been limiting the choice of the different inhalers for asthma patients due to the updated guidelines. Many people were more comfortable with the MDI because it has been around for a long time. However, it seemed that the guideline changes meant MDIs were not offered unless the patients displayed an inability to use Turbuhalers.

Stigma

All clinicians stated stigma as one of the most prominent reasons given by their patients, affecting their treatments and resulting in a lack of use of inhalers. Their patients over 12 and up to 30 years old seemed to be the most reluctant to use a spacer or otherwise hesitant to use inhalers in public. Usually, over 30 years of age, it was assumed that people care less about other people's opinions and focus on their own needs in any form. Besides the inhaler and spacer's associated stigma and awkward size, as discussed in the contextual review, some patients perceived the spacer as "childish" or "feminine". One clinician recounted their patient's child being asked, "are you a baby using a spacer?" by a teacher, which left the child feeling self-conscious and belittled. It was concerning to realise that asthmatics might not have reservations about their condition or forms of treatment, and involuntary exposure to negative perceptions by others can lead to troubled self-identities.

Inhaler Design

Several comments were made regarding the design of inhalers. Most of the clinicians' patients were familiar with MDIs and felt comfortable with the device; however, they acknowledged how difficult it was for hand-breath coordination. Turbuhalers were found to be easier to use as they do not require coordination. However, people were still confused about the direction to turn its base to dispense the medication, since it rotates both ways. The clinicians noted that patients may prefer MDIs for familiarity and the device providing indications that the medication has been dispensed (by taste or sound of the spray), so they know it works. However, this meant that less medication was travelling into the lungs. I understood from this insight that users were looking for functional or visual indicators in their devices, so affordances and signifiers were a high-priority focus for my concepts. Companies had proposed smart device ideas to Asthma NZ, highlighting breath-actuated functions and incorporating step-by-step voice instructions or electronic dose counters. However, cost becomes the issue as the nurses noted that people who seem to suffer from asthma the most are usually from low socio-economic backgrounds.

I asked the clinicians for suggestions on improving the current inhalers and their opinions on what would make an 'ideal' inhaler design. Overall, they mainly addressed ease of use, minimal instructions, compactness, portability, the addition of a dose counter, and sustainability as new prescriptions come with new devices. Other non-technical considerations included: removing reliance on healthcare professionals to educate the patients on techniques, designing for accessibility, encourage the use of inhalers, and targeting a younger audience.

The consensus was that inhalers should look more modern and feel natural to use.

Reflection

I did not expect that changing settings from in-person to an online platform would raise many additional considerations. However, hosting the interviews through Zoom shed light on the difficulties that the healthcare system can face under unprecedented circumstances. Since Asthma NZ nurses primarily meet with their patients in person or travel to schools to provide asthma education, conducting meetings online became less of personal interaction and more of professional interaction. The restrictions at the time meant that patient home visits were not possible, so assessments of their patients' living conditions could not be made to provide additional recommendations for better asthma management. I recognised that asthma issues are complex as the context extends to more social determinants (Ku & Lupton, 2020). These include healthcare services, inequity, socioeconomic issues, environmental concerns, and health education – most of which cannot be solved within this project's scope. To build upon the context around culture and understand their perspectives and experiences, I contacted a Māori-based community healthcare organisation but unfortunately did not receive a reply.

All the clinicians expressed an interest in the possibility of a new inhaler design that could be an improvement from available devices in the current market. However, they were understandably sceptical of anything that could implement significant change.

Anonymous Online Survey

The main difference between conducting an online survey and an interview in this project was to gather more generalised opinions from a larger population (Jain, 2021), which in this case was from past experiences from all ages. Due to the time constraint and ethical considerations, I could only have a small age range as participants (16-25 years old). However, I was highly interested in understanding the experiences and opinions outside my project's target audience. Asthma NZ advertised my survey on their social media on my behalf, as the universities' closures due to COVID meant the survey could not be advertised on campus. These approaches were all in accordance with the ethical approval from the Auckland University of Technology Ethics Committee (AUTEC). Several themes were drawn from the analysis of the qualitative data collected from over 110 responses.

Early Asthma Experiences

The first few questions were centred around early asthma experiences, particularly in childhood and adolescence (if respondents were diagnosed before adulthood). Since these experiences were in the past and cannot be changed, I decided to identify keywords from the respondents' answers that described their earliest memories of asthma and their use of inhalers. I constructed a word cloud for easier visualisation of the keywords, as shown in [Fig. 38], the most prominent words were "scared", "hated", "worried", "embarrassed", and surprisingly, "normal". Most respondents felt it was a complex condition to manage during their childhood, as it affected their daily lives greatly: they had to miss school, could not participate in many activities, felt different from their peers, and disliked feeling restricted or debilitated without adequately understanding why. Diagnosis during adulthood seemed easier to accept, but the initial reactions were shock and concern nonetheless because of the seemingly "late in life" diagnosis. Those who accepted asthma as part of their lives explained that they had other family members or friends with asthma, so it was not out of their ordinary or have had it as long as they could remember. "Embarrassed" was the most common description of what it felt like to use inhalers during childhood and adolescence.

Figure 38 – Terms that respondents used to describe how they felt about their earliest experiences with asthma. Word cloud depicted most common descriptors in larger font size.

Asthma Education

There was a consensus that spacers should be used with an MDI to maximise medication intake, make it easier to breathe in the medication naturally, and avoid the risk of oral thrush. Notably, a substantial number of respondents claimed the spacer would help them receive all the doses as they understood or were told by their doctors. In terms of recent experiences, many respondents said they still use the spacers, while others use them sparingly (“if my asthma is really bad”) or not at all.

Most respondents indicated that the techniques they were taught and the instructions shown to them by doctors were relatively similar. However, there were a few additional or varying instructions, such as the number of seconds to count after administering a dose and the number of seconds the user should inhale. Most respondents said they understood each step’s importance as the best practice, and many commented that it was only because that was what their doctors told them. However, several respondents admitted that they knew the importance of the techniques but became complacent, notably during an acute exacerbation, or were confused about the instructions as they received different information from various clinicians. Others said that they did not understand why the techniques were recommended.

In terms of changes in treatment, some respondents discussed altering techniques as they were updated, several respondents changed from MDIs to DPIs, and others described how they changed medications until they could find one that suited them best. A few respondents mentioned that their techniques changed over the years due to different information between doctors, nurses, and clinicians. It was encouraging that most respondents said they use their inhalers less over the years. This seemed attributed to better control, a better understanding of asthma, being more aware of triggers, realising the significance of preventer medication, changing to combination medication, and being more accepting of living with asthma. Very few respondents said they need to use inhalers more over time.

Inhaler Design

Overall, most respondents seemed to find inhalers easy to administer medication, except for the difficulty associated with the coordination of MDIs. Most also disliked the spacer due to its size, look, and need for routine cleaning. Interestingly, there was a relatively even split between respondents who feel comfortable using their inhaler in public and those who prefer to use it in private or only around family. There was a consensus from respondents stating that they prefer not to use spacers in public as it felt awkward, embarrassing, or may “cause a scene” despite being aware of the importance of a spacer. Few respondents felt comfortable enough to use both devices in public, stating that they would rather look after their health than care about what people around them may think.

From enquiring about characteristics that would make up the respondents’ ideal inhalers, the most common were small, compacts, discrete design, more comfortable mouthpiece, easy to hold, and a dose counter. Respondents’ desired features to improve their experience of using inhalers included limiting steps required to administer medication, making it easy to clean, preventing dust from entering the mouthpiece, being easy to inhale, and having refillable medication. These characteristics seemed to align with asthmatic respondents and participants from other research (Baggott et al., 2020).

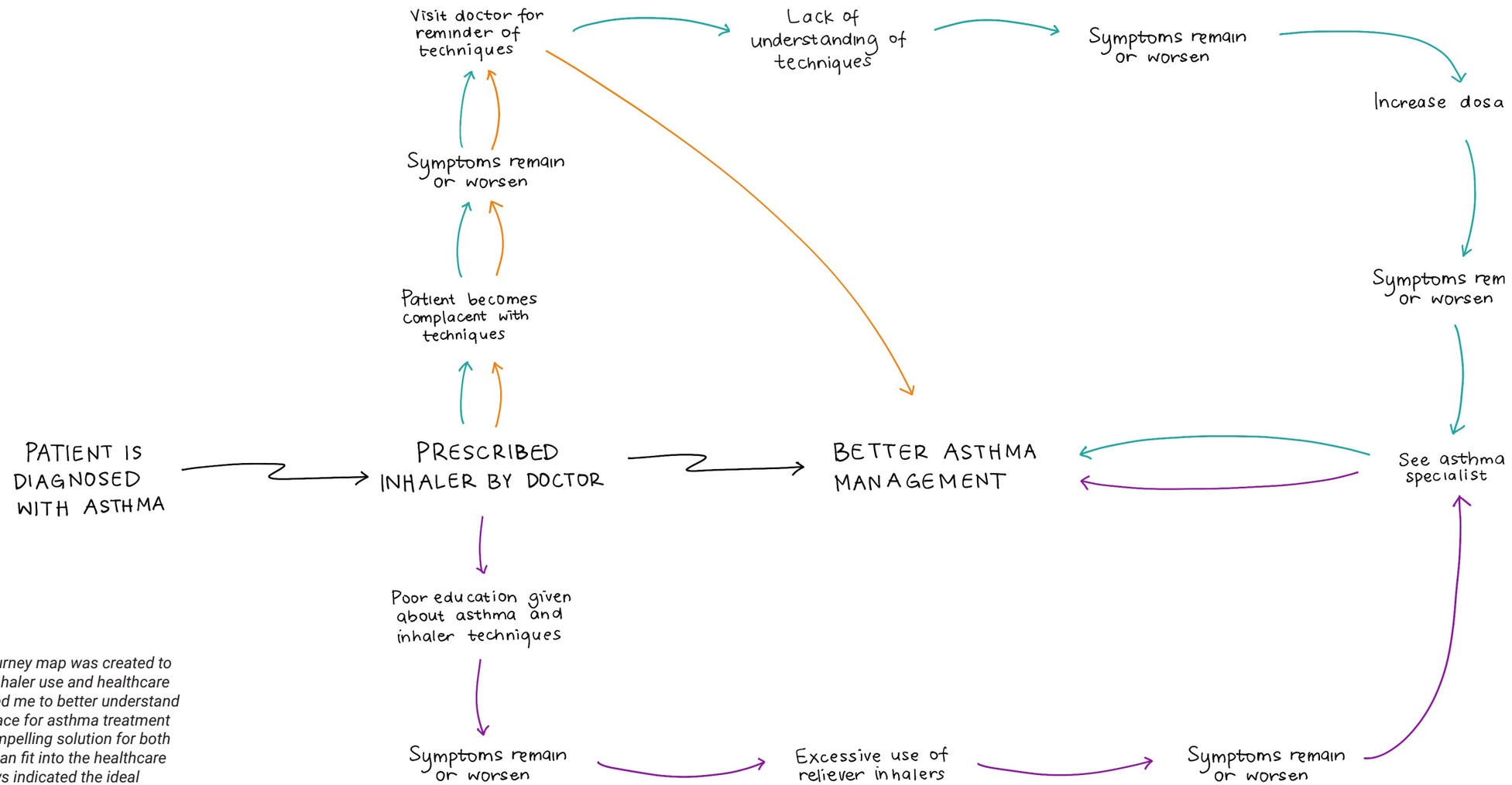


Figure 37 – A patient journey map was created to outline touchpoints of inhaler use and healthcare intervention. This allowed me to better understand the current system in place for asthma treatment to determine a more compelling solution for both the product and how it can fit into the healthcare system. The black arrows indicated the ideal asthma patient treatment journey, while the coloured arrows depicted the realistic journeys of most asthmatics.

Reflection

The anonymous online survey proved beneficial to this research for me to gain insight into the past and present experiences of people living with asthma in a (mostly) New Zealand context. Most respondents were between the ages of 36-45 years, with considerable numbers between 26-35 years, 46-55 years, and 16-25 years. I had to consider that the survey was published on the Asthma NZ Facebook page, so it was more likely to gather a younger and middle-aged audience.

I found it interesting that the three attitudes categorised by Adams et al.'s study (1997) still held relatively accurate decades later. Though most respondents diagnosed with asthma in their childhoods had negative experiences, many seemed to have become more accepting of their condition and adjusted well to their prescribed treatments that require less medication than before. As this was an anonymous survey, I could not delve deeper into the respondents' answers regarding asthma is associated with their identity, as Goffman (1961) theorised. As some of the nurses discussed, how people choose to manage their asthma is significantly influenced by their own life experiences and circumstances, which are often not in their control. The respondents' answers to receiving treatment emphasised the importance of accommodating medication and device options for patients since each individual's health and lifestyles are different. Similarities, however, were evident in the respondents' answers of their ideal inhaler designs, allowing me to outline a design brief for my concepts.

I realised that I did not include a question about the inhalers' cost in the survey, which would have proved helpful in determining how much respondents would be willing to pay for additional benefits in the device. I assumed most respondents were happy with the current costs – $5-10NZD with the government subsidy for eligible New Zealand residents – and would prefer to keep any new devices around the exact cost. However, it would have been more insightful to learn respondents' opinions should costs increase with added benefits.

Figure 39 – Thematic analysis board created to help me draw similar and prominent themes from both clinicians and asthmatics.

Initial Design Brief

At this point in the project, I had done early explorations of interactions with handheld forms. After conducting interviews with clinicians and gathering insight from asthmatics through the online survey, I tried to narrow down the main issues with the inhalers to create an initial design brief. I planned to involve users in this research through focus groups, but due to the COVID lockdown, it was further delayed. In this brief, I intended to retain a broader criterion as the project has yet to be refined. I selected the following aims:

Aesthetics
- Appealing design for all ages (particularly between 12-30 years)
- Updated, modern design
- Distance design from a distinct “medical” look
- Aim for a more organic form instead of geometric forms that have sharper edges

Function
- Incorporate the functions of a spacer within the inhaler for a single device
- Easier to actuate device and dispense medicine, requiring minimal pressure
- Requires little to no reliance on primary care knowledge for good techniques

Ergonomics
- Intuitive – leave little to no room for error
- Comfortable to hold
- Able to actuate medication with one hand
- Small enough to fit into a pocket or bag
- Sustainable design (able to be reused or refilled)

Cost
- Keep the cost as close as possible to current inhalers – subsidised for users to pay between $5-10NZD
- Or
- Justify cost for added benefits if the device becomes more expensive

PHASE II: Defining the Project Direction

Ideation II

Digital sketches

These concepts were drawn based on the contextual review and clinicians' and asthmatics' perspectives. I began with explorative sketches from existing inhalers and tried to brainstorm increments of improvements for the designs. I listed the functions of the MDI and spacer and sketch out their functions. This way, I may be able to view similarities between concepts and create embodiments combining the similarities.

It was a challenge to work around the constraint of the MDI's pressurised canister. The inhaler had to be larger than the canister, so I found it difficult to minimise the size. I decided to try incorporating the volume of a spacer within the inhaler itself to eliminate the need for two different devices. With a focus on making it easier to push down on the canister, I looked to spray bottles. They have bigger surface area on the handle so it would require less pressure to press. This action could be achieved with the palm of the hand instead of requiring higher pressure from two or three fingers. In turn, children and older people may find it easier to administer the medication themselves.

I decided to research the necessity of shaking the inhaler before use. This was one of the characteristics of the MDI that survey respondents wanted to eradicate for an ideal inhaler since it prolongs the time of using the inhaler and felt impractical during an acute exacerbation. Historically, CFC-propellant inhalers required shaking because otherwise, the active drug would not adequately settle in suspension with the propellant and thus produced irregular particle dispersion. However, many HFA-based inhalers have the drug and propellant in true solution, thereby eliminating the need to shake the inhaler before use (Gumani et al., 2016; Levy et al., 2016). The prescription box on the Ventolin inhaler I had analysed in [Fig. 29] noted to 'shake well before use', so it seemed that some HFA inhalers in New Zealand still require this step. I had also assumed that since older asthmatics and the healthcare sector may be accustomed to the instructions of CFC inhalers (such as shaking the inhaler before use), it would be safer to consider this step as crucial for all MDIs. To design with this knowledge, I sketched visual indicators so users are reminded of shaking before use and can observe the mixing process to understand why the step is fundamental.

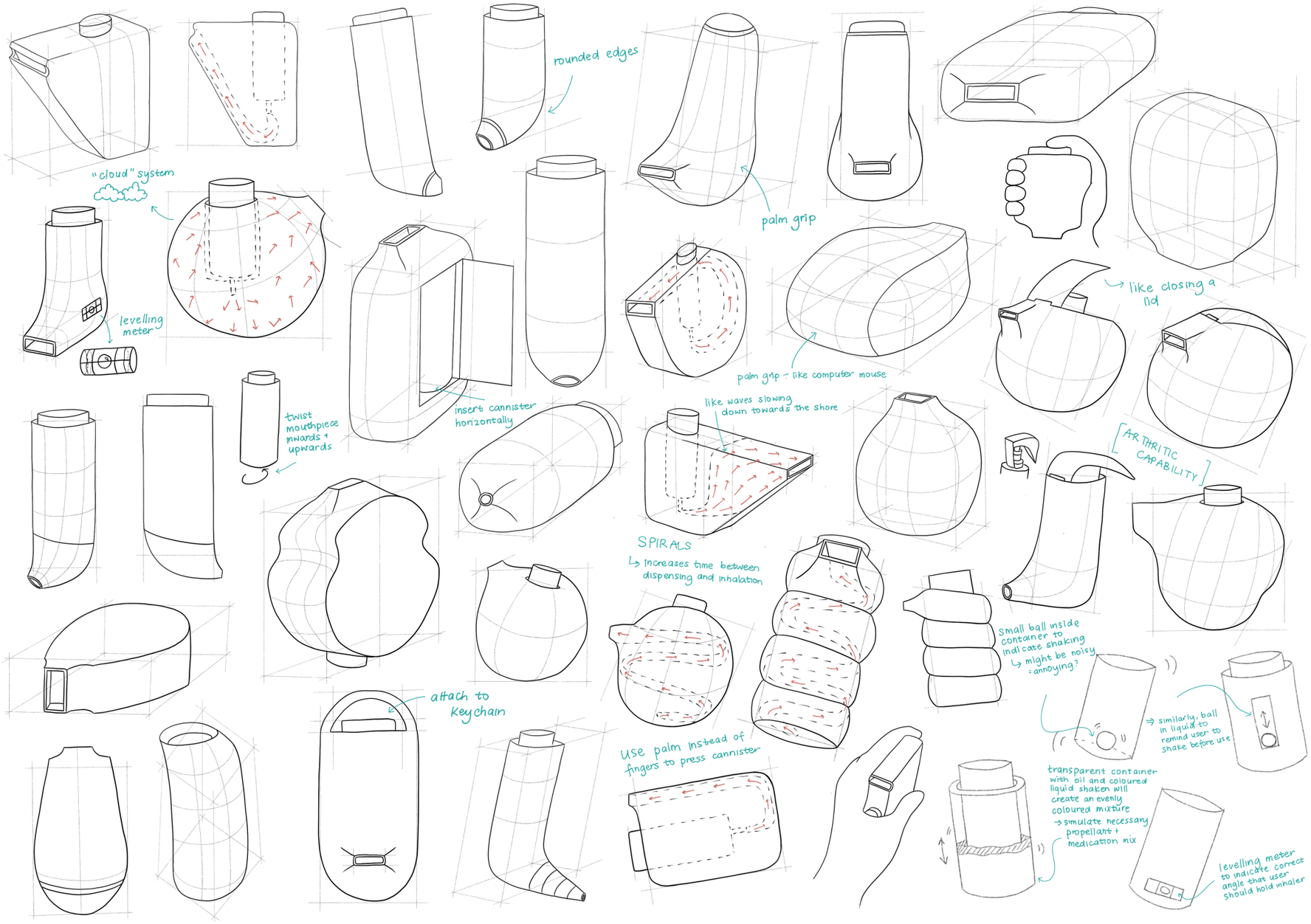


Figure 40 – Explorative sketches of inhaler forms, ways of actuating, and how users may be reminded of certain instructions.

Reflection

Creative Block II and Effects of COVID

After the sketch exploration, I hit another mental block. I kept trying to reimagine the volume of a spacer as different embodiments. However, I often circled back to spirals as they can slow down the airflow, just like the current cylindrical spacers. I considered a “cloud system” where particles are entrained by humidity or temperature changes to stay in a certain form for some time (Scientific American, 1997), which resulted in more spherical concept designs. However, this felt unsuitable because of the non-discrete form.

Having become slowly frustrated with myself at the lack of progress, I knew that although it was not ideal, I had to take a break. Forcing myself to keep working and thinking of designs would only lead to disappointment, so I decided it would ultimately be best to take some time off. Being in the lockdown made the situation more stressful, and it seemed that being stuck in the same environment made me feel mentally stuck in one place. I was disheartened at the thought of having no progress if I took a break, but I convinced myself that a short break may allow me to recharge and result in better productivity afterwards. Additionally, the restriction changes in New Zealand compelled me to reconsider my future planned methods that involve participants.

Shift in Focus

I decided to take a step back after my break, revisit the current research question, and re-analyse the main themes extracted. It became more evident that MDIs are being phased out and slowly replaced by other inhaler types. Though I had been aware of this, my reasoning for focusing on MDIs and spacers was mainly due to their simple mechanisms and knowing that reliever inhalers were more likely to be used in public. The push for Turbuhalers was mainly due to its combination medication and smaller form, thus is appropriate for a broad audience and age range for these reasons. DPIs have been increasingly popular worldwide, and are the preferred device for young adults as it is more discrete than an MDI paired with a spacer. The DPI’s design has solved a few prominent issues of the MDI such as breath actuation, size, and hand-breath coordination. Regarding the hand-breath coordination issue, I was further concerned that the MDI’s canister would restrict my creativity since it seemed to involve more of my engineering background than design skills. With the canister, I had to consider its volume, particle sizes, pressure, and atomisation of particles once dispensed. I felt that it may be wise to move forward with this project with the knowledge of how asthma treatment is seemingly moving forward and having to accept that I could not solve every issue to come up with a perfect inhaler.

One major advantage of the DPI compared to the MDI was eradicating the canister. According to a study by the University of Cambridge, 58000 tonnes of CO_2e (carbon dioxide equivalent) could be reduced annually if DPIs replaced 10% of MDIs due to the HFA-propellant mix required to dispense the solution in a spray mode (Wilkinson et al., 2019).

Although the guidelines seemed to restrict asthmatics from being able to choose their preferred inhaler device, I hoped that my future concept could serve to highlight the further research required for better drug delivery systems. I considered the possibility of redesigning the soft-mist inhalers (SMI) since the mist form of the medication can be easily inhaled by users of all ages. Unfortunately, it seemed that the SMI mechanics were rather complex to work with and would require more quantitative-based testing that was out of this project scope. Eventually, I decided that, given the time frame and scope, it would be best to focus on the DPIs.

The aims of this project remained the same, and only the mechanism focus would be changed from dispensing medication through a pressurised-canister to dry-powder.

Ideation III

With more creative freedom, I was able to break down the inhaler into its main components: the outer casing, the mechanics, and the mouthpiece. I continued the focus on creating an elegant device that would require minimal instruction and support, and be comfortable to use.

Clay Modelling

As the inhaler comprises several components, I decided to focus on the outer casing with a more aesthetic and discretion-based approach. I moulded various clay forms and used this exercise to brainstorm many possibilities with only a single limitation: for the models to be easily portable (and pocketable). I took inspiration from organic and ergonomic product forms. Albeit gathering data from a very general audience of asthmatics, it was clear that my design would not have sharper, geometric shapes for components that the user would directly touch. Comfortability meant that the mouthpiece and the outer casing should have smooth or rounded edges. This was a common preference for general product designs that aim to be organic and want to be perceived as “safe” (Anthony, 2011; Westerman et al., 2012). Much of the inspiration was from the human body, hand movement, and nature.

Although it was intriguing to create more abstract organic forms in this brainstorming process, I knew that manufacturing costs increase with increasing complexity, so it was best to narrow it down to simpler forms.

Figure 41 - Experiment with organic forms for the body of the inhaler through clay models.

Images removed for copyright reasons.

Figure 42 – Examples of stone shapes used to promote wellness and stone-shaped devices.

Promoting Wellness

Having analysed the feedback from survey respondents, reflected on my sketches and prototypes, and looked further into literature, I felt it justified that my inhaler concepts should continue based on a minimalist design approach. The minimalist style has been referenced through the Japanese “Zen” philosophy, which is often associated with calmness (Schenker, 2018). Wanting to build on the outcomes from the foam exploration, I looked for more inspiration from nature and found a design project that piqued my interest – the Calmingstone. Its purpose was to help ease anxiety using light and sound and its shape as a stone (Morby, 2016). I realized that stones are frequently used for advertising wellness, whether for spa treatments, meditation, beach settings, or the calming shape and feel they exude.

Foam Exploration

I began working towards higher-fidelity prototypes based on the previously chosen clay forms. These foam models were used to narrow down the shapes to develop further, as they were more rigid than the clay forms. Though sketches showed certain forms more attractive than others, the foam models proved their comfortability, portability, and discreteness.

Figure 43 - Symmetrical forms such as cylinders, cuboids, and triangular prisms were least comfortable to hold, even with rounded edges, which I had attributed to their more geometric shapes.

Figure 44 - Forms that showed more obvious signs of where the hand should be placed looked too gimmicky and may be problematic for manufacturing and engineering the mechanics to fit inside.

Figure 45 - I carved out models that had widths that were the same as the thickness to visualise having the mechanism work from the "front" of the device, but they felt awkward and unnatural.

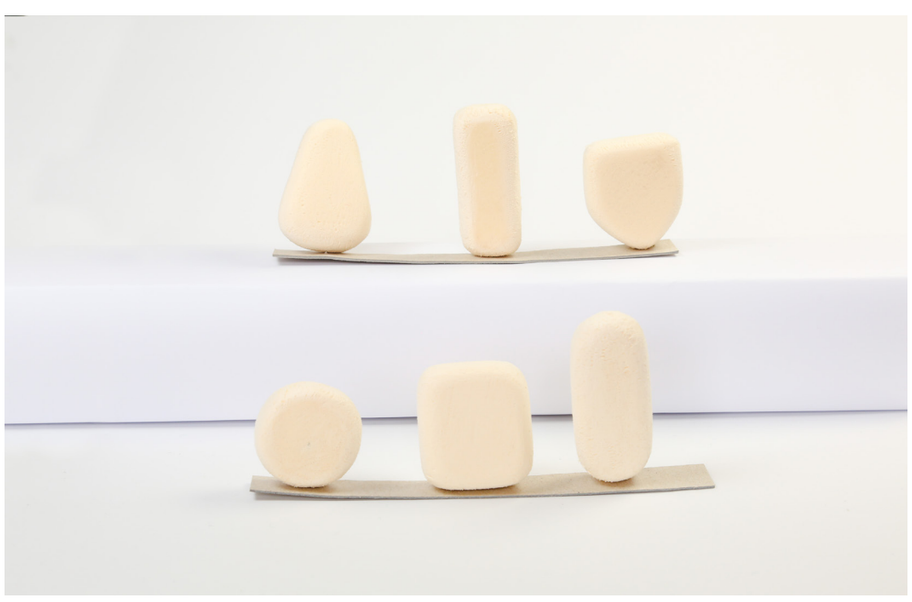


Figure 46 - I considered decreasing the thickness and increasing the width instead. This meant that the mechanism would likely have to be enacted on the side of the device to allow enough space for the internal components. I decided not to be fixed on this notion, however, as I wanted to discuss with participants first about their preferences. It was interesting to note that if the model was too thin, this also felt unnatural, and caused the edges to feel sharper even when rounded.

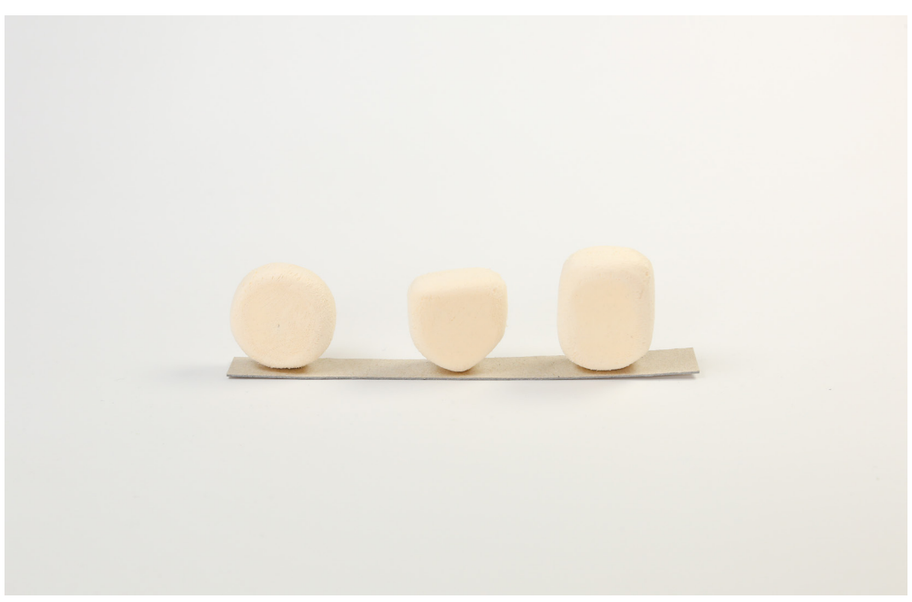


Figure 47 - Although smaller forms were more portable and better to fit into a pocket, when held in one hand, it felt like they could easily slip out.

Figure 48 - Ellipsoids, 'leaf' shapes", and 'stone' shapes stood out the most. They were comfortable to hold, did not feel too geometric, and felt secure to hold.

Form Sketching Based on Foam Models

Aside from wanting my design to exude a calming feeling, my decision for a minimalist approach was also because fashion and product aesthetics have turned towards minimalism in recent years, following a "less is more" motto (Pater, 2022). Minimalism is often synonymous with simplicity and sustainability and is still highly relevant in medical product design, particularly regarding functionality. Although most of the functioning mechanics will be housed inside, the outer casing indicates how the device should be used and where the action will occur. The user's attention should be instantly focused on the device's crucial points (Stipe, 2015). Based on the foam exploration, I decided to look further into ellipsoids and stone shapes since their minimalist form could also be easily manufactured. Moreover, simple products could help reduce the possibility of human error and confusion about usability. All the inhalers seemed to have a certain height and width of 90x35mm respectively and a maximum length of 80mm, so all my concepts were created with this size restriction in mind, as it seemed to be a standard size that can suit most people.

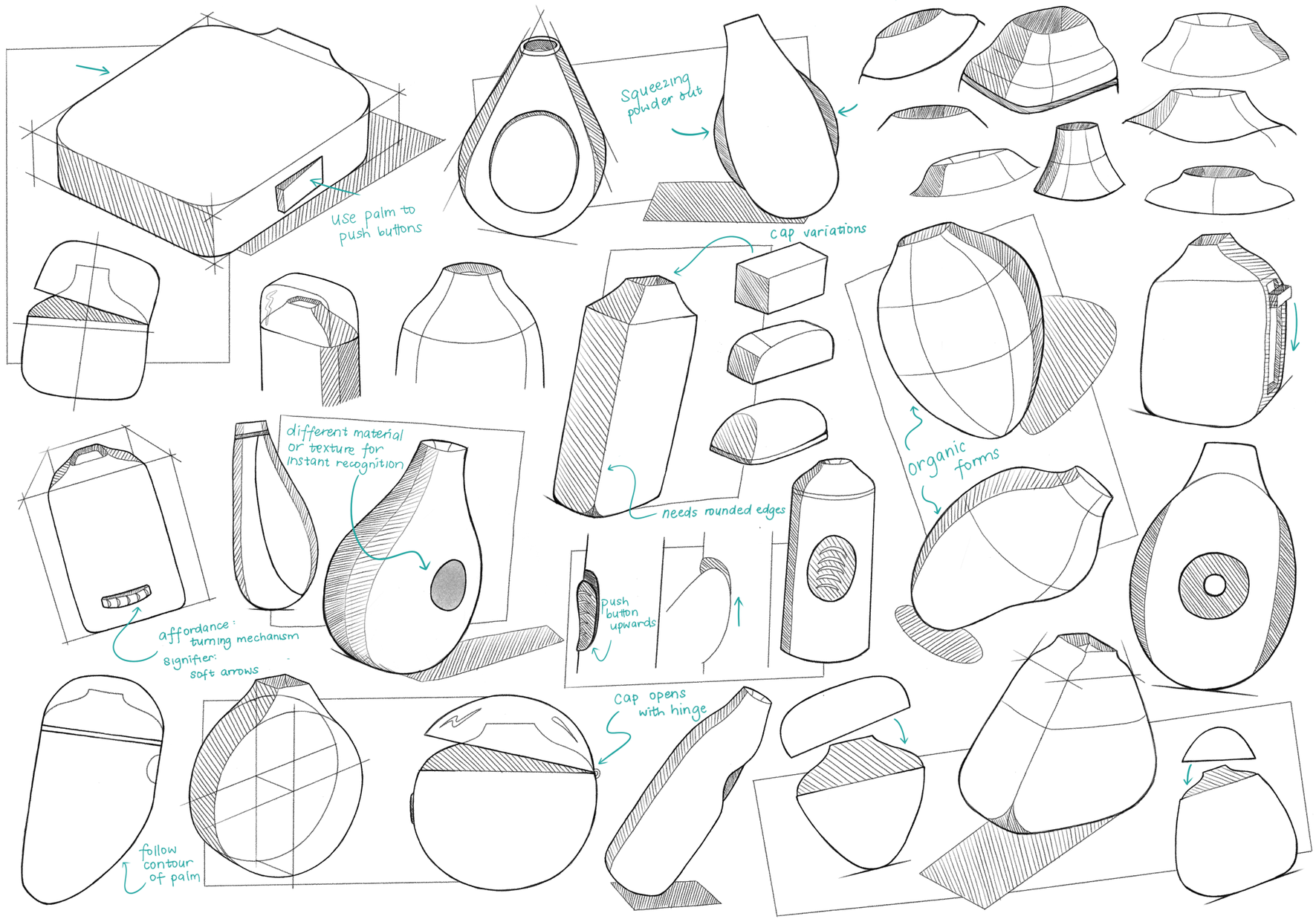


Figure 49 - Sketch exploration for the device's body including organic shapes and curves, and potential mouthpiece placement.

Developing a New Mechanism

With the shift in mechanism focus, I looked to the past DPIs for inspiration. At first, it seemed that dispensing a dry powder in single doses made the mechanisms more complex than MDIs, as they require several components working together one after the other, if not simultaneously. I recalled the Accuhaler's coil-blister system requiring the user to push down on the cover to dispense the powder. However, this system meant the inhaler is not reusable and has to be replaced entirely with new prescriptions.

I came across recent powder-based cosmetics that relied on gravity to dispense the powder before going down a rabbit hole where I discovered numerous systems of dispensing products. To obtain more inspiration for creative solutions, I branched out to look into products that people may be familiar with in their everyday life, such as cosmetics, mechanical pencils, pumps, bottles, and supermarket dispensers.

Images removed for copyright reasons.

Figure 50 - Examples of product dispensing mechanisms.

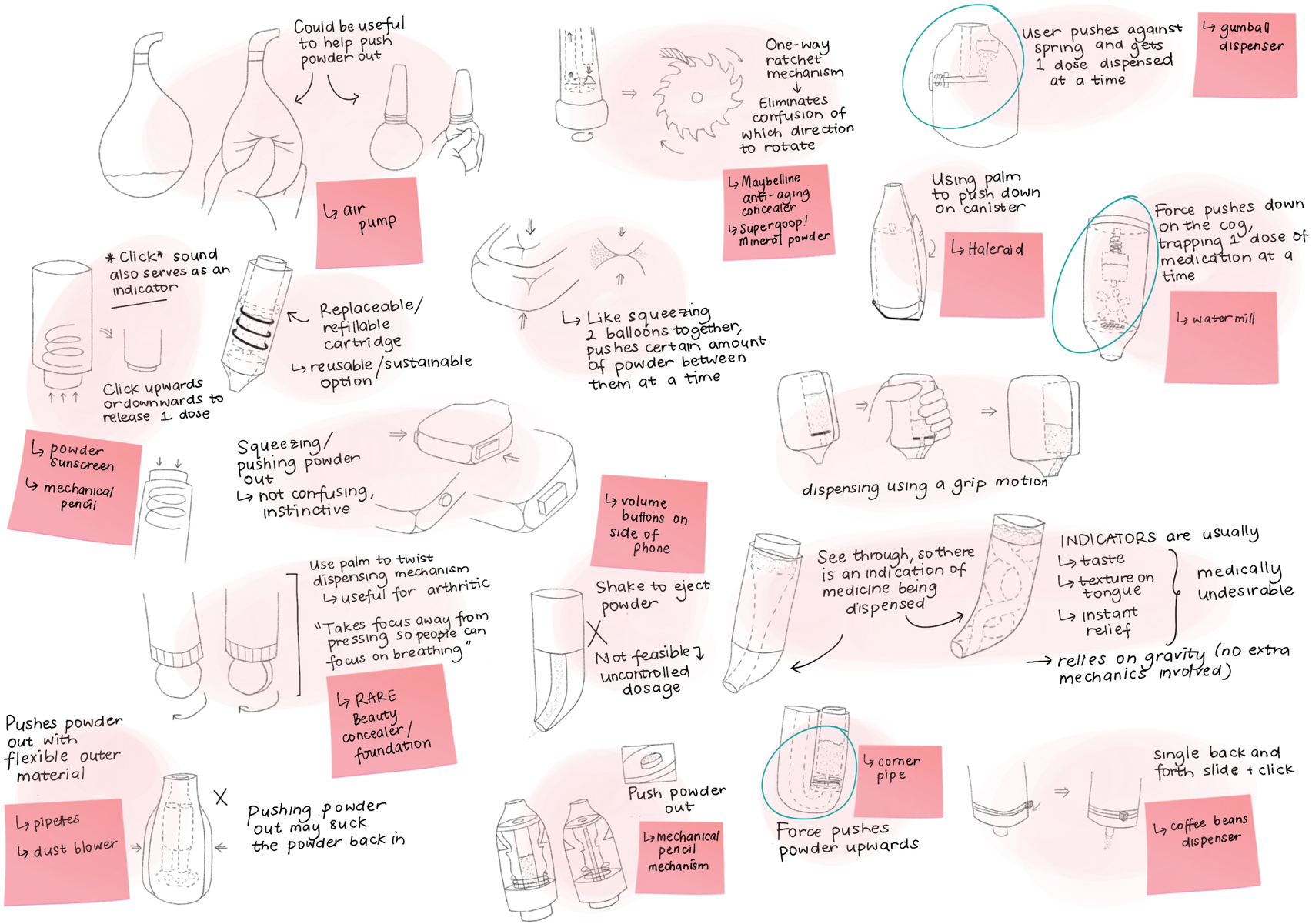


Figure 51 - Sketches of how exisiting products' powder dispensing systems could be used for DPI. Buttons, grip, and squeeze motions were mostly considered because they would typically require a single action.The mechanics I decided to explore further were circled.

Mouthpiece Development

Several survey respondents mentioned the mouthpieces, so I decided to analyse the existing and past inhalers' mouthpieces. The current MDIs have sharper edges with square sides, resulting in an uncomfortable feeling when placed between the lips. Older MDIs rarely used these days were very oval-shaped, almost circular, with a radius similar to the current MDIs. Considering that the medicine is sprayed fan-like when dispensed, the mouthpiece design did not seem to aid in directing a more linear flow. Contrarily, the DPIs have smaller, more organically-shaped mouthpieces. However, their mouthpieces seemed to follow the contour of the device itself, which may have been according to inner mechanisms. This emphasised the importance of balancing user-centred design and the engineering considerations required to create feasible devices.

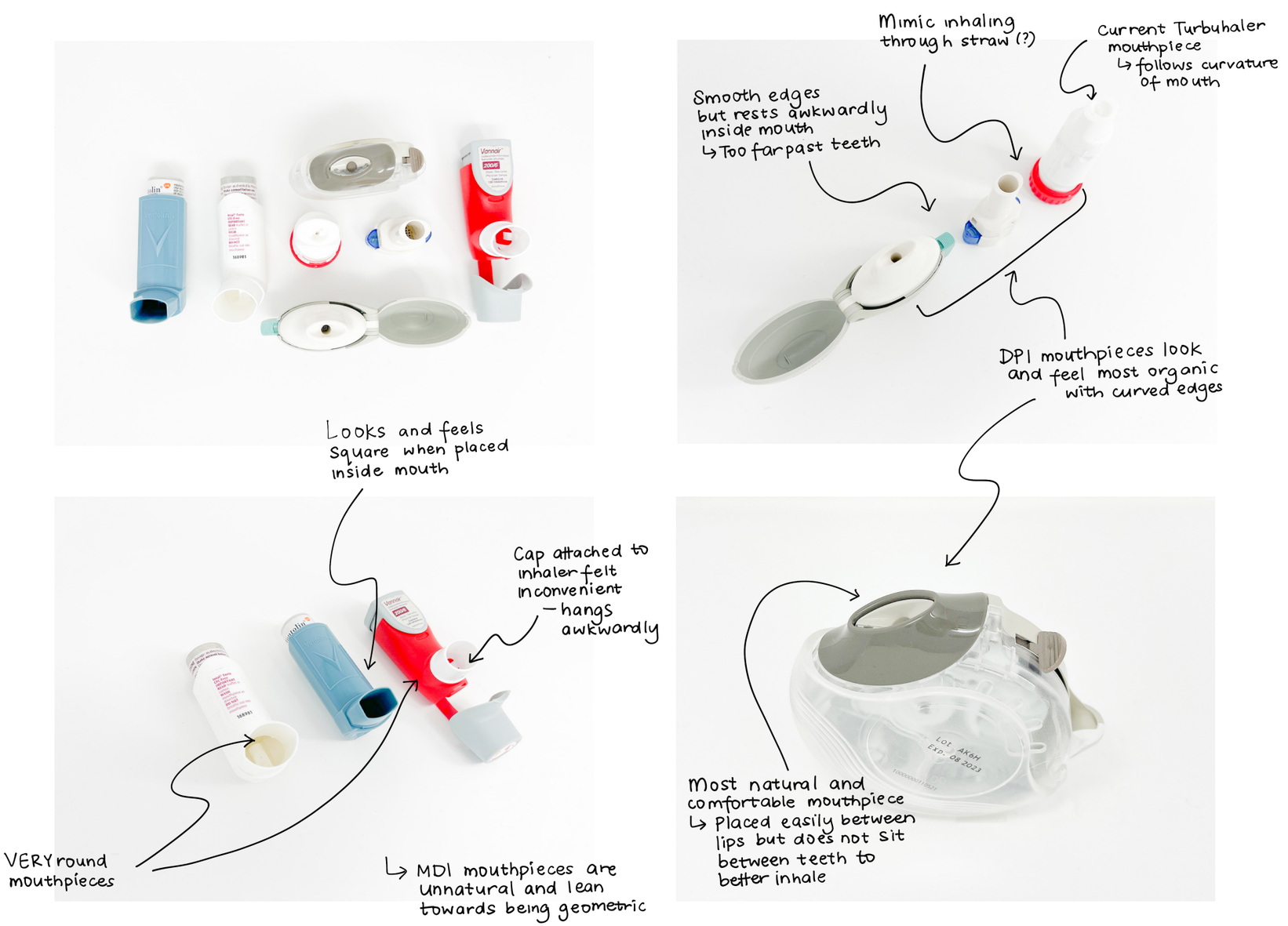


Figure 52 – Annotations of MDI and DPI mouthpieces.

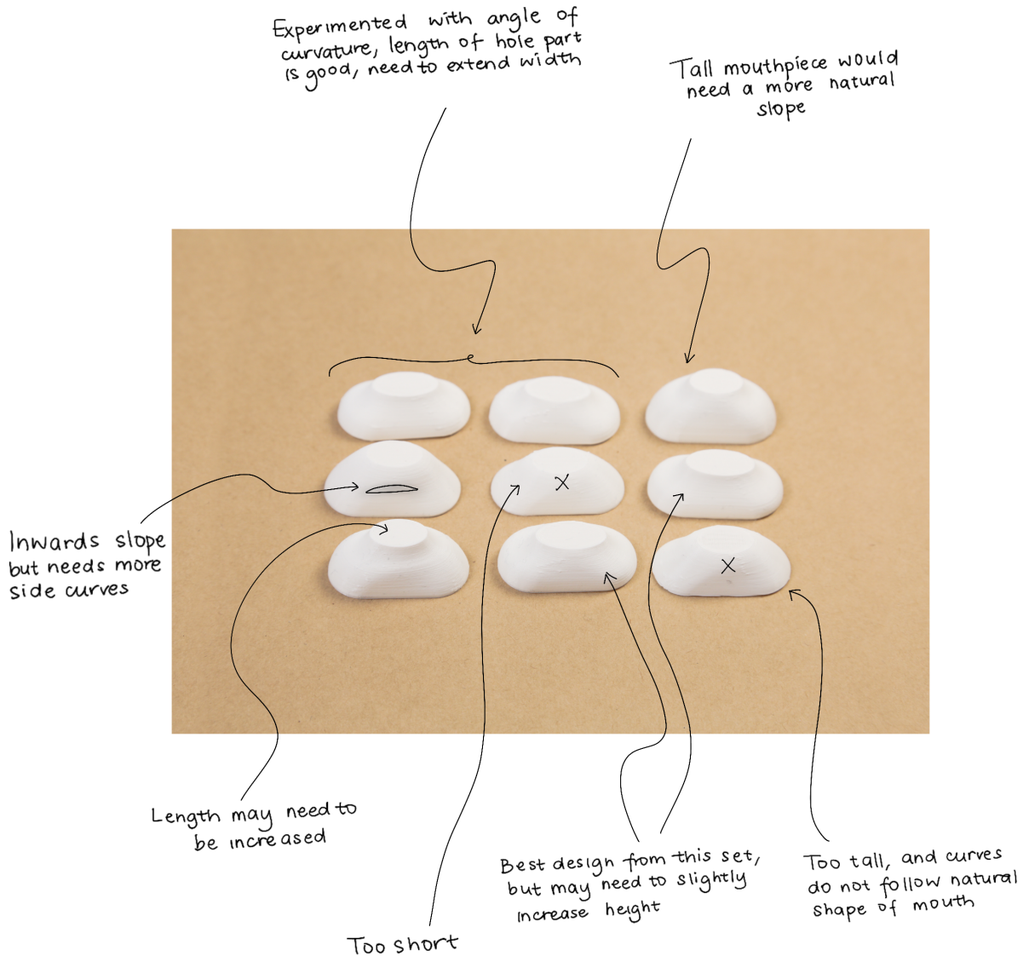


Figure 53 - Mouthpiece forms were drawn up on Rhino with subtle changes to the curves and slopes. I was surprised to find how minimal increase or decrease in dimensions could make a substantial difference felt when tested physically. The X marks on some prototypes were discarded from further development.

Testing Mouthpieces

I modelled some organic mouthpieces in CAD and 3D printed them to test their comfort, size, and ability to prompt better airflow from the device and through the mouth. It seemed that having dipped curves around the sides followed the curvature of the mouth more naturally, and the height of the mouthpiece proved vital as it could interfere with users' teeth. It was brought to my attention that an MDI was uncomfortably difficult to place in the mouth for someone with braces, and I also recalled this feeling when I had braces myself. On the contrary, from one of the clinician interviews, it was mentioned that a patient's parent had placed a straw through the mouthpiece of an Accuhaler and the child found it easier to inhale their medication that way. While I contemplated looking into two options – a shorter, curved mouthpiece similar to that of DPIs, and a taller mouthpiece that sits past the teeth, resting on the tongue – I decided to develop a shorter mouthpiece. Studies have shown that an asthma exacerbation may feel similar to breathing in and out using a straw (Institute for Quality and Efficiency in Health Care, 2017), thus would make it more challenging to take the medication with a taller mouthpiece.

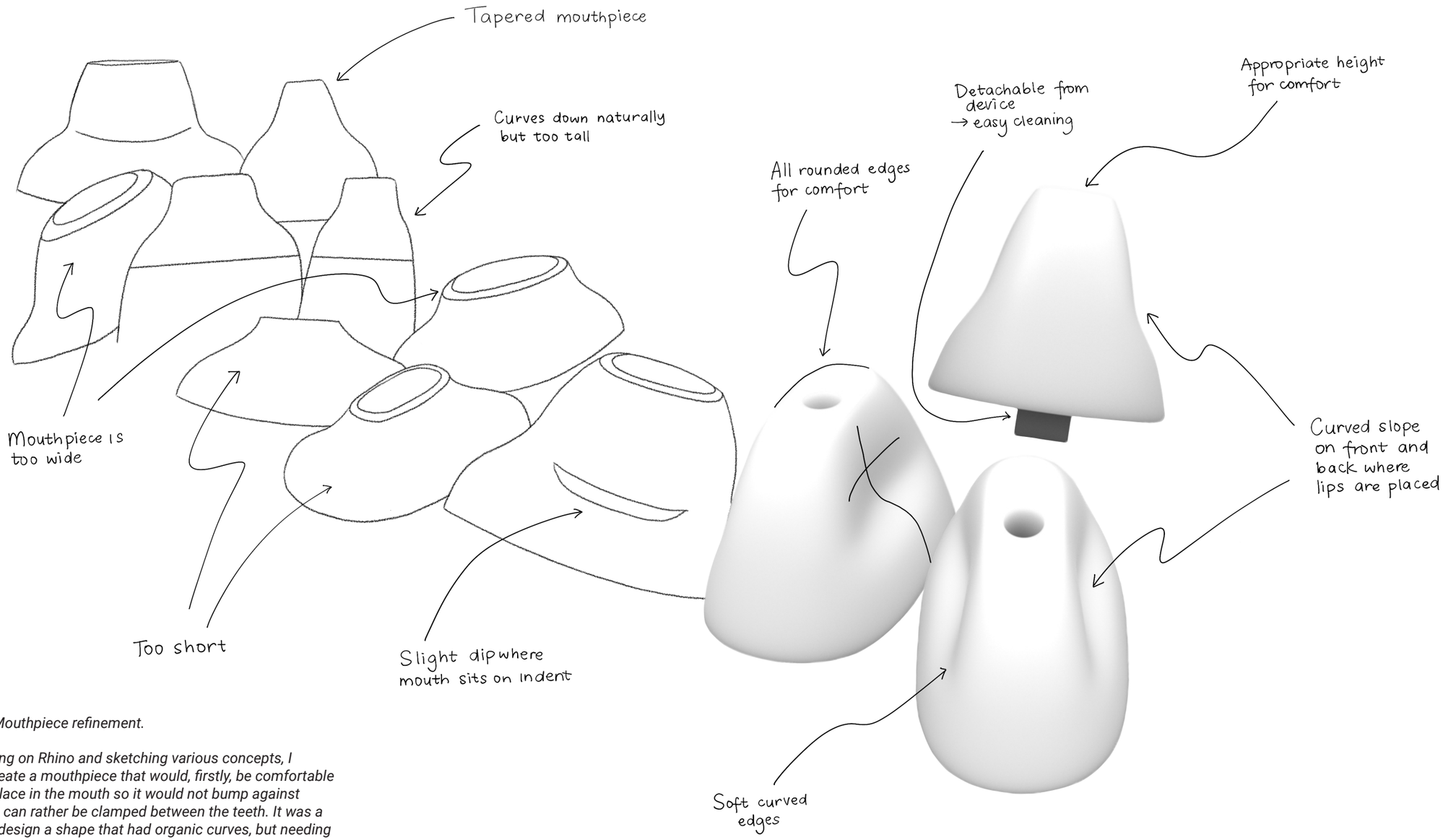


Figure 54 – Mouthpiece refinement.

After modelling on Rhino and sketching various concepts, I devised to create a mouthpiece that would, firstly, be comfortable in height to place in the mouth so it would not bump against the teeth, but can rather be clamped between the teeth. It was a challenge to design a shape that had organic curves, but needing to be generic enough for all users to find comfortable. I opted for soft curved details around all edges.

Taking a Step Back

Method Reconsideration

At this point in the project, COVID was worsening in New Zealand, and I had to consider this before trying to recruit participants. I decided to change the participant collaboration method from focus groups to interviews to accommodate the potential participants' health and safety. I was concerned about involving participants in the research late in the project. However, given the circumstances at the time, I would rather still obtain insights from asthmatics, even if it was limited to feedback and critique for my refined prototypes.

Designing for the Future

As I was nearing the refinement and finalisation stages, I was inquired about the potential of designing a smart inhaler. In my initial design brief, I wanted to keep costs low based on the interviews with Asthma NZ nurses who voiced that lower socio-economic communities show higher asthma rates. Upon further consideration of the advantages and disadvantages, I decided to explore the potential of smart technology being incorporated into the design of future inhalers and how this may help to challenge the status quo of the current asthma-based healthcare ecosystem.

Minimal Instructions, Minimal Techniques

One of the most prominent recurring issues with inhalers was their misuse and requiring 'perfect' techniques for optimal effectiveness. Through the existing product analysis, it was evident that all the inhalers required an action to dispense the medication, whether that be pushing down on a canister (MDI), twisting to a certain angle (DPI) or continuously pushing a button (SMI). Despite various inhaler options available on the market, the inhaler techniques were a recurring reason causing asthmatics to receive insufficient medication (Jahedi et al., 2017; Price et al., 2013). Various actions corresponding to different inhalers confuse patients and healthcare professionals. Asthmatics must focus on several techniques simultaneously to administer the inhaler correctly, and inhale as much medication as possible. As one of the clinicians mentioned, it would be ideal if the focus could be removed from the action "so people can focus on the breathing". From a human-centred perspective, I considered various actions that may be more natural than others. I deduced that buttons are one of the simplest signifiers requiring minimal thought about their action.

I was made aware from the expert interviews and online survey that asthmatics were not satisfied with the current devices having no visual or audial indication of the medication being dispensed nor a physical indication that the medicine has been properly inhaled. I surmised that a physical indication may not be possible once the medicine has entered the mouth since tasting medication would mean that it has deposited in the mouth instead of travelling into the lungs. A visual indication does not necessarily mean that the user could see the medicine travelling from the point of dispensation to the mouth. However, the current inhalers are opaque, and people cannot tell where the medication is located throughout its use. Users are having to trust that their action of administering the medication has worked, as the audial/physical sign for DPIs are 'clicks', and the spray of the MDIs can be heard or tasted.

Self-Management of Chronic Condition

Another advantage of smart technology was the possibility of motivating users to self-manage their asthma, as it is a chronic condition that requires treatment throughout their lives. Due to the busyness of everyday life and restricted GP consultation times, it may prove beneficial to both parties to promote self-management. Implementing a mobile app connected through Bluetooth to the inhaler could serve many functions. This may include tracking inhaler use, providing detailed information about asthma and its treatments, community support through online forums, contacting healthcare professionals, and customisable designs for the users to express themselves. An app can help users engage with treatment and learn from the community, so they may gain support from others in similar positions while being able to better self-regulate their treatment and have a form of self-accountability for medication misuse. Asthmatics could also learn to be more proactive in their asthma management, whereby tracking inhaler usage could send an alert to clinicians when there is a lack of or excessive use and opt to contact an asthma specialist if desired. The idea is to utilise the existing support better and provide opportunities for earlier intervention at more appropriate times rather than only being referred to specialists when they have severe symptoms or are admitted to the hospital. Ideally, self-management would lead to fewer hospitalisation rates, shift the available resources to those underserved, and require more attention.

Motivate Use – Remove Stigma

From the start of the project, I strived to design an inhaler that would remove the associated stigma. Through this reflection, I shifted my perspective to challenge removing stigma further and considered the possibility of making the inhaler look desirable enough to motivate users to take their medication routinely. Aside from the common dislike of inhalers in public, asthmatics can easily forget to use them if it is not already part of their established daily routine. With the examples of mobile phones and smart watches, these devices considered aesthetically pleasing are rarely forgotten throughout the day, so I believed the hedonic design of the inhaler would be critical in the motivational aspect of use. As part of human nature, we are attracted to good design and naturally gravitate to such products (Hosey, 2013).

On the other hand, the hedonic value ensures user satisfaction through product interaction (Bölen, 2020). In reflection on Bloch's study on product forms (1995), he considered that "the ideal form is that form which is superior to alternatives in its ability to evoke positive beliefs, positive emotions, and approach responses among members of the target market". However, I was aware of the tension between the aesthetic of medical and consumer products. Although the inhaler's design could be modernised to suit current and future times, it is still a medical device, and thus should not resemble consumer products too closely. As a medical device, it should provide a sense of security and safety for the user, so I had to keep a minimal amount of distinct "medical" aesthetic as the device should not be taken lightly.

Cost Considerations

A further point and perhaps the most crucial point to justify, was cost, as implementing electronic components will undoubtedly increase the cost of an inhaler. I recalled one of the clinicians' interviews who brought up smart inhalers, stating that hospital admission costs the NZ government at least $1000NZD per patient per night. As reported by the Asthma and Respiratory Foundation NZ, the cost burden of asthma in New Zealand was $1.182B, of which $269.7M was from direct costs (hospitalisations, prescriptions, and general practice consultations). $912M was from indirect costs (work days lost, disability-affected life years, and mortality) (Barnard & Zhang, 2021). If asthmatics are increasingly self-managing their treatment, then it is possible to shift the asthma-related hospitalisation costs to the subsidy of smart inhalers. A cost-benefit analysis must be conducted should a business model be formed.

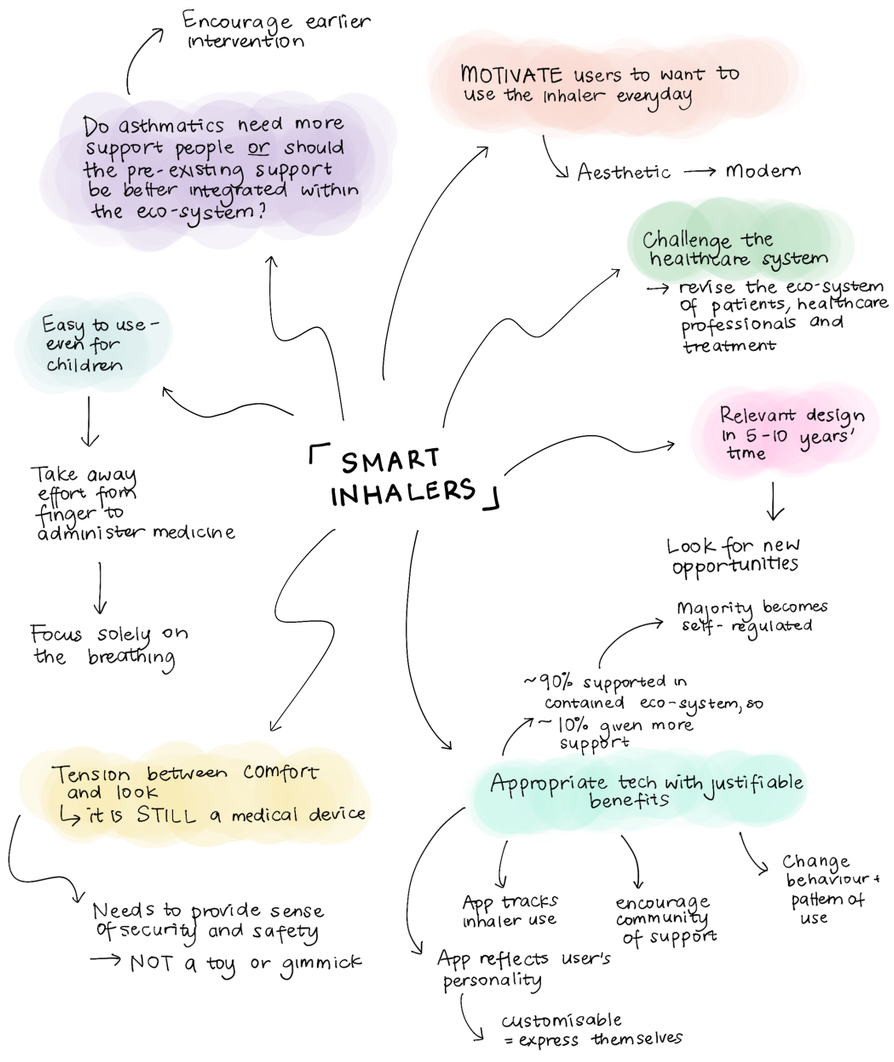


Figure 55 – Visual brainstorm of the potential of smart inhalers as future asthma treatment, and how it differs from other modern concepts.

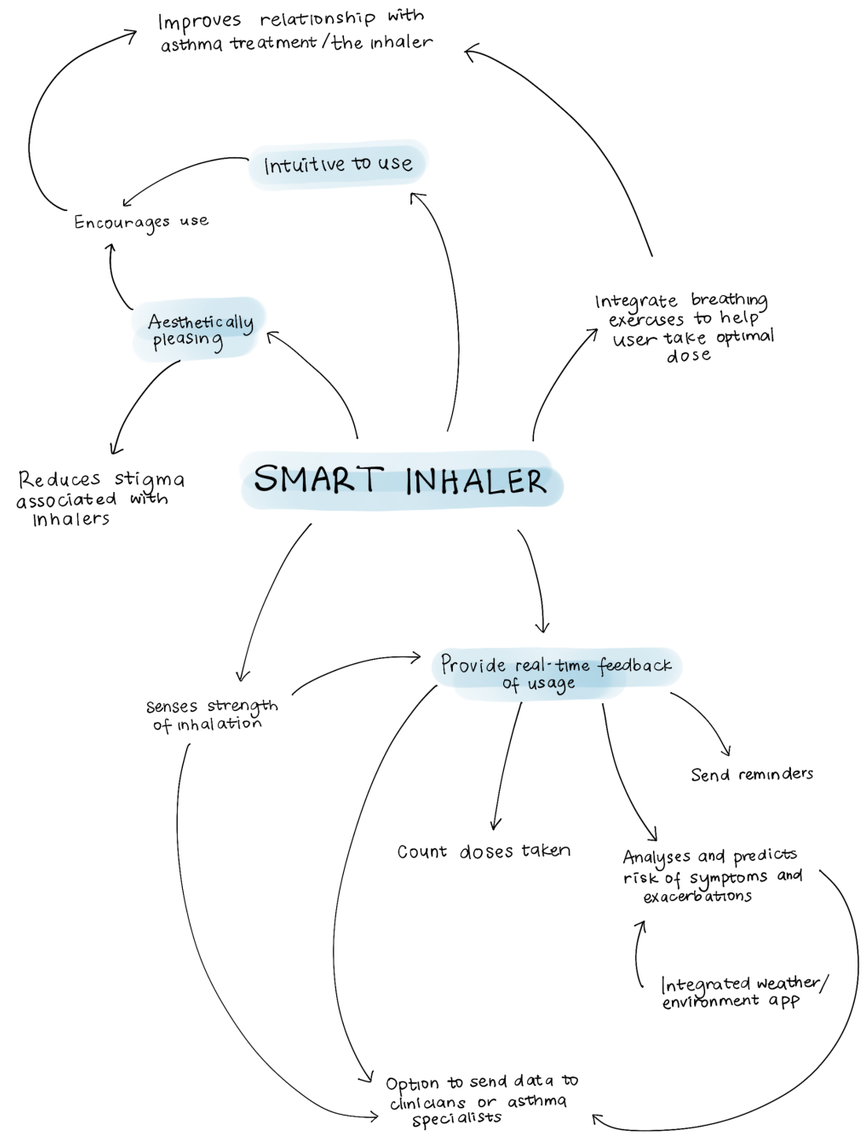


Figure 56 – Proposed eco-system in which my smart inhaler concept will be at the centre, and its three main purposes.

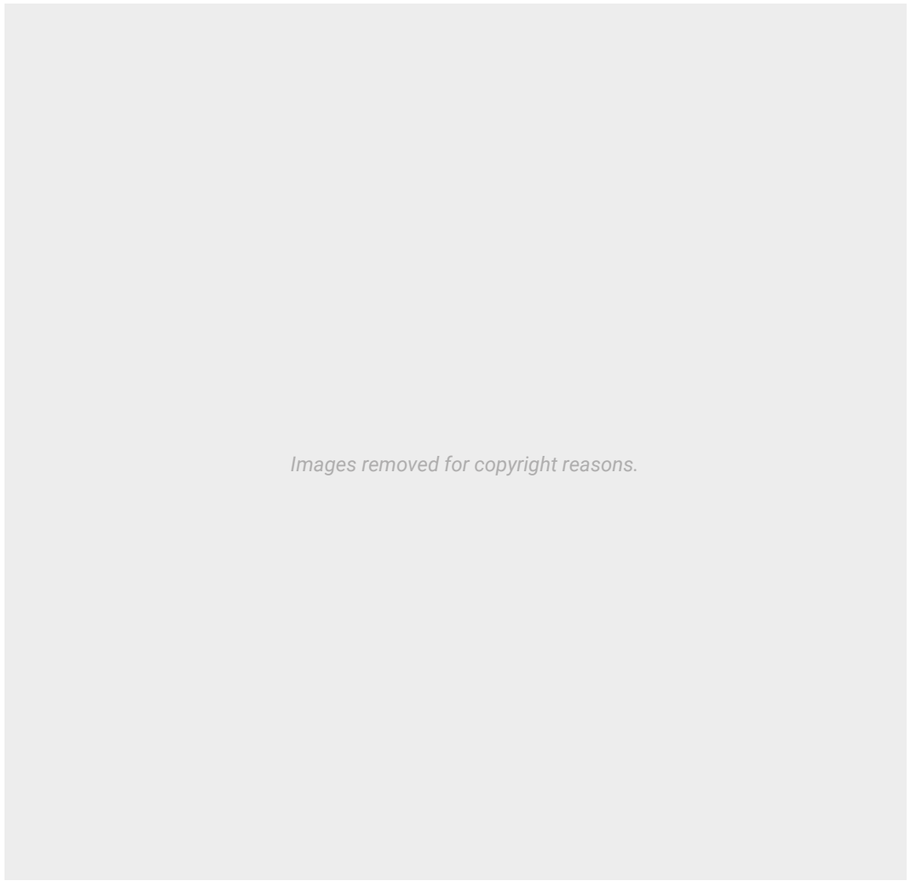


Figure 57 – Adherium sensors for inhalers (Adherium, 2020).

Existing Product Analysis II

From this shift in focus, I decided to analyse existing and conceptual smart technologies that encapsulate potential aims for my smart inhaler.

Smart Sensors – Adherium (2020)

Sensors used to track an individual's health through the device and connected via Bluetooth to a phone application have become increasingly common. New Zealand-based company, Adherium, designed a Bluetooth sensor attachment for inhalers that allowed users to track dosage and provide instant feedback into the mobile application. Research has shown that the Hailie sensors worked well for children and adolescents as the system was easy to operate and required little effort to navigate. Additionally, the data collected could be directed to healthcare professionals to show individualised inhaler techniques, such as the user's administration, inhalation and angle of grip (Makhecha et al., 2020). Unfortunately, this product was unsuccessful in achieving good market penetration and sales through monitoring technology, which demonstrates that the issues of user needs are beyond data acquisition (Venuto, 2019).

The idea of Bluetooth sensors for smart inhalers seemed like a step in the right direction, as more smart sensors for inhalers have emerged since Adherium. Many necessary elements for self-management were integrated into the mobile app, and especially advantageous with the ease of use for even young asthmatics. My concern was the extra cost on top of inhaler prescription costs, and the device attached to existing inhalers resulted in added bulk, as shown in [Fig. 57]. From what I gathered in the clinician interviews and survey responses, people are leaning towards smaller or more discreet devices, so the drawbacks may outweigh the benefits, causing people to be reluctant to purchase Adherium.

Wearable Blood Pressure Monitor Concept

Home Blood Pressure Monitors (HBPM) are crucial in managing hypertension, purposed to recognise the impending or increased risk of cardiovascular events and thereby provide for earlier intervention before symptoms worsen (Kario, 2021). Choi et al. (2020) discuss that when patients can self-measure their blood pressure, they are more likely to adhere and comply with their medication regimen, adjust their lifestyle choices, and become more proactive in understanding their condition. Although there has been increased use of HBPMs over the last 20 years, consistent calibrations are required to maintain precise and reliable blood pressure measurements, and adequate training is needed to ensure patients are competent to obtain accurate results (Kario, 2021). Furthermore, the traditional “cuff” measurement system can cause discomfort for the user, consequently increasing their blood pressure during measurement (Arakawa, 2018).

Bloomfield and Scott (2020) sought to design a hypertension monitor that “encourages blood pressure awareness and positive changes” Prehypertension may develop in the young adult years (Kishi et al., 2015), so Bloomfield and Scott wanted their product to focus on this age group. They aimed to motivate young adults to keep track of their blood pressure and, therefore, can begin to make healthier lifestyle habits if needed as a form of early intervention. The app connected to the wearable device can show the user their blood pressure over time, provide educational information, and space for personalised notes (Bloomfield & Scott, 2020). Lo presented the opportunity to utilise available resources to encourage better health self-management and early intervention.

Images removed for copyright reasons.

Figure 58 – Top: Home blood pressure monitor (Ibrahim, 2018)
Bottom: LO Hypertension monitor and connected app (Bloomfield & Scott, 2020).

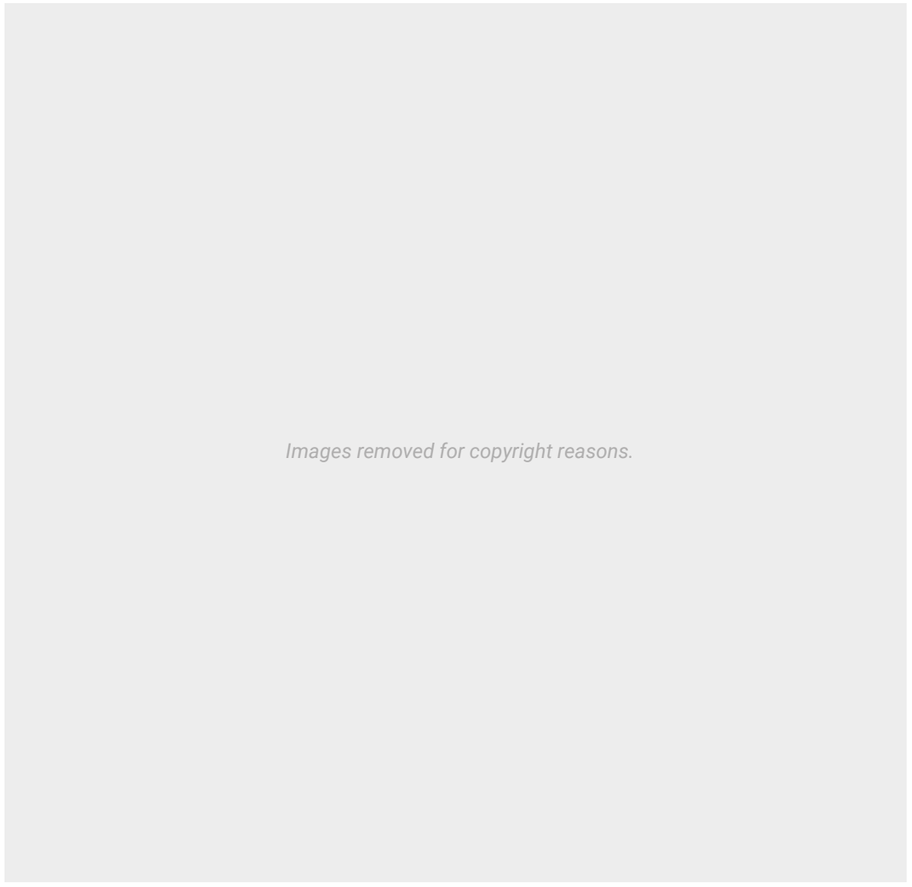


Figure 59 – Aer inhaler (Chowdhury, 2018).

Smart Inhaler Concept – Aer

Chowdhury's (2018) Aer inhaler recognised the stigma associated with MDIs and the poor adherence of asthmatics to their medical routines. He aimed to integrate modern technology to help asthmatics self-manage their asthma. Paired with an aesthetic design, Chowdhury wanted to de-stigmatise inhalers and motivate users to engage with their treatment actively and feel comfortable using them in public.

It was encouraging to come across concept designs such as Aer and know that designers have been trying to tackle some of the primary issues of asthma treatment. Unlike the Flohaler (Plimmer, 2019) and Aria (Aria Therapeutic Vapor Inhaler, 2017) inhaler concept designs [Fig. 31 and 32], Chowdhury saw the opportunity to combine MDIs with technologies that can potentially reduce the risk of worsening symptoms through sensors. With my renewed focus on a smart inhaler, I was inspired by Aer's design development. I took note of possible sensors, app features, and packaging design to improve the user's overall experience with inhalers.

Personas

Persona 1: Healthcare Professional
Name: Melissa Torres
Age: 43
Occupation: General Practitioner

As a GP, Melissa works with a few registered nurses in a medical centre. Since asthma is a relatively common condition, she has diagnosed and worked directly with many patients over several years to help treat and manage their asthma. Though she has demonstrated the inhaler techniques many times to patients, Melissa is unsure whether her patients continued to follow all the steps correctly after the consultation. Many of her patients booked follow-up consultations, explaining that their dosage may need to be increased since their symptoms have not reduced after a few weeks. When asked to demonstrate their techniques and recount their medical regimen to her, she noted that they seemed to be adhering to their routines; however, she knows that people tend to put more effort into their inhaler techniques in front of physicians. With newer inhalers being available in recent years, Melissa has also found it challenging to keep track of the various types and their associated techniques and, unfortunately, does not have the time to learn more. As much as she would love to help patients with more rigorous training to use their inhalers, her consultations are usually limited to 15-30 minutes.

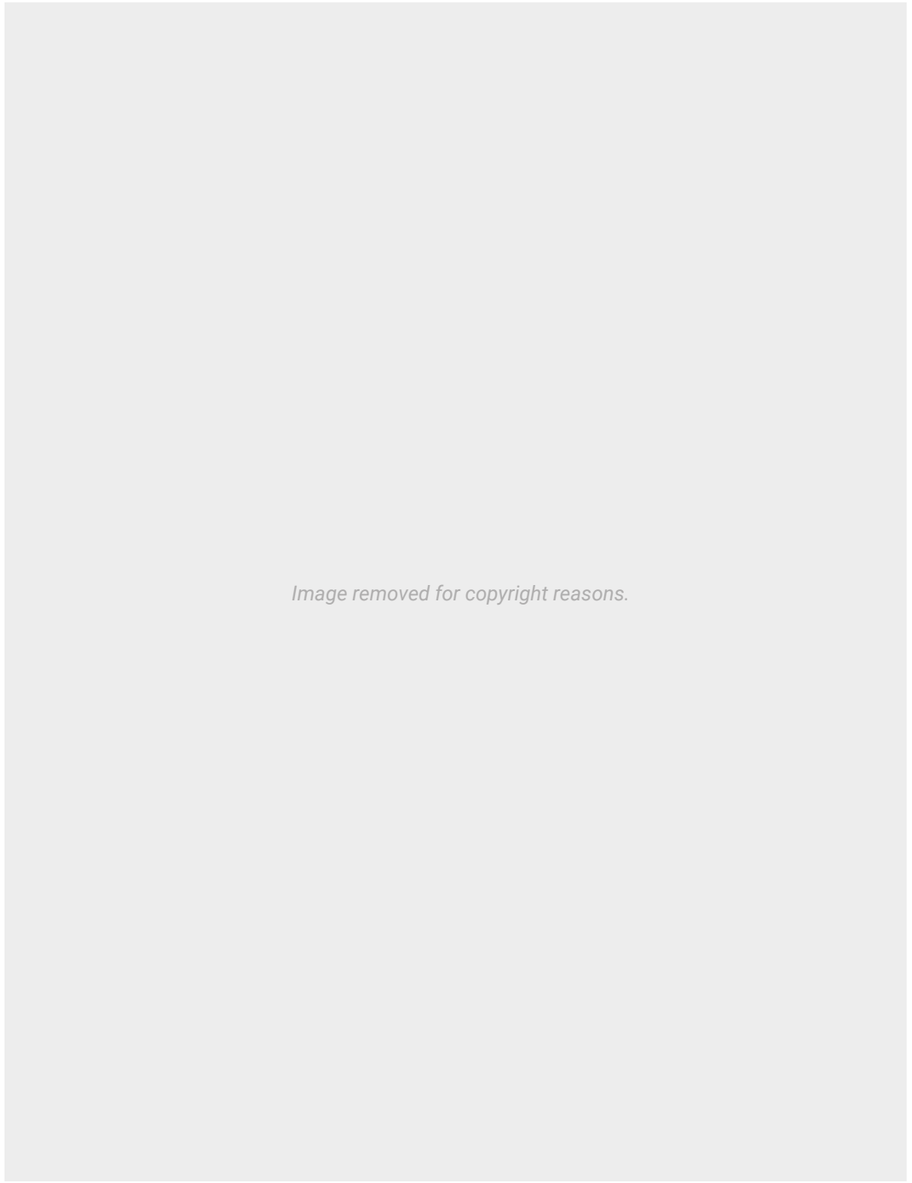


Figure 60 – A healthcare professional persona was constructed through the perspectives of the clinicians interviewed.

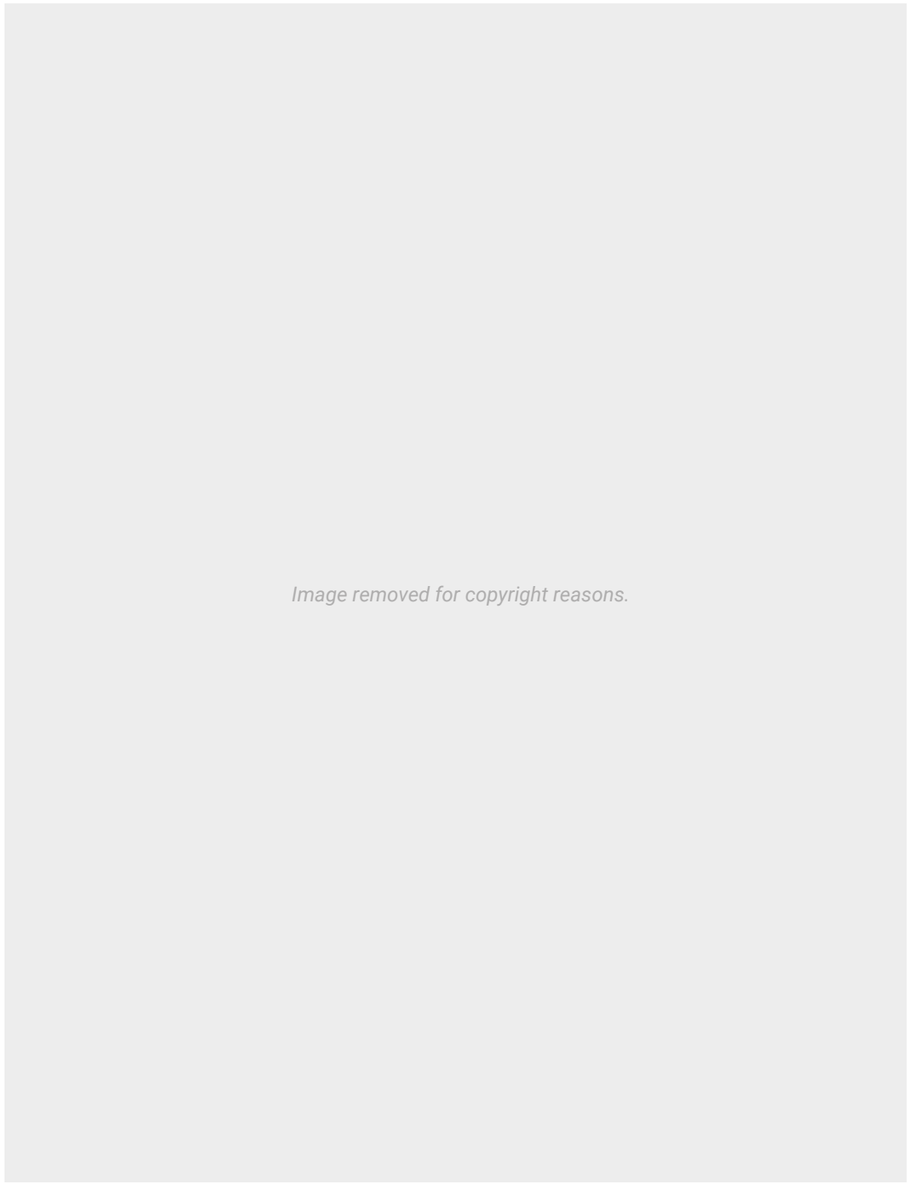


Figure 61 – A young adult asthmatic persona helped me define a character I could reference when developing smart inhaler designs. Her insights were based on the opinions and experiences through the clinicians' anecdotes, survey responses, and participants in the literature reviewed.

Persona 2: Young Adult Asthmatic
Name: Talia Roberts
Age: 20
Occupation: Student

Talia was diagnosed with asthma at six years old, and though she has used an MDI for most of her life, she still feels uncomfortable using one outside. She knew that most of the time, her symptoms were exercise-induced or otherwise triggered by the climate changes. Talia recalled being admitted to the hospital when she was younger, having suffered from asthma exacerbations, where she was advised to use both her preventer and reliever inhalers with a spacer to allow more medication to reach her lungs.

She loves socialising with her friends in her leisure time, but being cautious about her symptoms flaring up, she must always keep a reliever inhaler in her bag. Even though she knew that a spacer would increase her medicine intake, Talia preferred to carry around the inhaler by itself because the spacer was too awkward and large to always have on person, let alone to use in public.

Admittedly, she had forgotten to use her preventer inhaler many times, only starting her routine use again when she began to feel that her symptoms were worsening. As her asthma became milder when she got older, the Turbuhaler was recommended to her, which removed the need for two inhalers. She appreciated the more discrete design, comfortable mouthpiece, and requiring to turn the base to dispense her medication. Overall, she found the Turbuhaler much easier to administer but was still frustrated at how the base could be turned both ways and how she had to inhale a lot stronger than with her old MDI.

Even though Talia is more comfortable using a Turbuhaler, she still prefers to excuse herself to use her inhaler in the bathroom if needed, avoiding looks of concern or curiosity from her peers. She has also noticed that she had to throw away many inhalers that were not empty, since she does not regularly use her inhaler and felt this was a waste.

Final Design Brief

Smart Inhaler and Reimagining of Asthma Management Eco-System

My smart inhaler design aims to be in the centre of a new eco-system, motivating people to use their inhalers more routinely. Three sensors were considered for the device. The first was a pressure sensor integrated through the button. This senses when the user has pushed the button, and dispenses the medication. The second sensor in the device was connected to an app through Bluetooth that can also remind users to take their medication at a set time every day. By tracking usage, users may be alerted to overuse or underuse, with an option to contact their doctor or an asthma specialist. This serves as a form of more appropriate intervention, so asthmatics will not have to experience severe symptoms before seeking help. The third sensor is an airflow sensor that can measure inhalation rate, thereby determining the state of the user's airway health. The app may also include a moderated community forum to allow asthmatics to build a support community. The technology aspect aims to provide feedback to the system while encouraging users to be more active and self-manage their treatment.

In line with the wellness approach, I considered incorporating small LED lights to remind users to exhale all their breath before inhaling, where the lights show the direction of breathing. Additionally, breathing exercises may also be integrated into the device. Studies have shown that taking time to include breathing exercises at the start of the day can improve one's mental health (Cho et al., 2016; Seppälä et al., 2020). I wanted these simple exercises to help asthmatics train their breathing and enable them to inhale their medication better.

Form
- Discrete
- Aesthetically pleasing (desirable to use for all ages)

Function
- Able to administer medication with one hand

Ergonomics
- Intuitive
- Comfortable to hold
- Pocketable
- Fit against different hand sizes
- Sustainable design (able to be reused or refilled)

Cost
- Minimal production cost (excluding sensors)

PHASE III: Developing Toward the Final Outcomes

Ideation IV

Blue Foam Exploration

Based on the form exploration, I refined the ellipsoid and stone shapes using blue foam to take note of the curves, edges, grip, and interaction with the models. I simulated how the product may be handled, carried around, and where the cap may be removed. Having these more fixed forms allowed me to further refine the dimensions and thickness of the model before planning the arrangement of the other components of the smart inhaler, such as the buttons, cap, mouthpiece, breathing lights, and dose counter.

Figure 62 – Prototype one: this was the most "geometric" shape of the six prototypes, resembling most like a rectangular ellipsoid. It did feel stable in hand and easy to pocket, but due to its symmetric form, the user would not be able to recognise where to place their hand around the device instantly.

Figure 63 – Prototype two: I attempted to test a form with the pointed end as the bottom of the device. I realised it did not feel as comfortable as the other way around, although the slight outward curve for the back of the device made it feel more intuitive to know how it should be held. The pointed end at the bottom may confuse users, as it looked more natural for the point to be at the top of the device.

Figure 64 – Prototype three: the smaller size made this prototype easy to grip. In contrast to Prototype 2, the shape made it intuitive for the user to know where the top and bottom of the device would be. The slightly larger width at the bottom made it more secure in the palm of my hand.

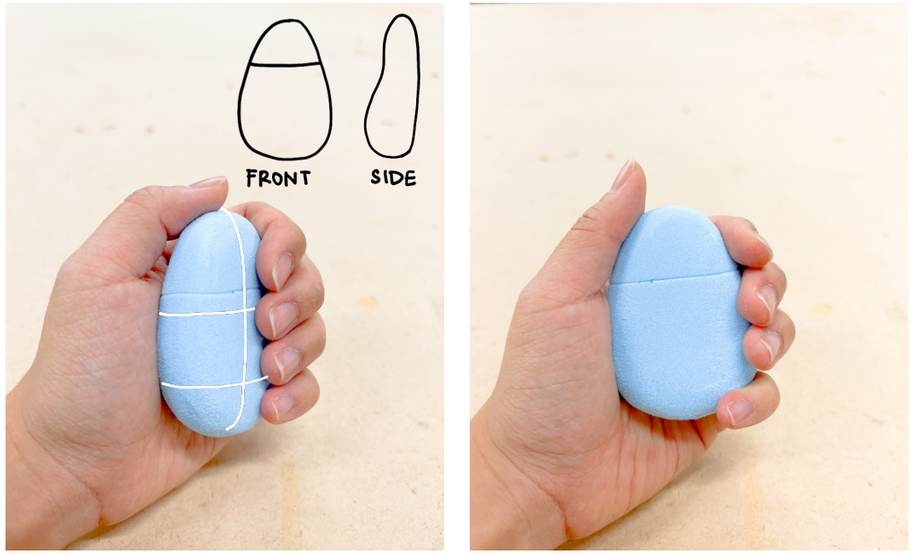


Figure 65 – Prototype four: this was the smallest prototype, making it easy to fit into a pocket and carry around. However, this size also meant it was more likely to slide out of the hand, especially for larger-sized hands. The curved back suggested following the curvature of the palm, so it was natural to pick up and rest the device against the hand.

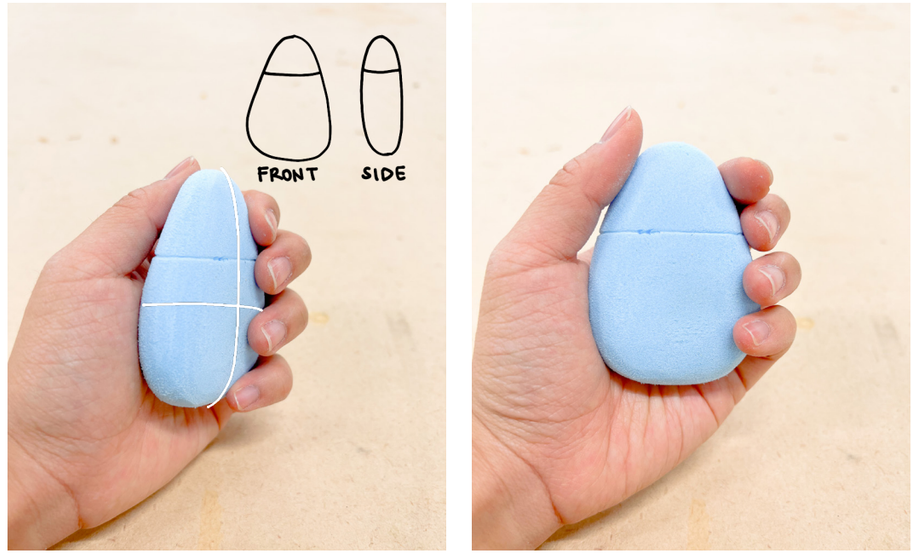


Figure 66 – Prototype five: I explored a slightly thinner width for this prototype compared to the others, so it would fit more easily in a pocket. The form remained stable to hold, however the downside was that sensors and other electronic components may need more space in the device's body. The straighter front and back also took away from an organic feel.

Figure 67 – Prototype six: I experimented with a slightly larger size and found it was more difficult to fit and carry around in a pocket. It was comfortable to grip, but from this I had to reconsider the size of the refined concept and find a balance.

Evaluation I

Using an evaluation matrix, I ranked the concepts from 1-10 against the listed criteria in the final design brief. The 'able to administer medication with one hand' criterion was not included as the button feature would ensure minimal effort from the user. 'Production cost' took into account the potential cost to design and manufacture the shapes; the more organic forms would result in higher costs.These prototypes confirmed how the shape of the product can indicate the direction it should be held. Concepts 1, 3, and 4 were most successful. These forms were used as the body of the device on which the other elements (cap, mouthpiece, button, and colour) were tested.

Discrete	7	5	7	6	7	7
Aesthetically pleasing	7	6	8	8	7	5
Intuitive	6	5	7	7	8	6
Comfortable to hold	7	7	8	7	6	6
Pocketable	8	7	7	8	7	6
Fit against different hand sizes	7	6	8	6	6	6
Production cost	7	6	6	6	5	6
	49	41	51	48	46	42

Figure 68 - Inhaler body form evaluation matrix.

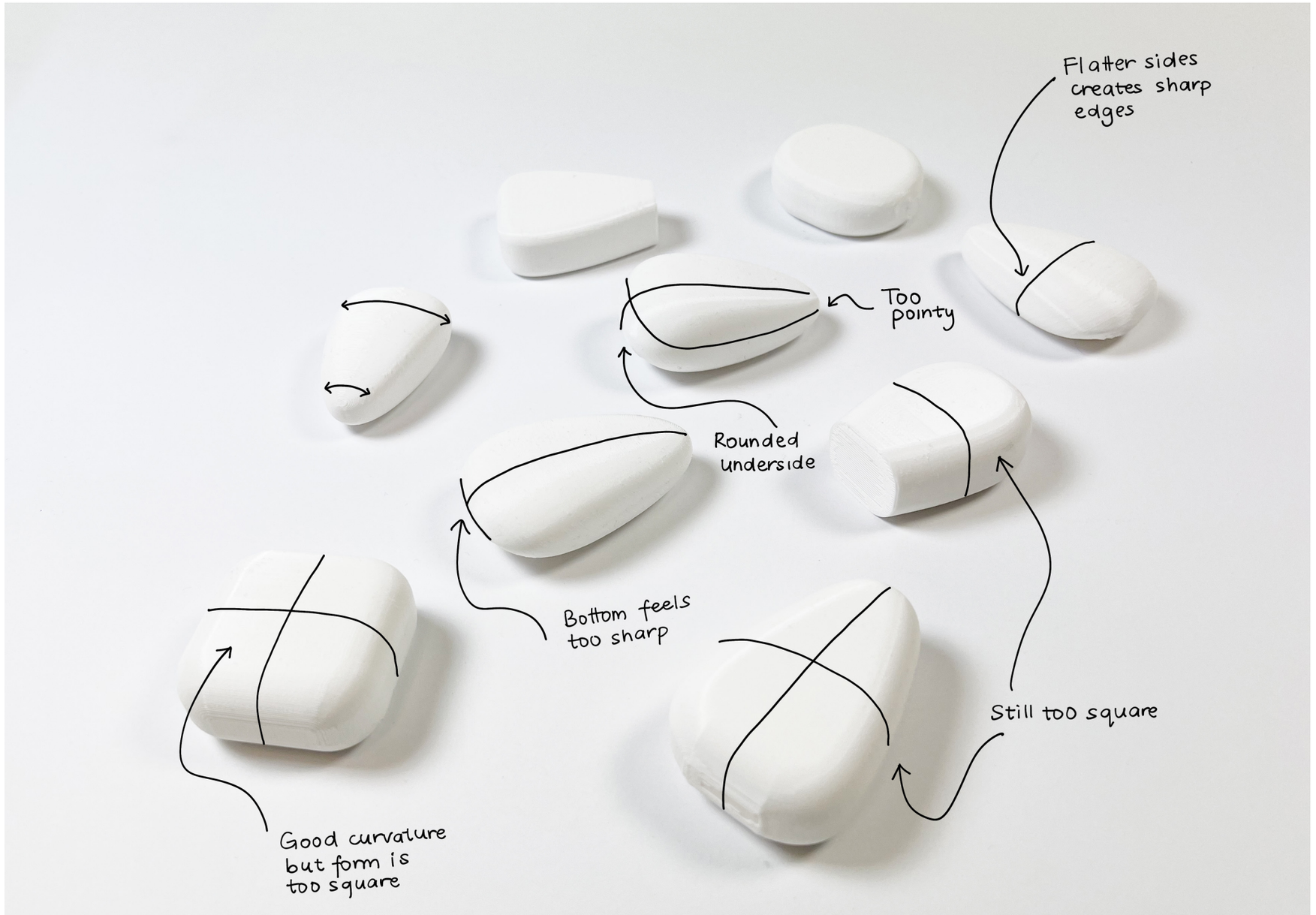


Figure 69 - Having narrowed it down to three forms, I decided to create higher-fidelity prototypes by creating CAD models experimenting with varying curvatures. For example, with prototype three, the width was larger towards the bottom. However, it was determined that a large difference in width from top to bottom made it feel like I was holding a ball and looked too playful. The weight of the 3D prints was heavier than the foam models, so holding these forms gave me a more realistic sense of them as real electronic devices.

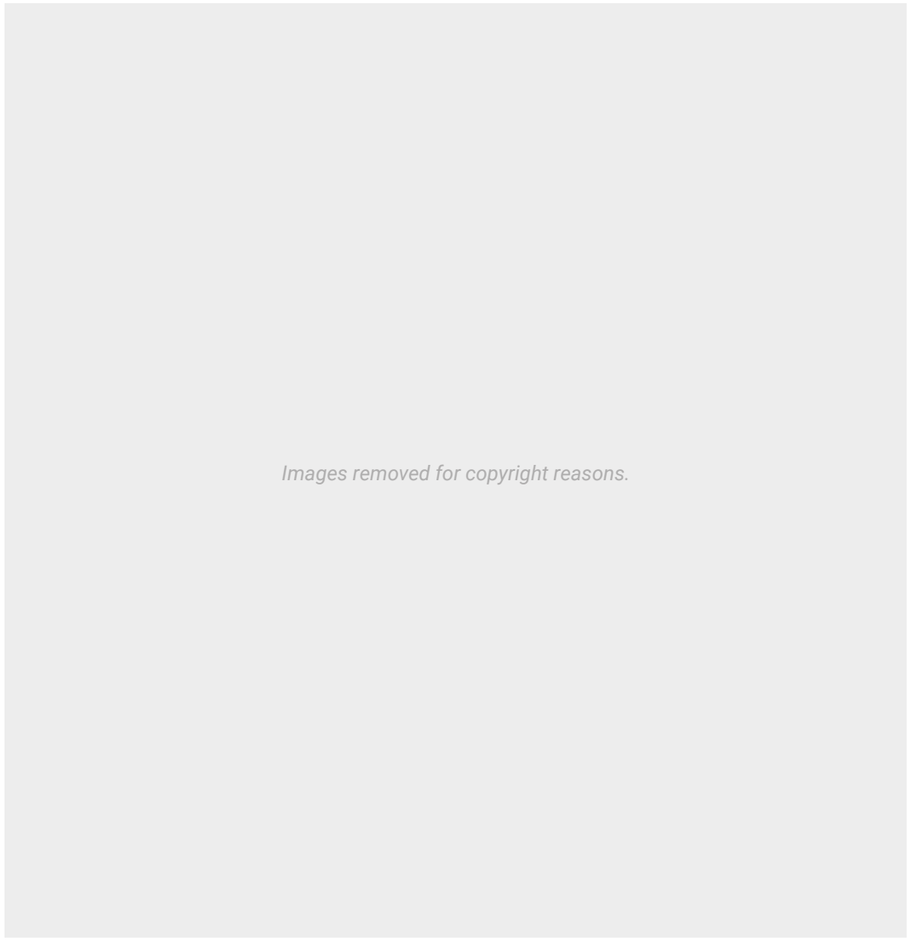


Figure 70 – Examples of products that require a cap to be removed before use.

Cap Component

The cap component of the inhaler was mentioned numerous times by survey respondents regarding the MDI. The comments were primarily complaints about how easy the cap falls off, causing dust to accumulate around the mouthpiece. I chose to keep the cap component for hygienic reasons. One of the clinicians described a patient struggling to open the Turbuhaler cap (since it covers the entire device) and decided to drill a hole at the top of the cap to access the mouthpiece. From analysing the Turbuhaler, the cap did not seem to have an intuitive design, as there was no indication on how to open the cap. Its cap is meant to be screwed on, but compared to other caps that require a screwing motion to open or close (such as jars), the cap is usually positioned at the top and does not cover the entire product. With a cap entirely concealing the device, my initial response was to “pop-off” the cap instead of screwing it off. This may also have been the case for the patient who was confused with the Turbuhaler. An unintuitive design would result in inconvenience, which would not be ideal for a device that may need to be used during a stressful asthma exacerbation.

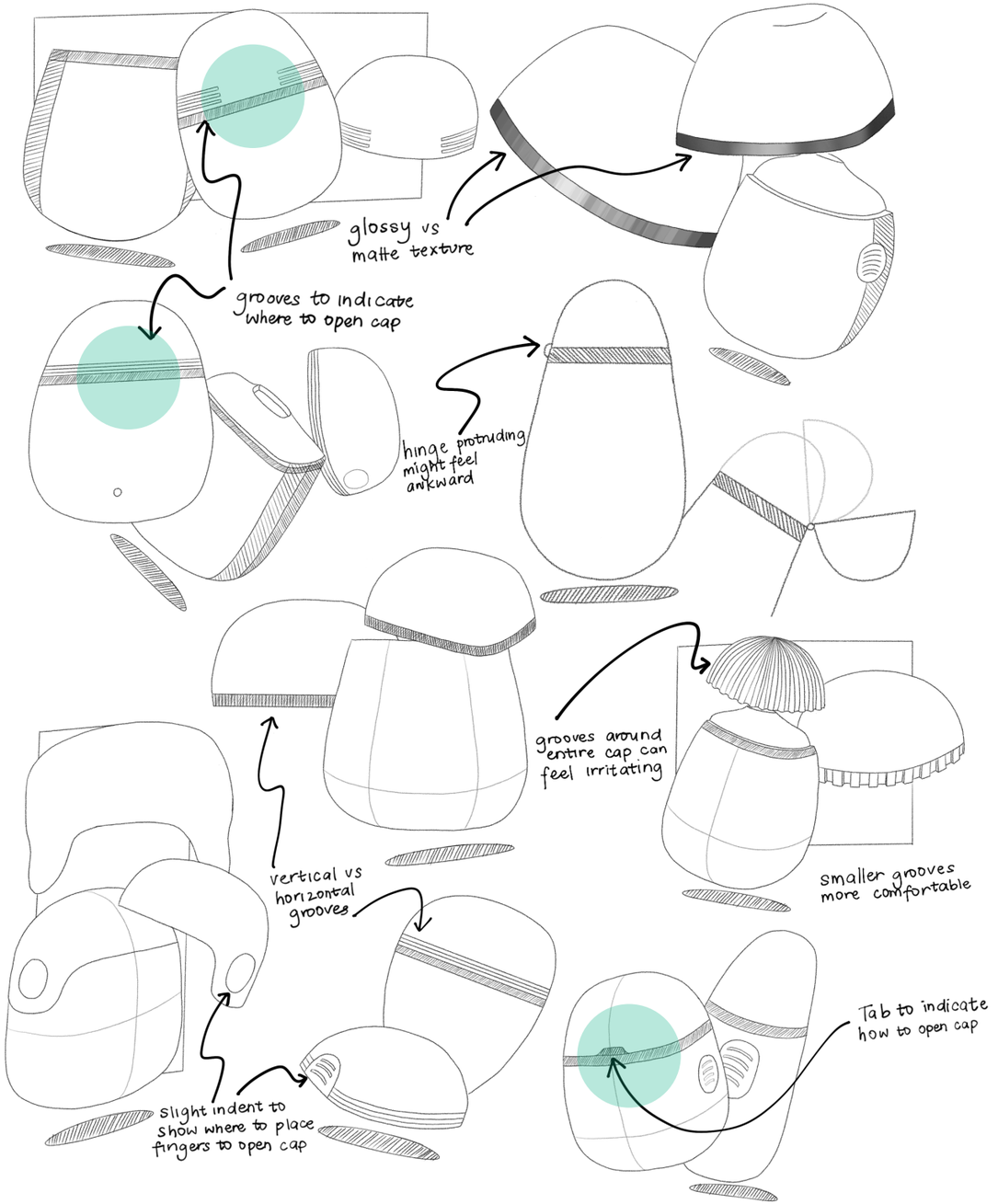


Figure 71 – These sketches explored the possibilities of taking the cap off more intuitively, and I highlighted the options I decided to develop further. These included ridges, hinges, magnetic attachments, grooves, and different textures separating the cap from the device's body. The chosen elements were highlighted. I decided to incorporate a magnetic attachment at the bottom of the cap so people with movement disabilities (e.g. arthritis) who find it challenging to open lids with their fingers can use their palm instead. The cap will be completely detachable, as I found that an attached lid may feel intrusive during use.

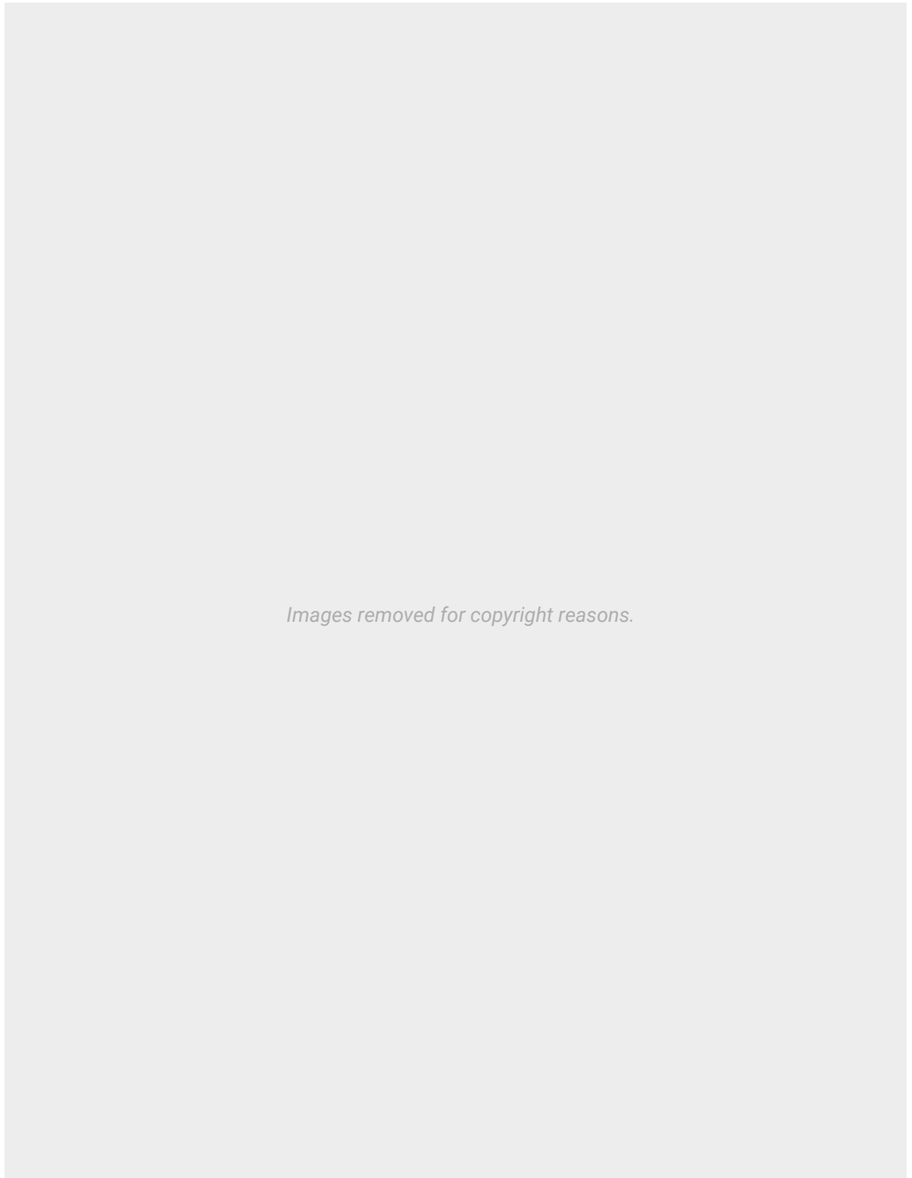


Figure 72 – Examples of button placement with varying textures, sizes, raises/indents and shapes.

Button Feature

I kept in mind that the size I personally considered comfortable to hold in one hand would not be the case for different sized hands. With a button, I felt that it should serve as a signifier without standing out too much from the rest of the device. The examples showed how buttons could be discrete, blending well with the device's overall aesthetic. In this exploration, I did not look into colour yet, and instead focused more on the physical interactive features such as its size, texture, shape, and placement.

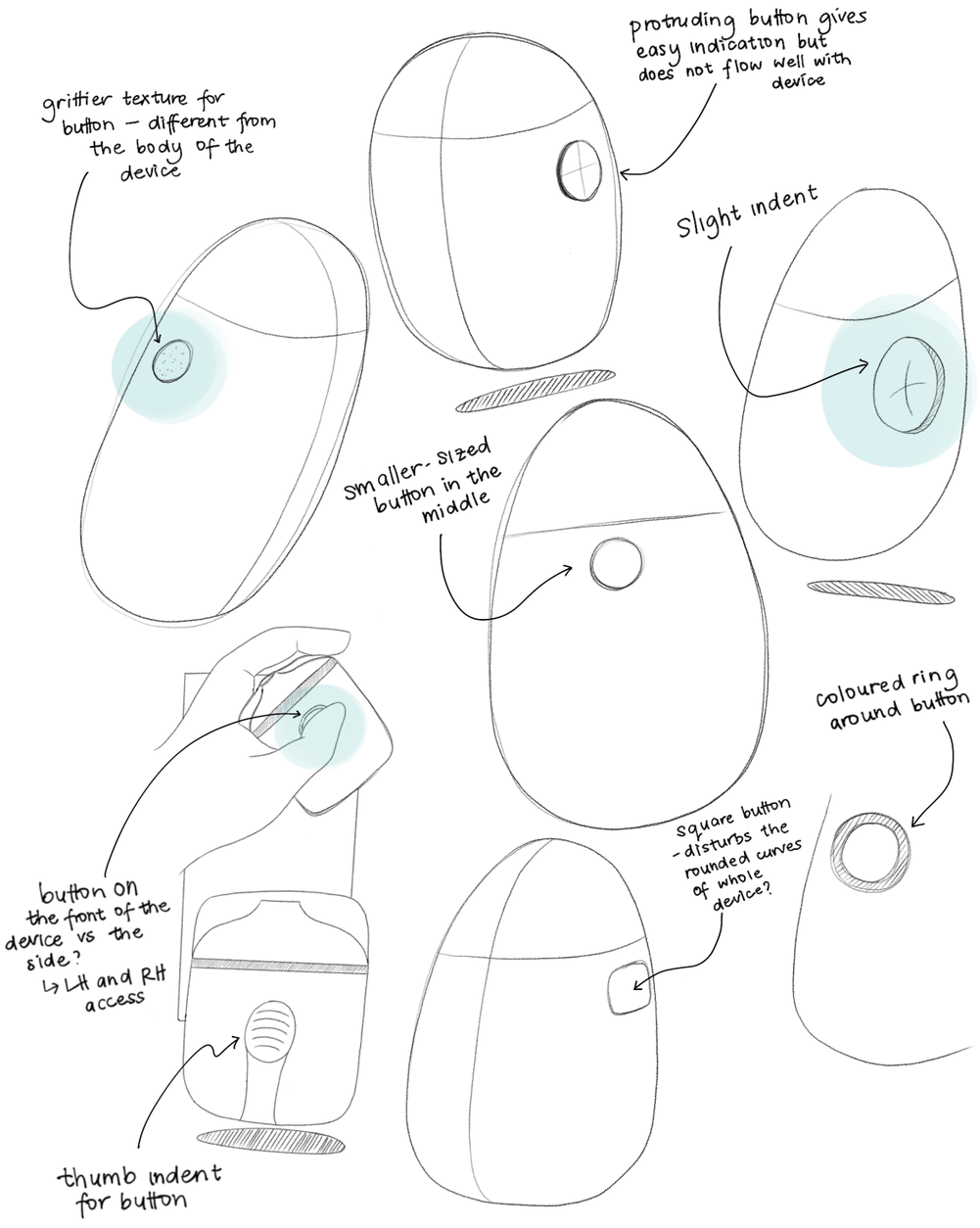


Figure 73 - From these sketches, it seemed that buttons that protrude too much did not look aesthetically pleasing compared to buttons that are flush against the device's wall. Designing a slight indent for a button may also provide better indication to the user about where to place their finger to administer the medicine. Like the cap design exploration, I considered how texture may influence the instinctive interaction between the user and the device. The selected concepts for development were highlighted. I felt that the button having a different grit texture compared to the body of the device and would not be completely flush as to make it easier to see its location.

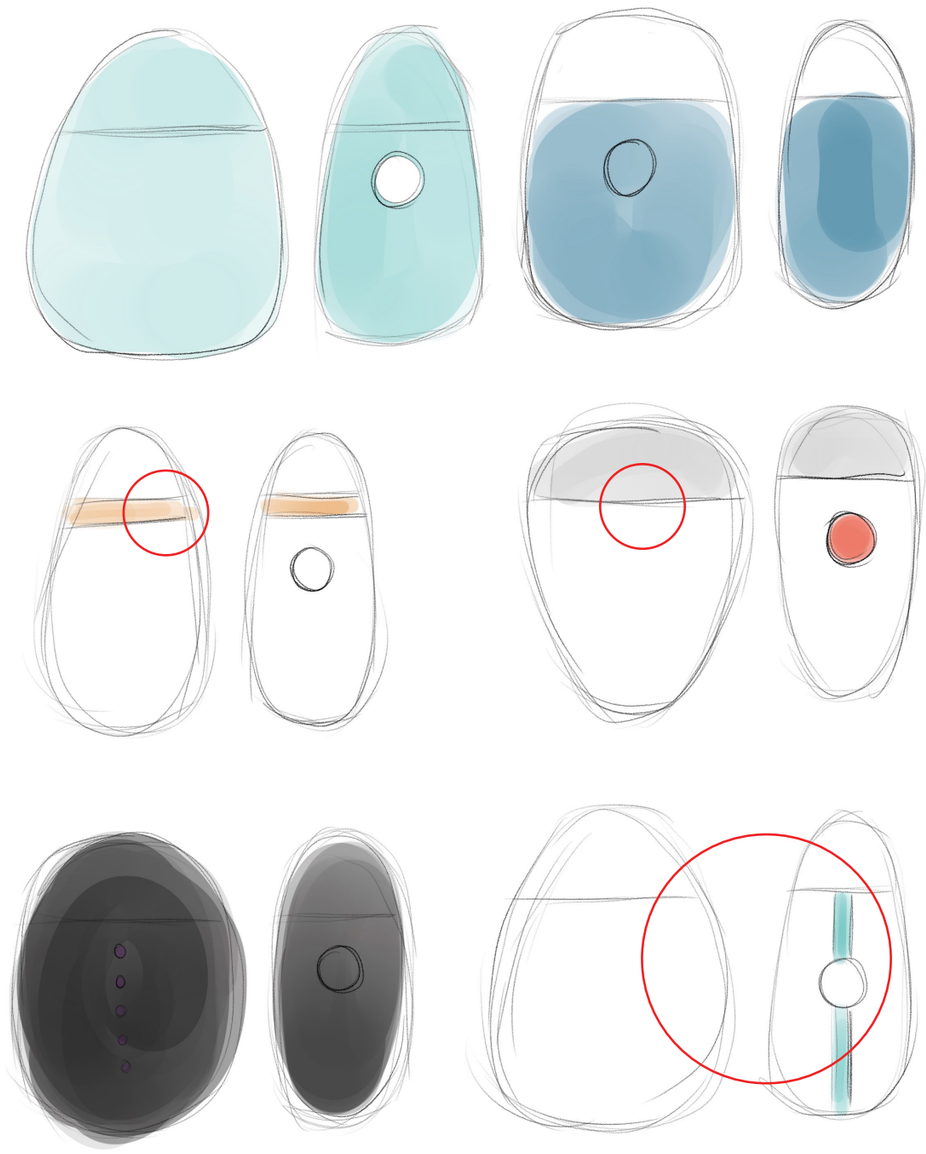


Figure 74 – Sketches of colour placement for the body of the device.

Colour

Colour is a large factor in how people initially perceive and interact with products (Singh, 2006). The past and current inhalers had colours associated with the medicine type, so I wanted my designs to account for this to avoid confusing future users. Additionally, I felt that a medical device's minimal distinguishing feature(s) from consumer devices could be related to colour, so I decided to explore using white as a base colour. I contemplated having the base colour as the medication colour but decided that white would be the most neutral and relatively discreet. The highlighted concepts were the ones selected to be incorporated in further developments. However, there is also potential for user choice with various colour palettes or customisation with further research and input from asthmatics.

Breathing Guide Lights Feature

I had not come across the idea of existing lights that guide the direction of breathing. Many of the examples found were indications of battery charging or for the purpose of illumination. Since this seemed like a new concept, I decided to keep it as simple as possible.

Images removed for copyright reasons.

Figure 75 - Examples of lights on electronic devices.

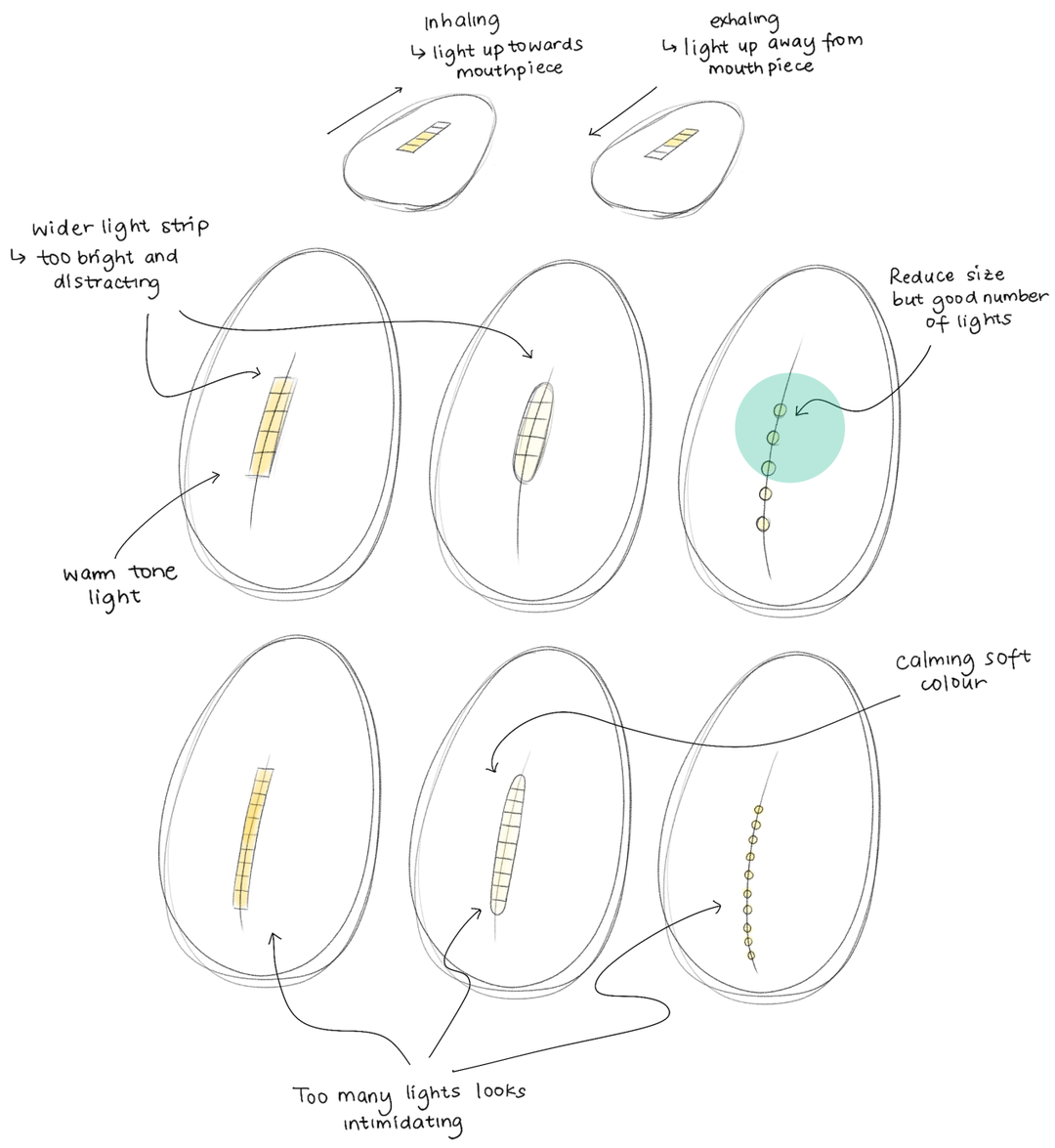


Figure 76 – Most light features I observed were circular. I tried to experiment with a rectangular strip of light, but I felt that keeping the circular shape would work better with the rest of the device's aesthetics. As to not overwhelm the user, it seemed that five lights would be a reasonable number. Less than five may make it difficult to show the direction of breathing through the lights, while more than five made the device seem rather antagonising.

Refined Mechanics

By experimenting with possible mechanics of the medication dispensing system activated by a button, I narrowed it down to two possible variations. The first was inspired by the Easyhaler and Turbuhaler mechanics but worked with a one-way ratchet that allowed the user to push the button once to rotate the dispensed powder to the mouthpiece tube where it would be inhaled. The second mechanism was more straightforward and allowed the medication to be dispensed horizontally. From the advice provided by my supervision team, the second mechanism could be integrated electronically, and a solenoid could achieve linear action.

As part of the final outcomes, I intend to 3D print the components separately for further testing and will create a cross-section model to take high-speed videos showing how it could possibly work.

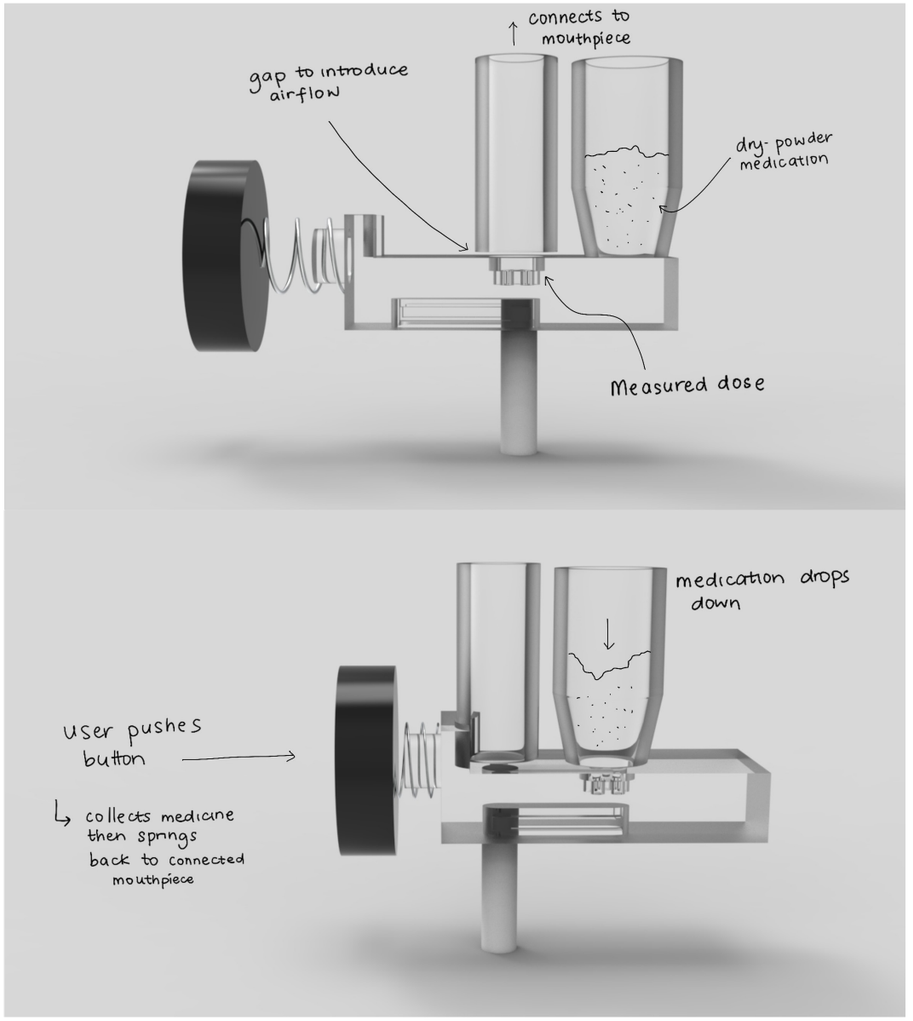


Figure 77 – Inner mechanics concept one. This mechanism followed a linear horizontal motion, where the user is only required to press the button to dispense the dry powder medication.

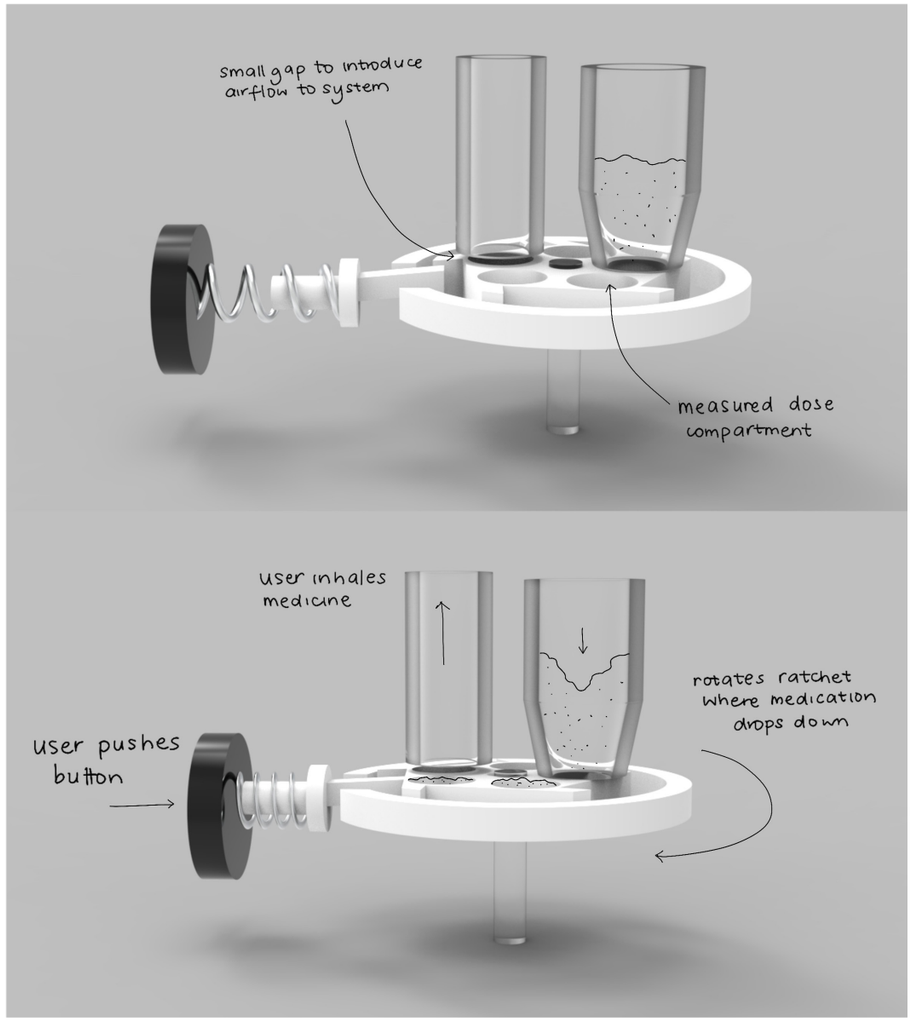


Figure 78 - Inner mechanics concept two. I took inspiration from the Turbuhaler's design, but with the use of a button instead of a base to turn. This way, the user will not be confused about the direction to turn. Although this mechanism followed a horizontal motion, the rotational component would make it more difficult to implement electronic components.

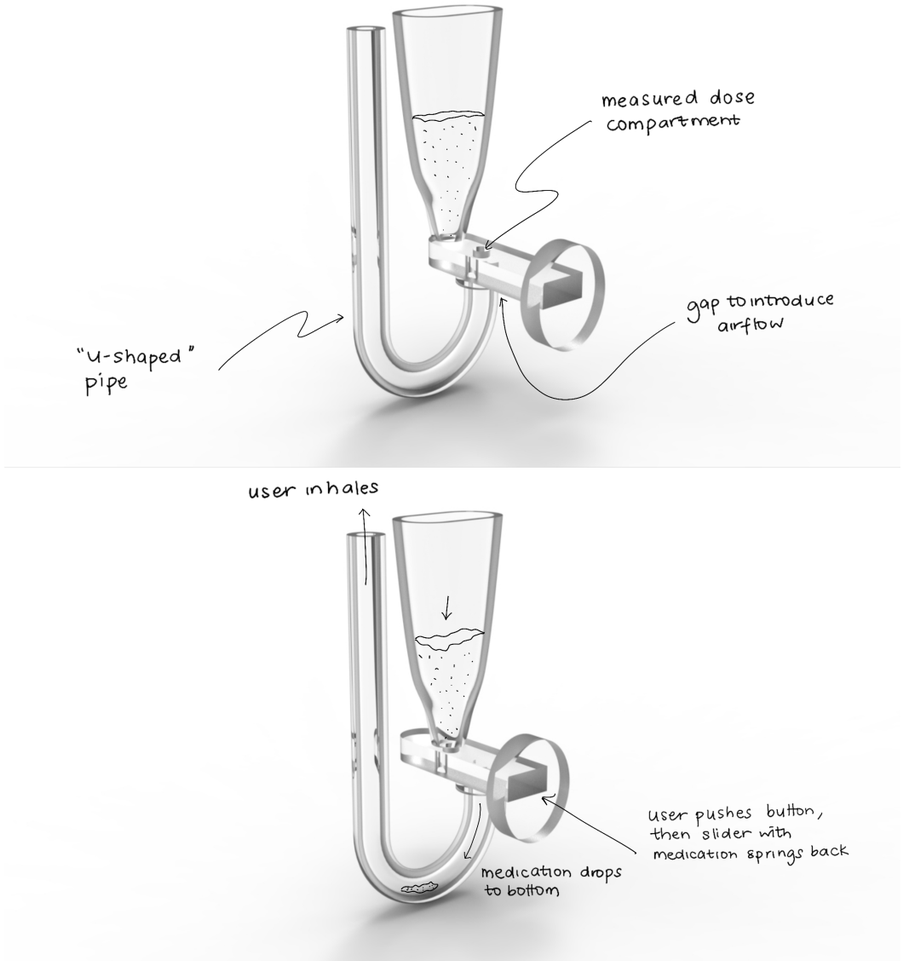


Figure 79 - Inner mechanics concept three. This concept was similar to the first with a simple horizontal motion to dispense the medicine. It used a U-pipe as the dose drops to the bottom, and the user can easily inhale.

Images removed for copyright reasons.

Figure 80 - Overall aesthetic mood board: a final mood board was put together to explore various materials, finishes, and textures for the different components of the inhaler. The core focus was to determine what the overall aesthetic of the smart inhaler could be like, with the intention of wanting the design to portray calmness, serenity, and relief.

Critique

Expert Critique

Before further refining the concepts, I sought critique from Asthma NZ clinicians about my idea of a smart inhaler. I planned to ask for feedback from clinicians earlier, but due to the COVID situation in New Zealand putting tremendous pressure on the healthcare system, I managed to only continue with interviews at this point in my project. I had been nervous about pitching the idea to the clinicians since they were relatively hesitant about smart technology, as I gathered from the initial interviews. Unfortunately, I was unable to recruit young adult asthmatics to provide feedback on my refined concepts.

Cost Concerns

As expected, the cost was the leading cause of concern. Smart inhalers would be significantly more expensive than current inhalers. I outlined a brief plan for a subsidy scheme to the clinician, explaining that increasing self-management can potentially reduce the risk of asthma-related hospital admissions. Regarding resources, the clinician described that the changes in the New Zealand healthcare system within the next few years may mean that Asthma NZ might not receive funding, and it is uncertain what the funding distributions will be.

There were no issues regarding the production of inhalers, but as mentioned in the survey responses and initial clinician interviews, the lack of recyclability was a significant concern. Currently, all MDIs and DPIs are disposed of after use, which is even more wasteful if the medication is past the expiry date and was only partially used. Having taken inspiration from the newer Respimat SMIs, the canister is replaceable, so the body of the inhaler only requires cleaning for future use. A refillable device would mean that people are not required to purchase a new device for each prescription renewal, potentially accounting for part of the cost that people would typically spend for inhalers in at least one year.

Dry-Powder

One of the other concerns was the dry-powder formulation. As previously discussed, the lactose carrier ingredient means that people who are lactose intolerant or have diabetes would not be able to take this form of medication. I explained that once I had settled on designing a smart inhaler, I was initially interested in experimenting with the soft-mist mechanics as the medication is easier to inhale through its device. With an SMI mechanism, the device may function like a vape, where the user can take a slower breath in at their own time. However, given the timeframe, limited resources, and the design scope of the project, I chose to pursue the DPI mechanics. For further research, a more extensive study could be done to explore the potential of semi-automating an SMI, where the user requires minimal instructions and effort to administer the medication.

Mindfulness

One insight I was surprised about was how mindfulness and self-care should be positioned as breathing exercises incorporated in the device and app itself. The clinician believed that it could sound like a trap for asthmatics, as they may see that the exercises through the use of the inhaler is meant to help reduce anxiety and thus reduce their risk of asthma symptoms. However, they would feel undermined if they thought that anxiety was connected to asthma. However, when asthma symptoms flare up, it is because asthma is a physical condition rather than a psychological condition. Mindfulness would need to be worded differently if I explore this direction further. I felt it would be best to not include the exercises in the inhaler to avoid creating issues and wrongfully correlating anxiety with asthma symptoms. However, I decided to keep the breathing guide lights feature in the inhaler, which would remind users to exhale as much breath as to increase how much medication is then inhaled. The app could potentially have a section to teach users good inhaling techniques. This would allow users to build their inhalation practices by personal choice (and physician recommendation).

Design

Overall, the clinician was positive toward my smart inhaler concepts. They commented that the white colour of the body of the device would be easy to locate and was identifiable as a medical device. The refillable aspect was well-received, as different medications can be placed inside. Not everyone can take the combination medication, and some require separate preventer and reliever medication or change medications over time, so it would be helpful to have a single device where vials of medicine can be interchanged. The colour associated with the medicine was helpful to be included in the design. It was suggested that the coloured band around the device would also be interchangeable, depending on the individual's medication.

AUT X-Challenge

During this part of the project, I entered my smart inhaler idea to the first stage of the AUT X-Challenge, and was short listed to proceed to the second round. Although the feedback from judges cannot be included in this research due to ethical considerations, I was pleased with their comments and excitement for how I would continue developing my idea. Since the entry had limited characters to explain my concept, I was challenged to keep my description concise, but with enough detail to convince the judges that this was a promising idea. When writing this document, the competition was underway and no further results were announced.

Further Refinement

Components and Features Combined

Upon development from the foam explorations, sketches, and moodboards, I created CAD models of more refined concepts that combined all the highlighted and circled features. Although my target audience for participants had been between 16-25 years of age, asthma affects all ages, so I kept the features in mind that could be suitable and attractive to as many people as possible. For this reason, I also considered the maximum size of the inhaler to be 80x60x30mm based on the relative dimensions across all current inhalers. All concepts had a magnetic attachment for the cap to the body of the device. Dose counters were purposely placed on the side, as the battery would likely fit at the back or underside of the device. The breathing guide lights were tested for front and side placement, and both positioning was able to be seen by the user.

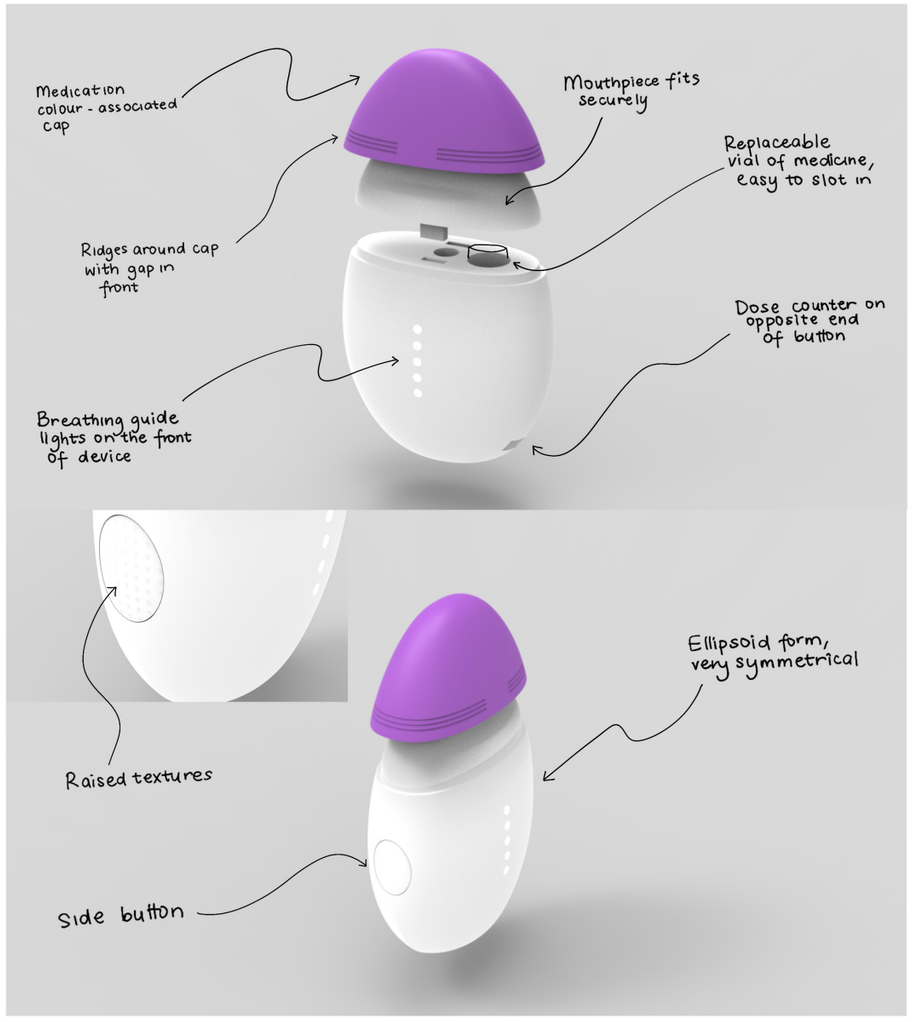


Figure 81 – Refined concept one. This first concept was the simplest form that was relatively symmetrical. The coloured cap makes it easier for the user to know what medication is inside; however, it could not be interchangeable between medications. A side button was natural to press (like on phones), but the shape made it awkward to grip with this placement. A different texture for the button can allow the user to feel this point of interaction. I noticed that the lights on the front could be obstructed by the hand during use, rendering them useless. Including ridges around the side of the cap with a gap in the front meant the user could understand having to use a pinching motion to open the cap. The coloured cap did not flow well with the rest of the device.

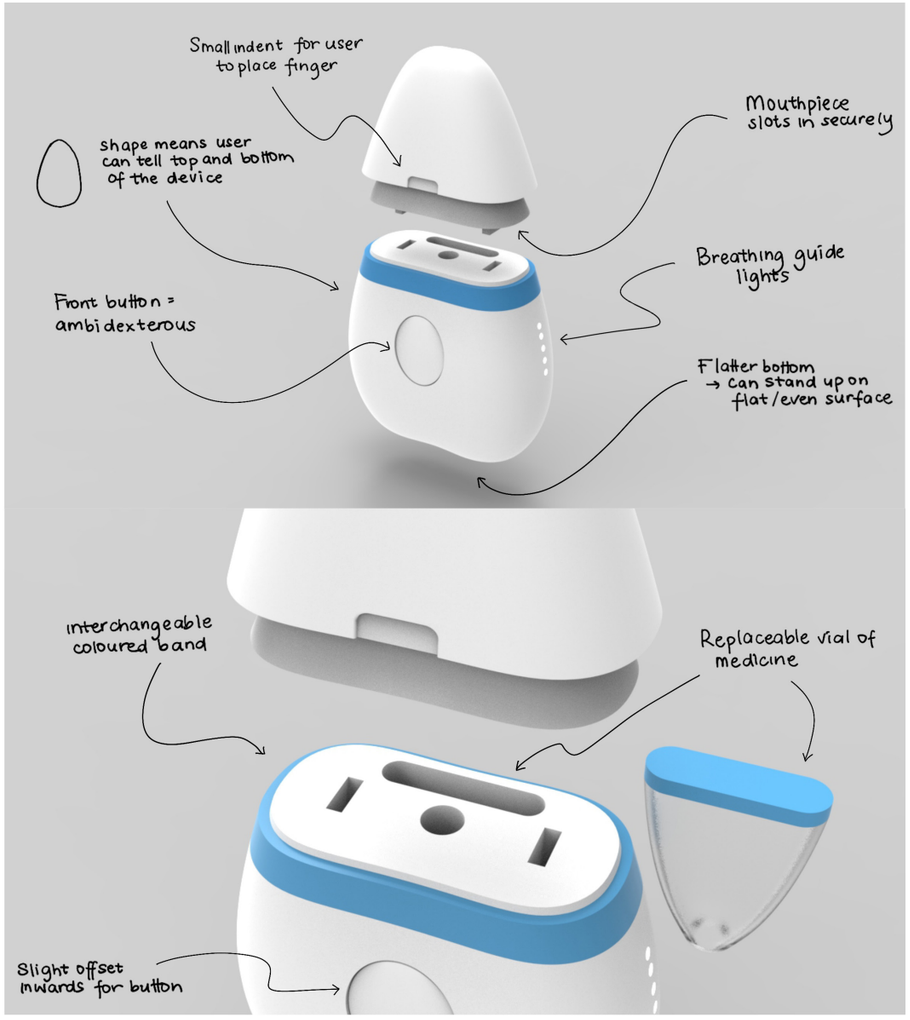


Figure 82 – Refined concept two. The second concept felt more ergonomic than the first as the shape is not symmetrical all around. Users can immediately understand where to place their hand around the device even when it is not in sight (i.e. inside the pocket). A front button means it can accommodate for ambidexterity. The slight offset allows the user to instinctively place their finger on it without having a different texture. Instead of ridges around the cap, I carved out an indent at the front, which I felt was a minimal but practical signifier for opening. A flatter underside allowed the device to stand up on an even surface, but I noted it may not be necessary and could even reduce its comfort when held.

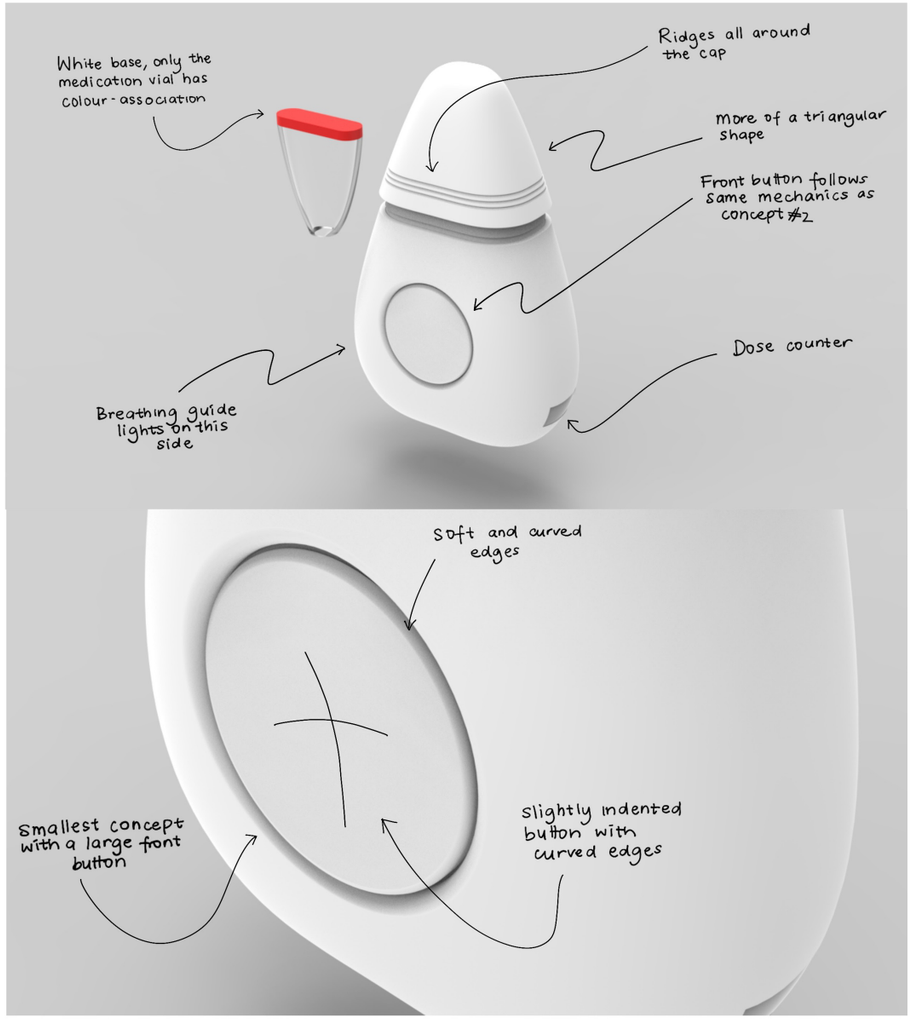
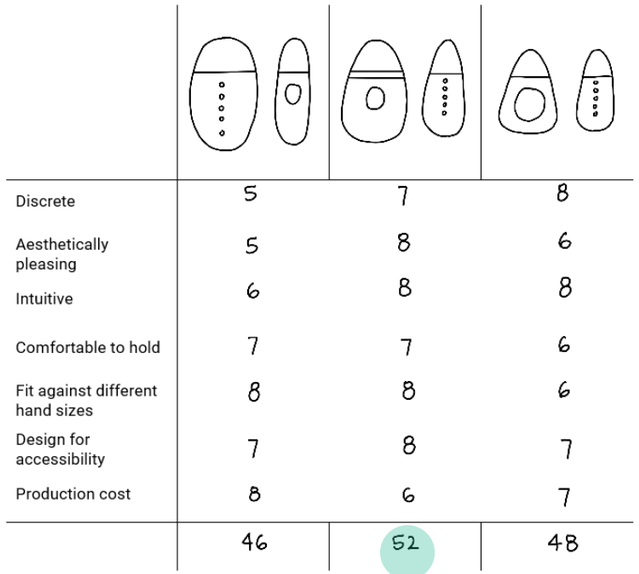


Figure 83 – Refined concept three. The last concept was the smallest, as I wanted to explore slightly reducing the size for a minimal and pocketable design. However, I found that similar to the foam exploration in [Fig. 47], the device was still too fiddly. To consider all ages, I believed it would be more favourable to have a form similar in size to concepts one and two. Increasing the button size would make it easier to notice and feel, but may be too glaringly obvious. The concave shape of the button could be enough for a clear interaction signifier. The lack of colour was the most evident difference. I tried to create a fully white device, with only the colour-associated medication vials. Although this produced a clean appearance, I felt this was too minimal, and users would not be able to tell which medication is inside before use.

Evaluation II

The models were then evaluated against the criteria in the design brief. I chose to add a ‘design for accessibility’ criterion to consider asthmatics who may struggle with accessibility issues. ‘Production cost’ in this case, considered the difficulty level of manufacturing the various components’ shapes, and therefore the placement of ribs and springs to achieve horizontal motion with the button. The cost of the inner mechanisms were assumed to be relatively similar for all three prototypes.

The matrix ratings showed that concept two was the most successful overall. Having a front button meant that it could be equally intuitive for both right and left-handed users. Since some of the features from concepts one and three were higher rated, I tried to implement them into the final concept.



Discrete	5	7	8
Aesthetically pleasing	5	8	6
Intuitive	6	8	8
Comfortable to hold	7	7	6
Fit against different hand sizes	8	8	6
Design for accessibility	7	8	7
Production cost	8	6	7
	46	52	48

Figure 84 - Smart inhaler concept evaluation matrix.

Manufacturing Considerations

Materials and Sustainability

The body, mechanisms, cap, and mouthpiece components would be injection moulded. The body was split into several components for easier manufacturing. I contemplated blow moulding for the body, but found that injection moulding was best for easier cleaning and assembly. A small pilot scheme found that approximately 29% of returned inhalers to pharmacies for proper disposal were not empty (Whittington Health, 2014); thus, a considerable amount of medication was wasted. In 2017, studies determined that 50 million inhalers were being prescribed to more than five million people in the UK (Roberts, 2019), resulting in a significant amount of plastic ending up in landfill. One of my main aims was to create a more sustainable device, so replacing the containers of medication per prescription can improve recyclability. For this, the device would need to be more rigid and durable.

Current DPIs are made of a mixture of polymers such as polylactic acid (PLA), polypropylene (PP), ABS, polycarbonate (PC) and modified acetal (POM) (DeStefano et al., 2020; Duckworth, 2017). I looked to consumer technology for inspiration, as life cycles of many electronics are planned for an average of 1.5-13 years but are realistically used between 4-5 years (Elder, 2019). Further research is required to determine the best composition of a polymer mixture for the smart inhaler. However, the likely primary plastics will be PLA, PP or PC to ensure sufficient rigidity and high durability. This means the user can use their device for a few years, only needing to replace the medicine containers. They would most likely be made of polyethylene (PET), high density PET (HDPE) or PP, and blow moulded (Bennett, 2014).

Various metals, such as titanium and steel, are commonly used in the healthcare industry for implants and surgical purposes as they are biocompatible (Gotman, 1997; Waurzyniak, 2011); however, there was no real need for metallic materials besides the electronic and magnetic components for this research. I felt that keeping metals to a minimum would also help save costs.

The interchangeable coloured bands would be made out of silicone, a biocompatible material also widely used in medical applications (Zare et al., 2021). The manufacturing process may involve injection moulding, transfer moulding, or compression moulding (Medical Device & Diagnostic Industry, 1999).

Regarding the medication labels, as the device would have replaceable medication containers, they would be placed around the medication component instead of the device. Connecting with the app would make more detailed information linked to the medication and patient data available.

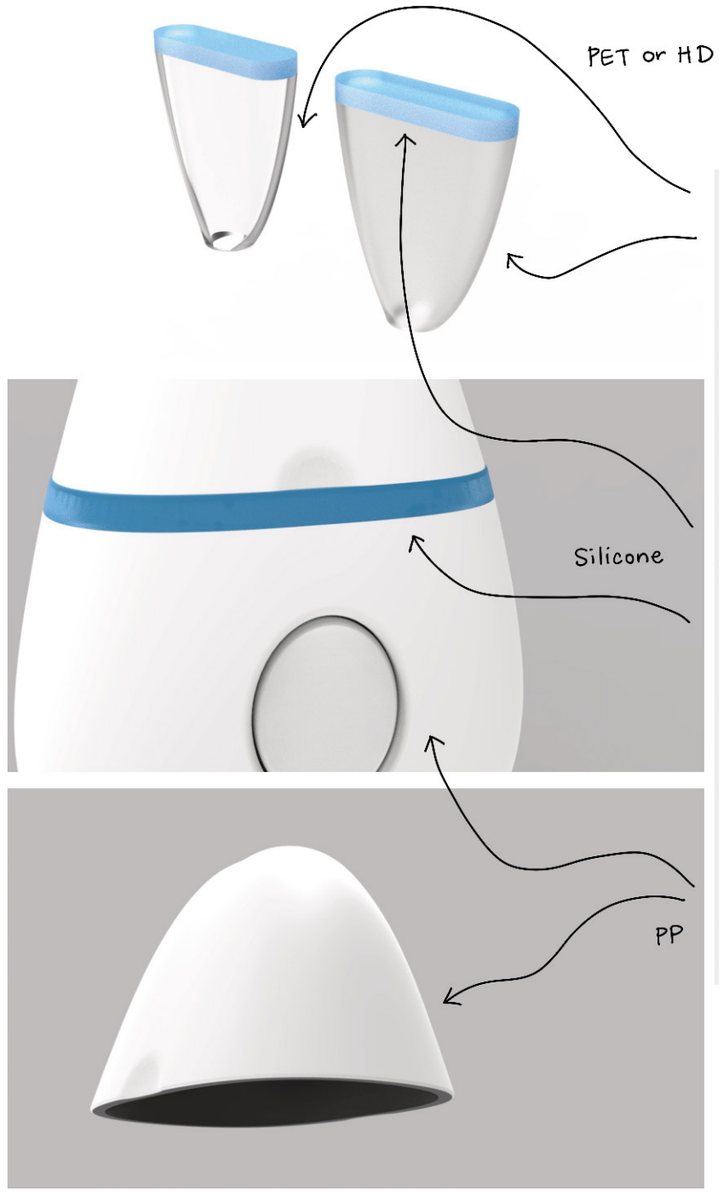


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Figure 85 – Potential material examples, top to bottom: HDPE (Miroo Technology, 2022), silicone (Rubber-Cal, 2022), PLA (Modern Plastics, 2014)

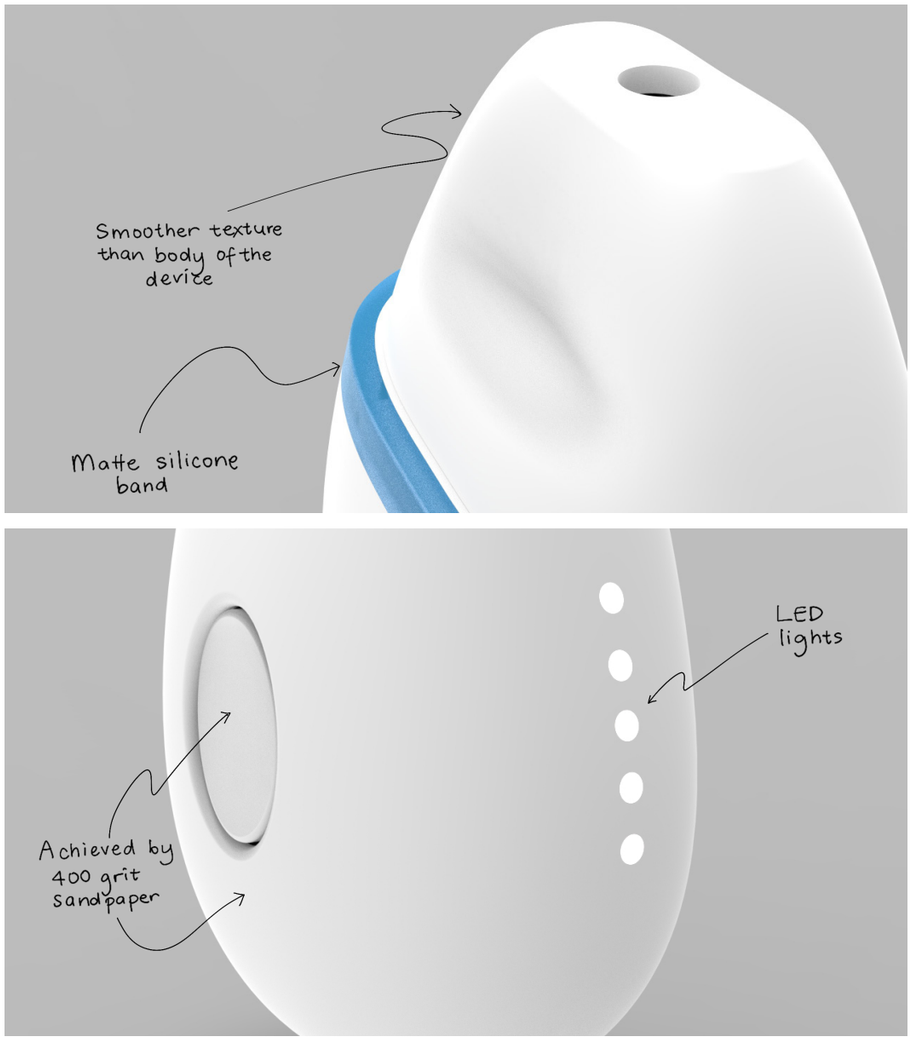


Figure 86 - Rendered textures for various components of the inhaler.

Texture Exploration

While the current inhalers mostly seemed to have a glossy finish, I found that many modern products lean towards a more matte finish. I explored various rough finishes using different grades of sandpaper on the 3D printed test models. I wanted to design my concepts with a matte finish since it felt like a more natural texture to hold, compared to the glossy finish that attracts fingerprints and may feel sticky against the skin from the hand's natural oils (Molteni, 2016). It was interesting to see that specific grades of sandpaper achieved too smooth or too rough textures, so I experimented with several techniques including dry sanding, wet sanding (sanding with water), sandblasting, and using fillers. From this, I determined that wet sanding with 400 grits was best to achieve the desired matte texture. The mouthpiece was wet sanded with 600 grit sandpaper for a smoother finish that could be easier to clean (Fopp-Spori, 2010).

The Finalised Smart Inhaler

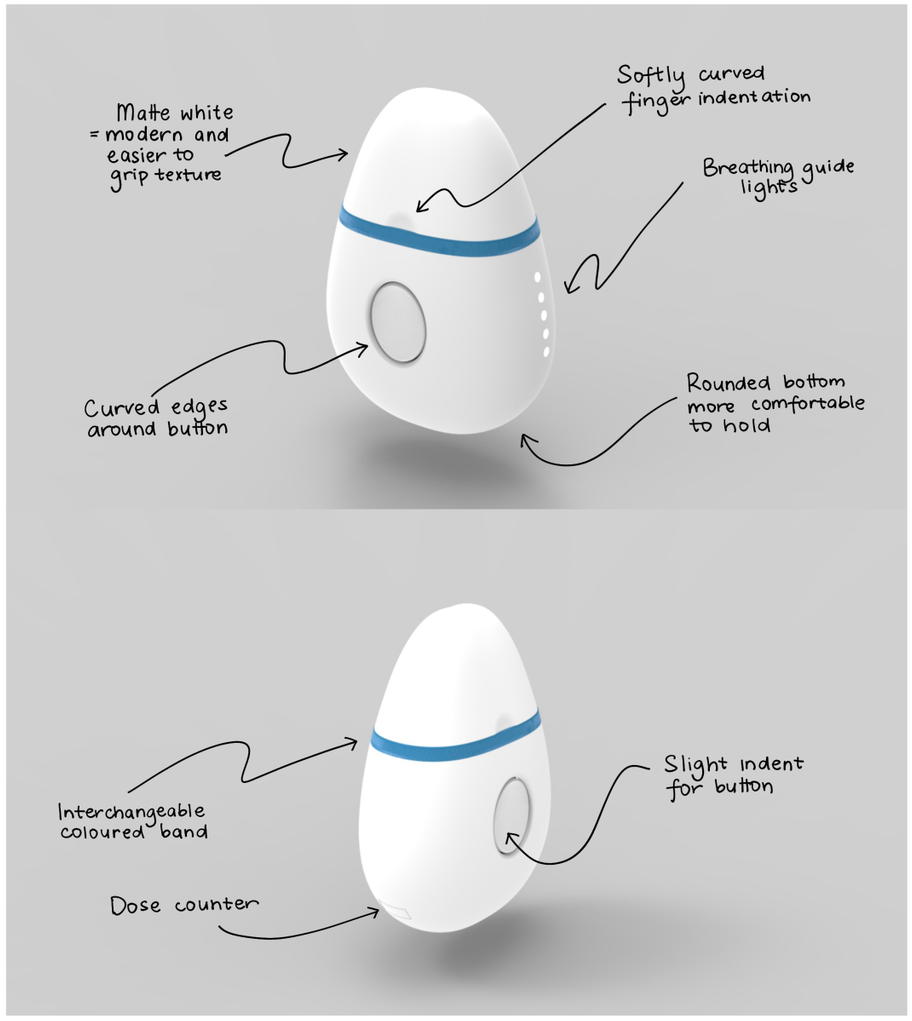


Figure 87 - Side views of the smart inhaler concept with all the highly rated features combined as a result of the evaluation matrices. The indent for finger placement was made with softer edges.

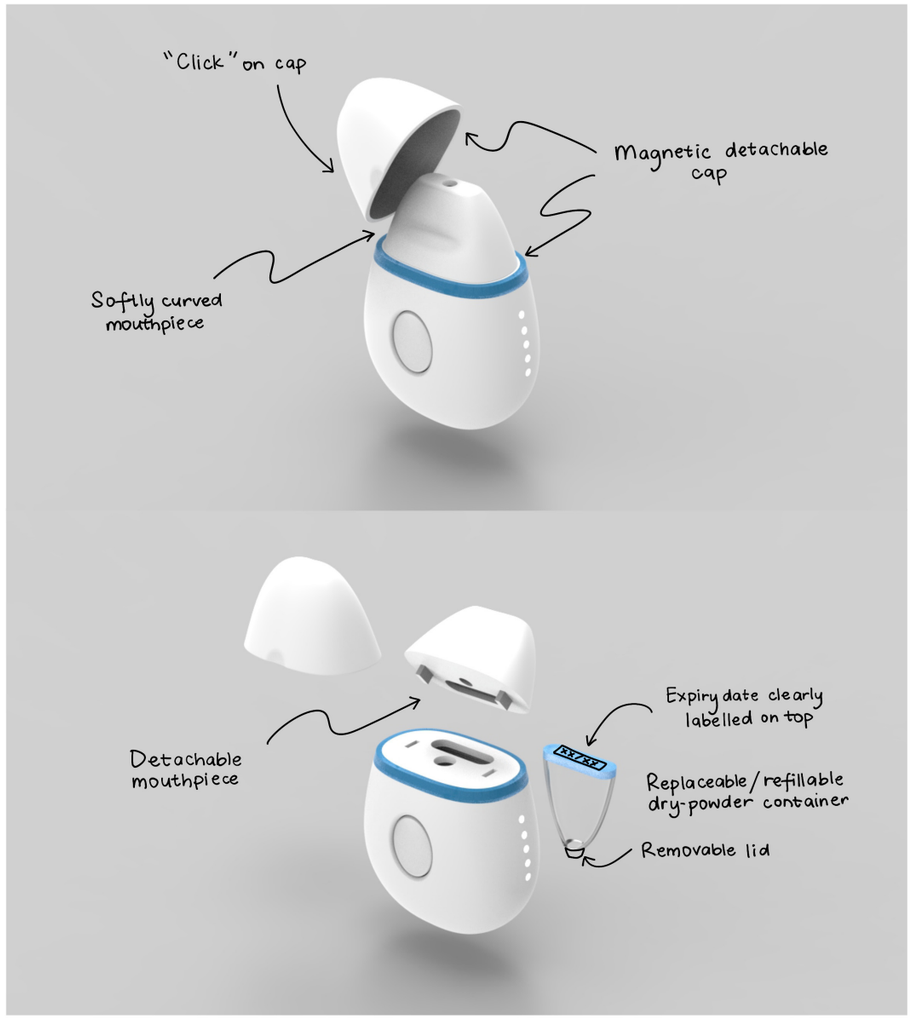


Figure 88 - All the detachable components and how they fit together. The exploded view and potential placement of sensors will be included as part of the final research outcomes.

App Design

As outlined in the final design brief, the app connected to the smart inhaler includes several key features:

Tracking the usage

Gives feedback to the system - predicts risk of asthma symptoms or acute exacerbations

Provide an option of contacting an asthma specialist or clinician

Send reminders for usage and prescription renewals

A moderated community forum

Weather forecast predictions and predict the potential onset of asthma symptoms through triggers

Detailed information about the user's medication

Standardised device instructions

Section on good inhaling techniques.

Regarding the design, it was crucial to create a layout that would be engaging enough to motivate people to keep using their inhalers and connect to the app. I had to acknowledge, however, that designing an app through a user experience (UX) and user interface (UI) approach was out of this project scope, so I kept this focus to a minimum given my time restriction. As shown in [Fig. 89], I simply drafted the possible sections the app could include.

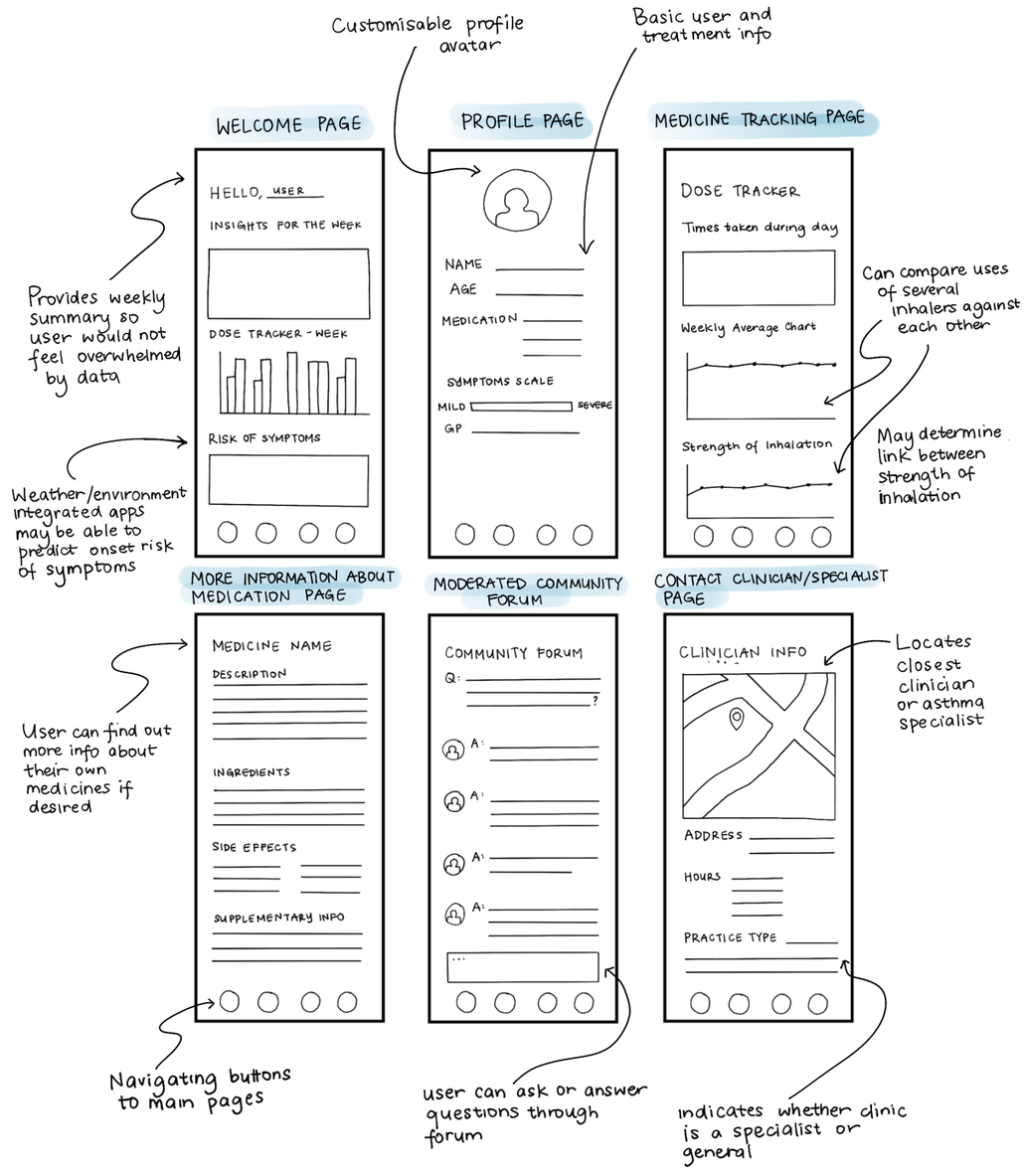


Figure 89 – Examples of health mobile application user interfaces (UI) with annotated commentary explaining positive and negative aspects in relation to my own potential concepts.

Images removed for copyright reasons.

Figure 90 – Examples of modern wireless chargers and devices that seemed to have a sculptural form. I took inspiration from standard phone chargers, those with unusual materials such as wood or fabrics, and those usable for more than a single device.

Wireless Charger Design

A smaller part of the project was the wireless charger component that will be used to charge the smart inhaler. I considered creating a charger that would require the user to plug in their device; however, with how technology seems to be moving forward, I surmised that plugs on a device are slowly being eradicated as wireless chargers allow for ease of use.

From the mood board, I created a standalone charger that follows the device's curves, and clicks perfectly with the underside, as it can indicate to the user that the device has successfully coupled with the charger. I recognised that a flat wireless charger like the ones currently available for mobile devices would not work well with the smart inhaler due to its curved edges, thus will not allow it to lay flat or charge properly.

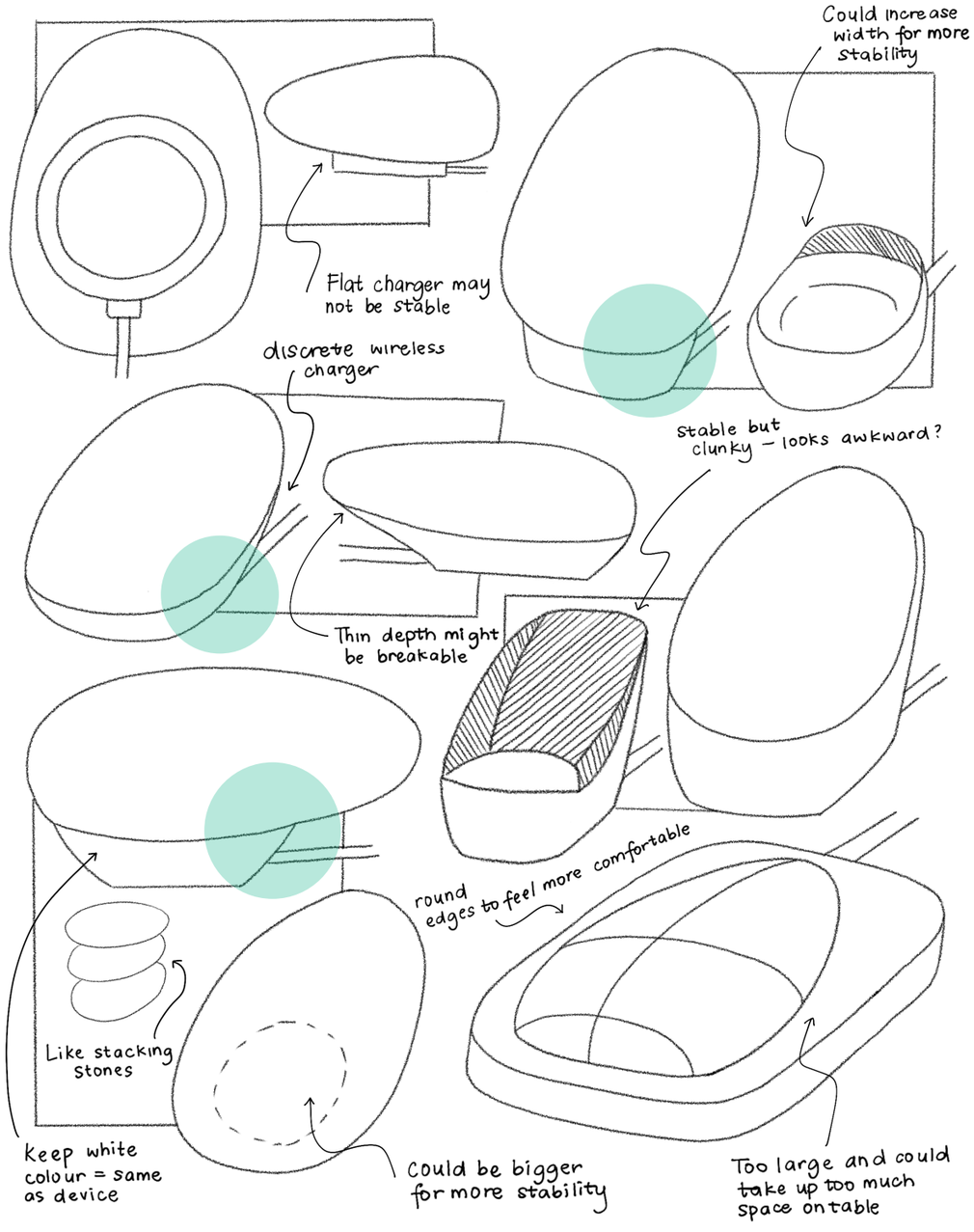


Figure 91 – Visual brainstorm of possible wireless chargers. I considered how people stack stones on the beach, and knowing this would be too unstable for the device, I tried to create an indent of the underside to fit precisely. However, I eventually developed a more discrete design, as the bottom of the charger was best kept flat to ensure maximum charging capabilities and make it easier to incorporate the electrical components. The chosen features were highlighted.

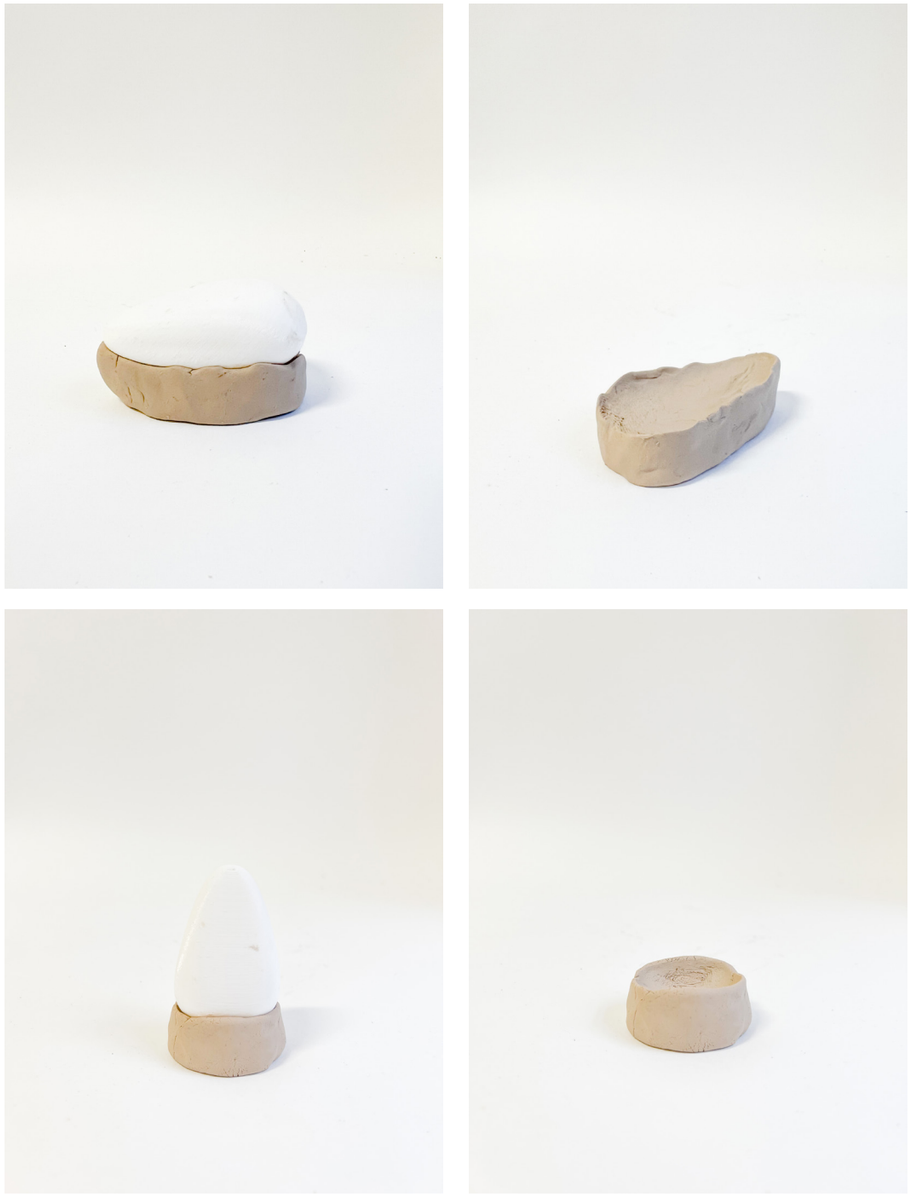


Figure 92 - While CAD models allowed me to picture how the inhaler would sit on the charger, I felt it was also necessary to make physical models for me to test the interactions with both. I used clay to shape the two concepts I had in mind in their simplest form. The second concept was the easiest option to take the inhaler off and set it down.

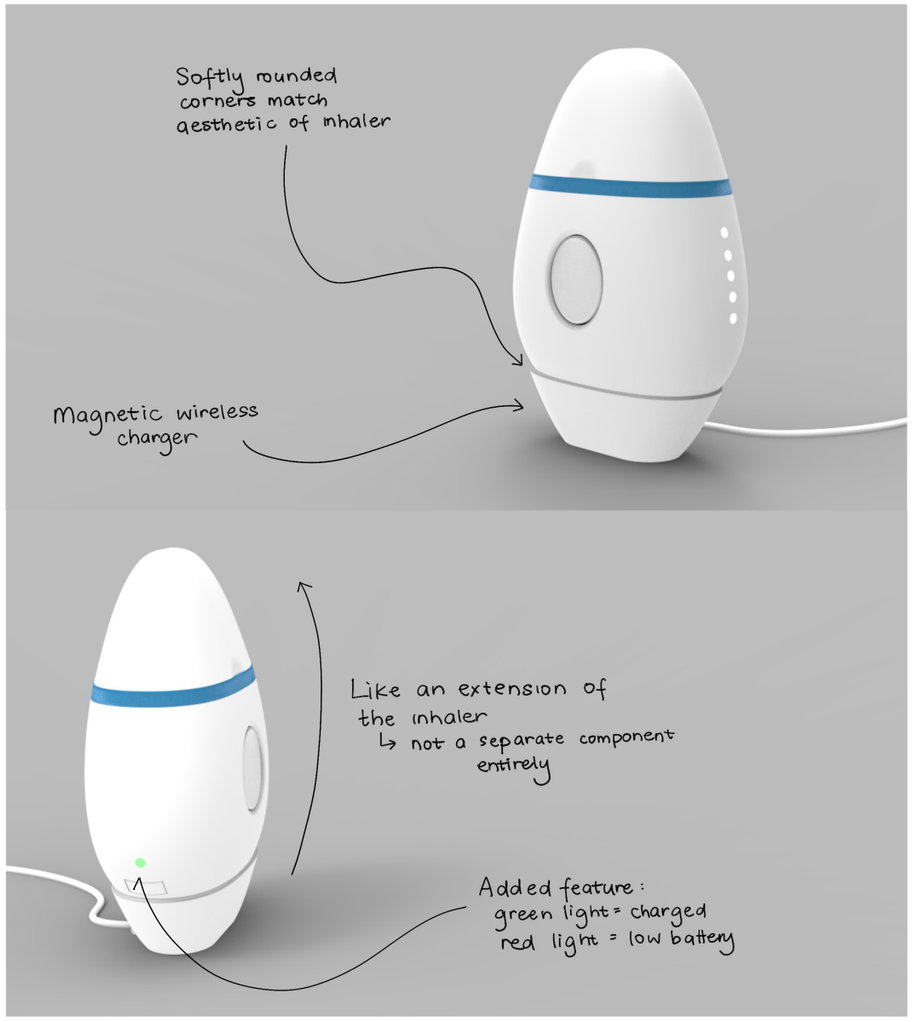


Figure 93 - Final wireless charger. Instead of the charger base extending outwards like with the chosen clay concept, I decided to slope it inwards following the curves of the inhaler.

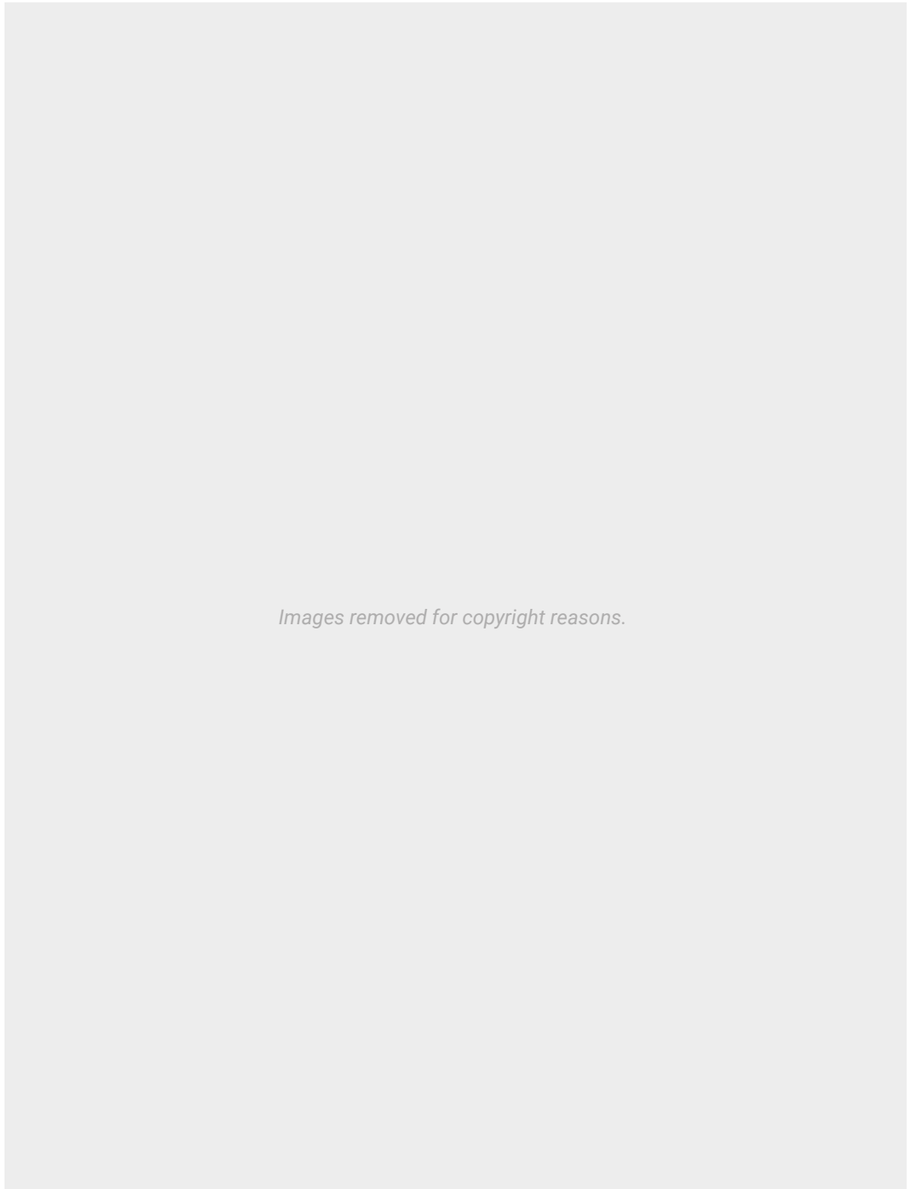


Figure 94 – Examples of modern medical device packaging.

Packaging Design

Packaging is part of the user's experience as the first impression of the device when purchased. The development of medical packaging (colour, material, and infographics) could also be an entire project itself, requiring input from communication designers, and was thus out of the scope of this research. However, I wanted to briefly experiment with the design to understand how the user may interact with the products through packaging.

Though boxes are available in many shapes, I decided to continue with a rectangular shape as they are the easiest and cheapest to manufacture. I wanted to ensure that the box itself would be simple yet contain all the necessary information for the user to use their inhaler as well as possible. If there would be an added cost compared to a plain box, I chose to shift this cost to the details on the box. Although it might provide extra security for the device, the foam (as pictured in several examples) would be an added cost, and moulded card or thin plastic could be a suitable alternative.

Many consumer packages can confuse people on how to open them or are difficult with completely flush edges. From my explorations, a top lid box design was selected, though I strongly considered a horizontal-pull design with a tab. My only issue with the tab was that it would not flow well with the rest of the product design and its components, and having extra material (e.g. ribbon) may be an unnecessary cost.

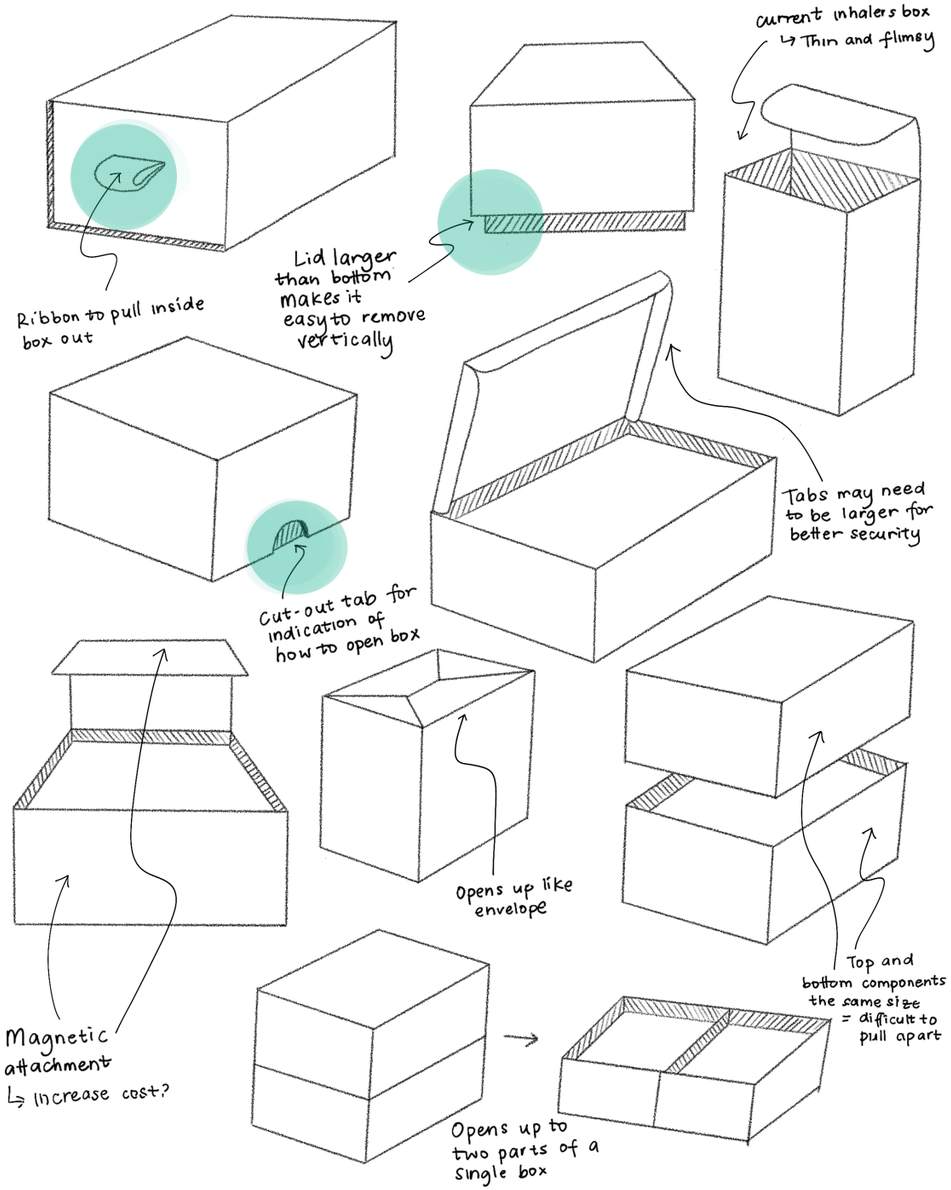


Figure 95 – Sketch exploration of packaging for smart inhaler.

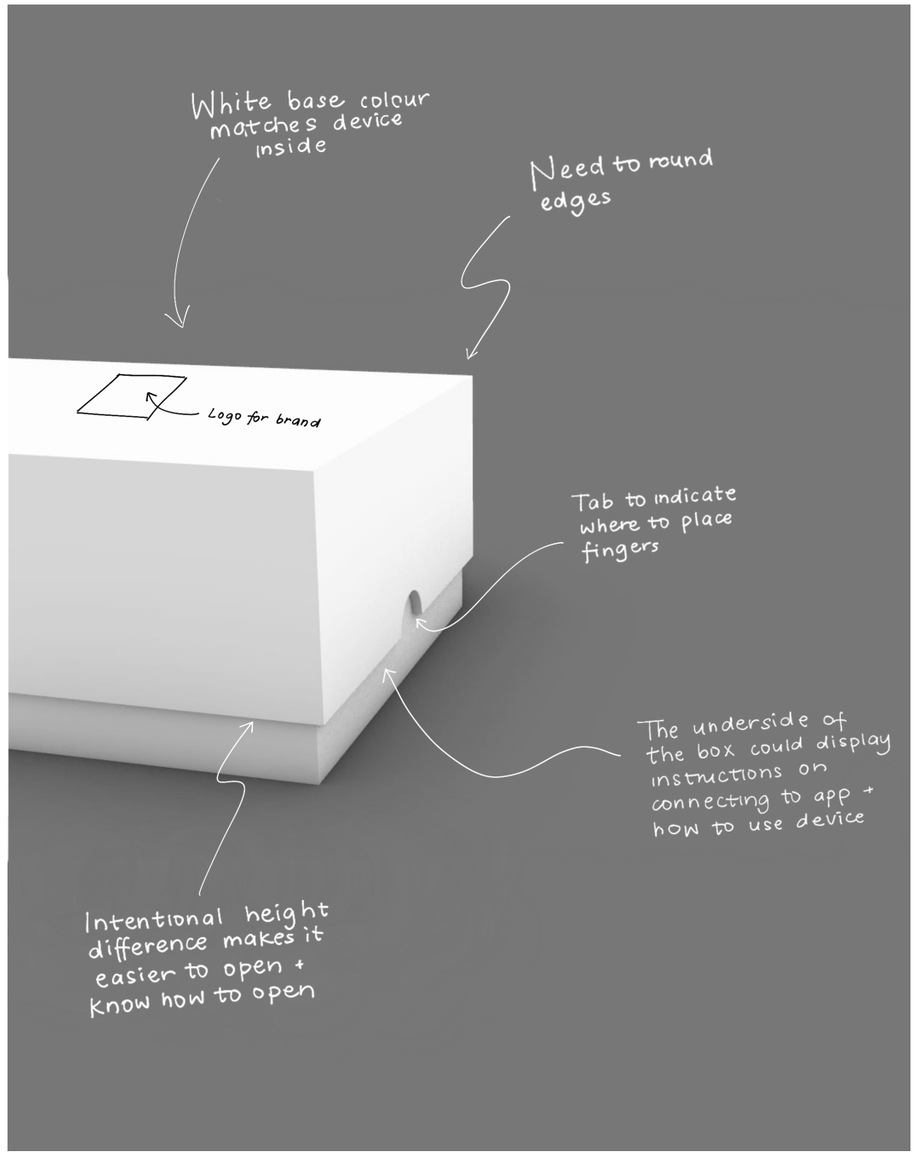


Figure 96 - Selected packaging chosen based on previous sketches with further observations noted for refinement.

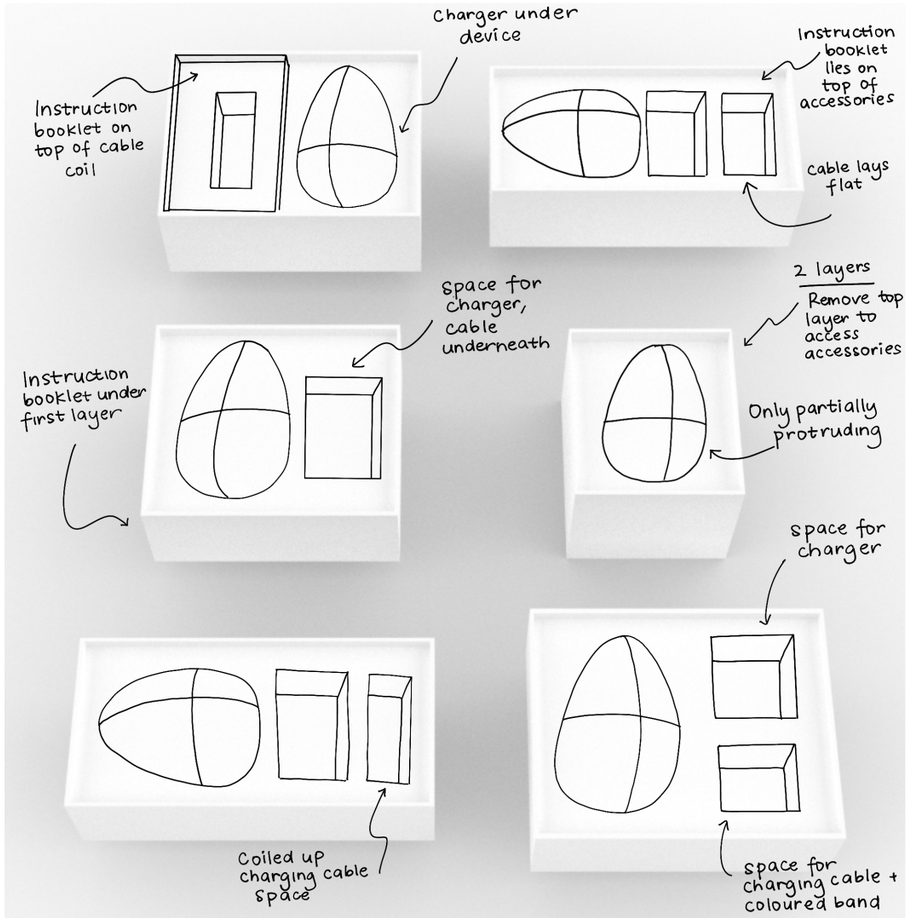


Figure 97 – Product placement within the box. I found that a larger box may be inconvenient and look bulky, so I decided to refine the highlighted option. Creating a two layered box helped reduce the width/length with only a slight increase in height. This may also help to not overwhelm the user with several products seen all at once and focus solely on the device and the instructions at first glance.

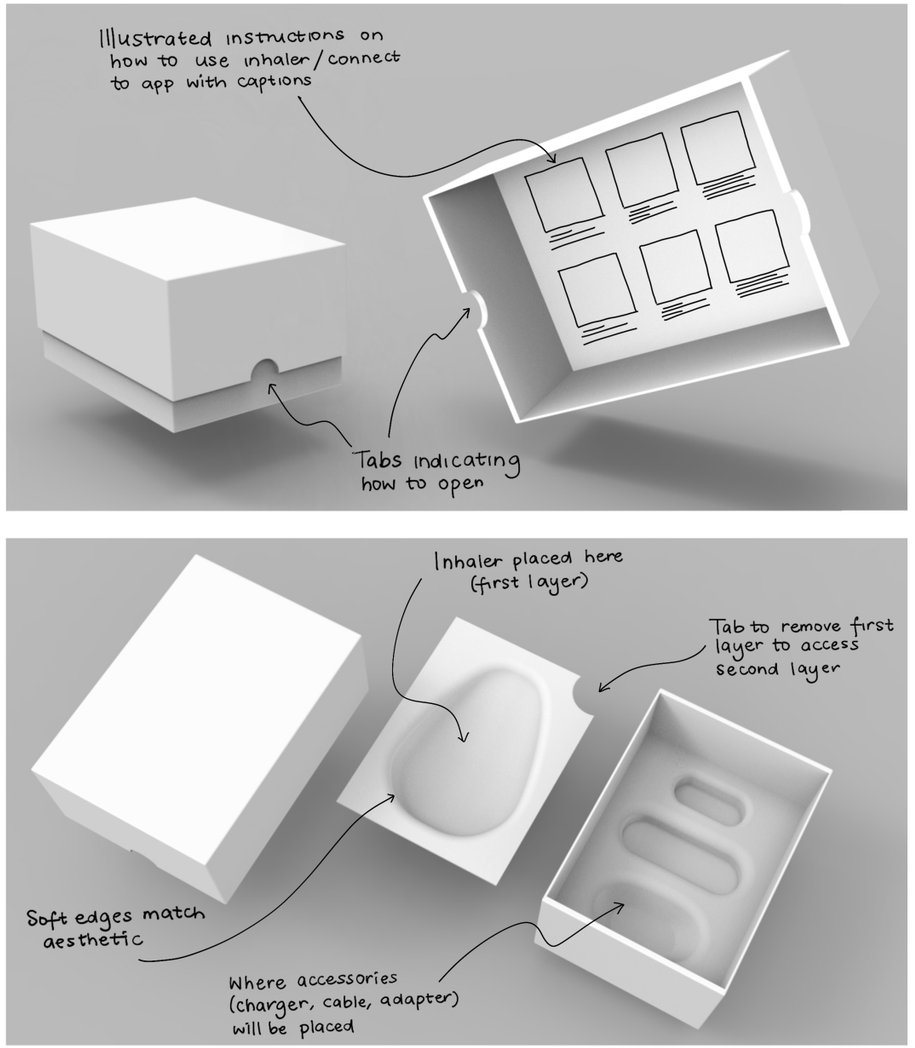
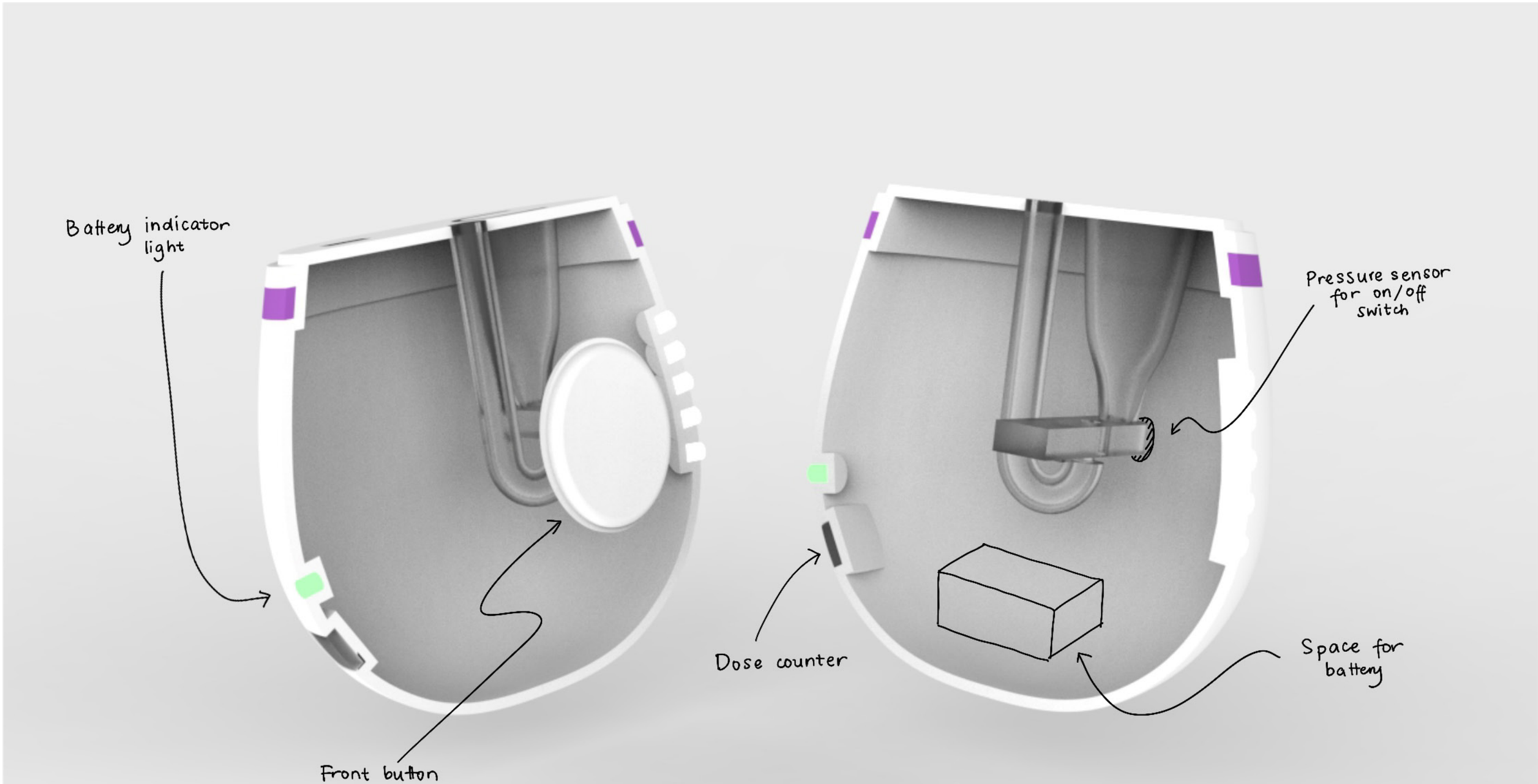
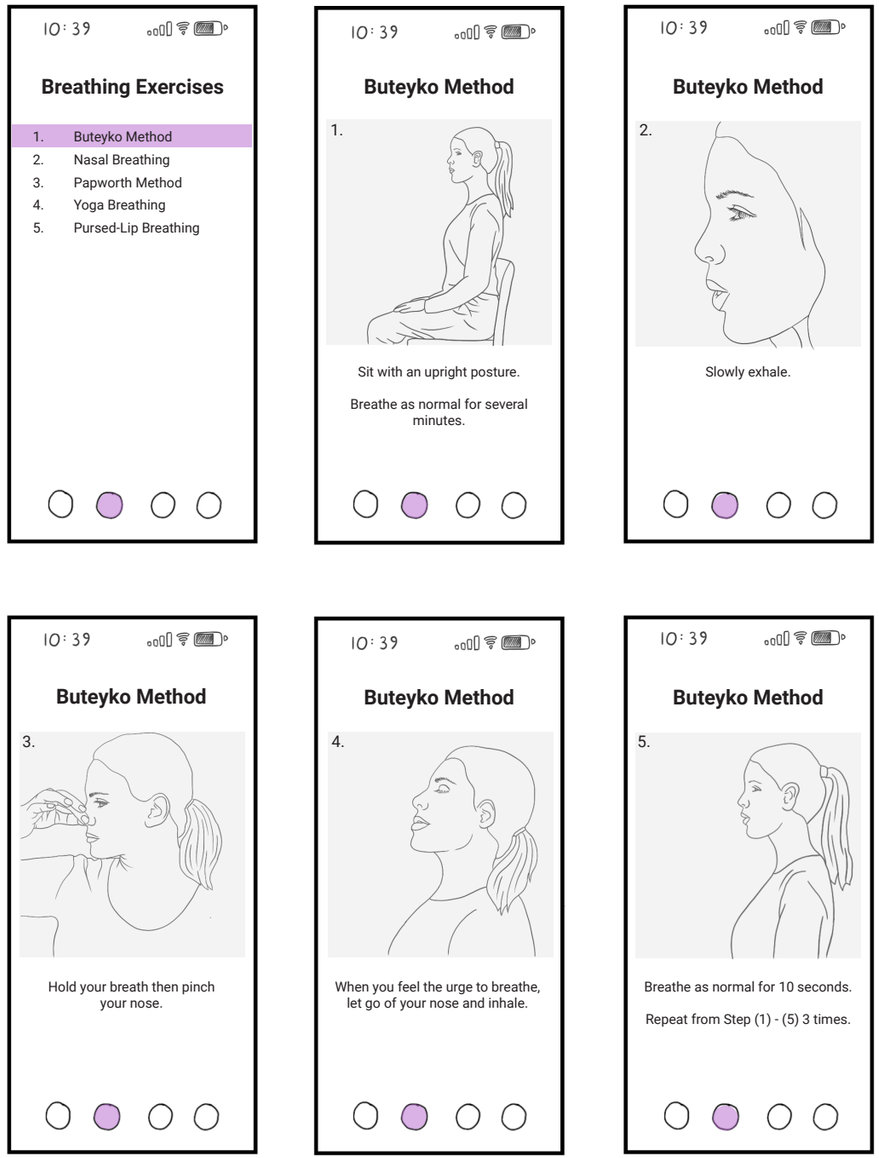


Figure 98 - Final packaging render.

RESEARCH OUTCOMES


Battery indicator light
Front button
Pressure sensor for on/off switch
Dose counter
Space for battery



Example of a breathing exercise located in the mobile app that can help asthmatic train their breath for better inhalation of their medications and overall control of symptoms.

DISCUSSION

This research explored the opportunity to design an asthma inhaler that could disassociate a user from the stigma of asthma. The metered-dose type has not changed over the last few decades, so I became curious how other asthmatics felt about the design of their inhalers. Through this research, it became evident that the appearance of the inhaler was only one of the aspects that needed to be reviewed. Despite asthma being a common chronic condition, few studies discussed people's thoughts about their treatments and how asthma affects their lives.

I set out to explore opportunities to improve the experiences of asthmatics using inhalers by starting at the core of many of the issues - the inhaler design itself, including its mechanics. Using an HCD approach, I could better understand how asthma fits within the New Zealand healthcare system and recognised the challenges of providing adequate treatment that suits most asthmatics. In qualitative literature, asthmatics suggested shared decision-making between all parties involved in asthma care, better access to asthma services and more suitable treatments to help empower patients to control their asthma management (Baggott et al., 2020; Bidad et al., 2018). It became clear that both clinicians and asthmatics were frustrated with the lack of change in treating asthma. Reiterating the importance of correctly following techniques can only help the patient so far if the device itself lacks the consideration of natural human behaviours and thinking. Lee (2014) argued, "is it the fault of the patient or the fault of the design?". I hope my research may support future asthma treatment research by offering insight into the benefits of prioritising user experiences.

Research Contributions and Design Output

My primary goals in this research were summarised as follows:

> An appealing concept that fits well within modern standards and audiences, removing a great deal of stigma associated with inhalers
>
> Consider user interaction to create a more intuitive device
>
> Re-position the inhaler by establishing it in the centre of a re-contextualised asthma eco-system

This research was not intended to produce a concrete design solution for asthma treatment - it was a single approach for this extensive research area. Instead, the collective primary data, literature, existing products and concepts, and my own design perspective were used to construct key components that can inform an improved device for treatment that does not yet exist. Overall, I learned that by focusing on both aesthetic and usability, there is not only potential to improve the user experience with an inhaler, but also the relationship with the device as a lifelong treatment.

Intended Use and Misuse

Asthma has been thoroughly researched and reported over the last 50 years, yet there have been minimal changes to asthma treatment. Inhaler techniques were a primary focus in much of the literature and healthcare services. Many of the recommendations included more attention required towards medication adherence and training sessions to help improve asthma control (Bosnic-Anticevich et al., 2018; Kebede et al., 2019; S. Newman, 2014; Price et al., 2013; Sánchez-Nieto et al., 2022; Westerik et al., 2016). Consequently, I attempted to shift the narrative away from technique improvement. The clinicians interviewed voiced that most asthmatics may become more complacent to correct techniques over time. However, the issue remains that many healthcare professionals are also limited in their knowledge of asthma treatments and do not demonstrate correct inhaler techniques to their patients (Fink & Rubin, 2005). I found that many inhaler options give asthmatics the advantage of determining their most personally suitable medication or device. Unfortunately, the disadvantage is that healthcare professionals can find it difficult to be well-informed about all the different options. Therefore, my design solution had to be intuitive and require minimal instructions for users to remember and minimal support from healthcare professionals.

Form Study

People may not be conscious of their medical device's design, having accepted the device as the only known option for treatment. From my experience, I perceived inhalers as having a distinctly medical design, and the media portrayal of inhalers only added to the associated stigma. Many survey respondents reported that the mouthpieces (of MDIs) were uncomfortable. However, the shape and form of the inhalers were not brought up. I assumed this may also be due to the appearance of inhalers being mostly unchanged since their invention. From the comments, however, I gathered that the geometric shape of the mouthpieces was what felt unnatural, hence my direction to explore more organic forms.

Maintaining the organic form meant discerning how the functions could work together with the aesthetic. Form studies sought to balance medical with consumer aesthetics. I was inspired to experiment with forms inspired by nature (e.g. stone shapes and textures) as they are often correlated with wellness. Having started with sketches and clay forms, I then expanded the form exploration to various foam materials and used CAD and 3D prints to capture the close likeness of a final product. I found that an intuitive design accounts for more than feature placement, but also through the product's shape, for more natural and instinctive interaction (Wang et al., 2021). Colour is an essential consideration that influences how the user will perceive a product, often by evoking emotion or connection (Joong-Gyu, 2012). Although I sketched out possible colour options, I felt adhering to the existing colour system was more necessary since inhaler colours have relatively well-known colour associations with the various medications.

Overall, I aimed to design a minimal and elegant aesthetic that would capture the attention of people with asthma, motivating them to take their treatments regularly.

Promoting Self-Management

As technology becomes more integrated into society, smart inhalers can empower asthmatics to be more actively engaged with their treatments through mobile technology. Existing apps connected to sensors can track adherence, predict the risk of exacerbations or worsening symptoms, and make asthma information more accessible (Morton et al., 2020). In New Zealand, these apps are not commonly used, as the sensor attachments to inhalers are sold separately and not covered by the public health system. In this study, it was recognised that support systems could help people better manage their conditions through shared accountability and sharing of experiences and learning. It seems likely that asthmatics would support the implementation of a moderated community forum through the app, but their direct input should be provided.

My project does not intend to replace healthcare professionals. Instead, it aims to better integrate asthma-specific needed for earlier intervention. As health systems change to become more online (e.g. GP appointments and patient records), connected management systems will become the norm. From this, it seems viable to link existing patient portal software to the app, so asthmatics could have the option of contacting healthcare professionals or asthma specialists directly.

This project identified the potential of using sensors and related smart technologies to improve asthma management. There is an opportunity for further exploration. For example, integrating existing sensors that measure environmental factors could notify the user about increased symptom triggers. Secondly, an airflow sensor can measure inhalation rate, building airflow patterns to determine the state of airway health and open up predictive software to estimate the risk of acute exacerbations. Furthermore, information regarding lung quality and function may be obtained through the data. From a larger population of users, data can be analysed and compared between different parts of the world. Such technologies would require more in-depth research by engineers.

Addressing Health Inequity

After the lockdown ended, I seized the opportunity to put myself in a new environment. Afterwards, I saw my project from a different perspective and was able to make better progress. Until this, I had not considered how my surroundings could greatly impact my mental health (Pragati et al., 2021). Discussing the full effects would be beyond this project's scope, but I learned to empathise with other people whom COVID impacted. I recognised my privilege in having the opportunity to temporarily leave my current situation, and felt for many who were unable to do the same. Thinking back to the literature and from the interviews with clinicians, health inequity has been an ongoing issue within New Zealand, particularly for Māori, Pacific and lower socio-economic communities (Barnard & Zhang, 2021; Pattemore et al., 2004; Sheridan et al., 2011). Research showed that poor housing conditions are one of the main causes (Asthma Foundation NZ, 2020), which means there are already unbalanced opportunities to maintain good health for some people compared to others (Howden-Chapman et al., 2021). Similarly, the evident health inequity also relates to the receiving and understanding of health education (Sheridan et al., 2011), putting lower socio-economic communities at a disadvantage until they reach a worst-case scenario of being admitted to hospital. I surmised that designing a new inhaler alone would only continue to aid those with a higher socio-economic status who have received and understood sufficient health education, instead of those who may need more support.

Reframing the project's potential to challenge the status quo of healthcare services allowed me to re-evaluate how the inhaler is used within the asthma eco-system. Incorporating sensors to enforce usage tracking, sending reminders for recommended use, and giving options for earlier intervention with asthma services could drive better self-management for most people who would like to be more proactive in their treatment. I recognised that smart devices would more likely be used by people who are more adept with technology, which cycles back to acknowledging privilege. From my perspective as the designer in this research, if the majority of asthmatics could be contained in a self-managed and self-regulated eco-system, then the health professionals can, in turn, focus more on those who remain underserved.

Limitations

Selecting action research as my methodology encouraged more active collaboration with asthmatics and clinicians who work directly with asthmatic patients while being able to adapt my approaches throughout my design process (Swann, 2002). Many obstacles throughout this project allowed me to consider the next steps for future work in this area. Packaging for medical devices and app design, for instance, were only explored briefly in this project and could be further developed from a communication design perspective.

Limitations due to COVID-19

Going into my master's project, I was aware that COVID would likely disrupt my planned research methods as New Zealand was still under pressure to contain the virus as much as possible. While the Auckland lockdown in February 2021 was short-lived, knowing that new variants were emerging worldwide meant that potential longer lockdowns were not ruled out. User and clinician participant recruitment had to be carefully outlined to consider the best time for collaborative engagement. I decided to delay arranging focus groups or interviews with young adult asthmatics. With a human-centred approach, I wanted to involve the users as early as possible in the research. However, I had to balance developing my ideas without users, as I would only be able to collaborate with them at a later time. I felt that many young adults might have been in a similar position mentally, finding it difficult to re-adjust their lifestyles with lockdowns (Chadi et al., 2022; Gasteiger et al., 2021). Even if they had been willing participants, there would have been many external factors outside of asthma that affected their opinions and attention, which would not accurately represent their thoughts outside of being in the lockdown situation.

Once I began preparing my participant recruitment plan, New Zealand was again under strict COVID restrictions. Although there was no lockdown, I had to consider my potential participants' mental and physical well-being, understanding that it would not be the right time to recruit until the outbreak had settled. From my own mental struggle to move my project forward as lockdown kept being extended, I reflected on the pressures that healthcare services was under, amongst everyone who had to adjust to the current environment (Imlach et al., 2021; G. Wilson et al., 2021). As a result, there was further delay, and I had to change my collaborative user method from focus groups to online interviews.

I felt that collaborating with young adult asthmatics was best through Zoom with the nature of unpredictable situations. This, however, posed several limitations. Firstly, focus groups intended to encourage participants to share their experiences of using an inhaler with a group of asthmatics and their opinions on its product design. By displaying inhaler components during the session, participants could reframe the inhaler's components or attributes to their personal preferences and liking. The inhalers were not impossible to display in a video Zoom meeting, but I believed having physical forms in hand could have evoked different emotional responses. Texture, size, and even colour may not be fully comprehendible through video. Secondly, group collaboration was meant to encourage participants to be more open in sharing their stories, especially if they observed similar experiences from other participants. Ideas could have been exchanged or built upon between participants, supporting creative thinking. With one-on-one interviews, I was compelled to arrange more of an open discussion with participants, built on their answers individually.

Barriers to Product Implementation

Cost

The cost was one of the most important factors to consider when designing a new medical device, especially one that implements smart technology. Although the current inhalers may not be ideal, they are the accepted standard of treatment, so with new devices, the benefits need to be justified for potential cost increases. The clinicians interviewed were understandably skeptical about smart inhalers since existing ones exhibited little rationale for devices that would significantly more for the user. Furthermore, it was mentioned that Pharmac has much of the control of medication availability in New Zealand and must remain within their given budgets (Pharmac, 2022). Many of the clinicians and survey respondents suggested that dose counters could help asthmatics manage their treatment better and avoid discarding partially used inhalers. However, it was discussed that higher cost was the reason inhalers with dose counters are not made available in New Zealand. Pharmac control affects more than asthma treatments; hence, the restriction on new devices or treatments extends beyond the project scope.

The potential of reducing asthma-related hospitalisations may result in funding available for a subsidy of the smart inhalers, but a more in-depth cost analysis would need to be conducted. During the critique session, the clinician voiced their concern of how the budget allocation within the new Auckland district health board (ADHB) in the next few years is still uncertain. The justification of the potential smart inhaler cost may be on hold until there is more stability with the new healthcare system should further developments bring the device to market.

Range of Devices Available

Rogueda and Traini (2016, p1043) suggested that "simplifying the number of inhalers might help compliance". Although having many options can help patients select which inhaler and medication would be most personally suitable, using multiple devices can result in contradictory behaviour where the users become less adherent (Price et al., 2012). Introducing a new device may run this risk, especially as available medicines are relatively affordable. As considerable costs are attached to new technologies, healthcare budgets are revised, and the health literacy issue remains (Babar & Francis, 2014), it would be an immense challenge to propose a new inhaler in the market. I aimed to use my research as a starting point for creating a single standard inhaler that could interchange medicines instead of having one per device.

Future Recommendations

Participant Recruitment

Recruiting expert clinicians and user participants proved to be the most significant challenge in my research. I was thrilled to find out that over 110 individual responses were collected through Asthma NZ advertising my survey on their social media platform on my behalf. This showed the considerable interest that people with asthma had in my research to redesign the asthma inhaler. However, user interview participants were the most difficult to recruit, even after the lockdown ended. Following the AUT ethics committee-approved application, I was limited to putting up posters around the campuses to invite students to participate in my research. By the time more students attended lectures in person, it was the final weeks of the semester, so I assumed there was little chance of students interested in taking part in extra work. My Asthma NZ contact was happy to encourage other staff to let their young adult patients know about my research. However, due to ethical considerations, they were unable to provide more formal invitations or follow up as their patients may feel that their support or treatment received from Asthma NZ could be affected.

Working with Asthma NZ was beneficial in recruiting clinician interviewees and survey respondents. Several nurses expressed interest in participating and most had accepted the formal invitation. However, their insight was based on their experience within the Asthma NZ organisation in Auckland and did not reflect other healthcare services. I contacted several asthma-specific and non-specific services based in other parts of New Zealand. However, I only received replies from Asthma Waikato and i3 from the Waitemata DHB (in Auckland), so the information was mainly based around the Auckland and Hamilton regions. For further research, it may be ideal to work with healthcare services in the Southland region and more rural areas to compare the differences in asthma prevalence with larger cities (Barnard & Zhang, 2021; Lewis et al., 1997).

Towards the end of the project, only one Asthma NZ nurse expressed interest after being formally invited for a critique session, thereby limiting potential improvements to a single expert's perspective. I understood that with increasing COVID cases at the time, the healthcare services may be under higher pressure due to delayed patient screening from lockdowns (Govasli & Solvoll, 2020; Wilson et al., 2021). Especially since asthma is a respiratory condition, I surmised that people with asthma may be at increased risk of worse COVID symptoms than non-asthmatics, though studies have shown the risk was posed to older patients or with comorbidity-related factors (Dolby et al., 2022; Izquierdo et al., 2021; Mendes et al., 2021).

As discussed in the contextual review, many studies reported the disproportionate prevalence of asthma for Maori and Pacific people. Yet, it was discussed in the clinician interviews that there had been little done to improve the statistics. Racial biases have affected non-Europeans within the healthcare systems, particularly toward Māori and Pacifica people (Harris et al., 2019). I knew this was not just concerning asthma but in all healthcare, so addressing this issue had to be kept within the project's scope. Although the clinicians interviewed had worked directly with patients all around Auckland, I may have been able to obtain deeper insight by speaking with Māori and Pacific organisations providing healthcare and social services. I reached out to a few, but, unfortunately did not receive a reply during my project. With more time and resources, I believe this could be an essential next step to better understanding how asthma and its treatments impact different cultures.

Co-Design

In action research, the users in particular, are actively involved in the design process and analysis stages to validate the design (Gray, 2004; Swann, 2002). To continue this research further, I would recommend hosting co-design workshops with a wider age range, using probes as co-design tools "to evoke inspiring responses from individual participants" (Sanders & Stappers, 2014). These probes (prototypes, foam models, and sketches) could present more creative forms of products by depicting that "the way things are" is not the only option (Bowen, 2007). These workshops could be held in-person, spread throughout various project stages, so users would be more engaged in the research. Although Zoom meetings were best at the time, in-person meetings would have been more ideal. I could not properly observe specific visual cues or characteristics such as voice tones, facial expressions, and posture through video. It may be ideal to create opportunities for both users and experts to provide feedback before the end of the project, for which refined prototypes and renderings could be displayed so participants can interact with the concepts to generate new ideas.

In the expert critique, I was posed with the question of whether my smart inhaler concept could open up opportunities to research the treatment of chronic obstructive pulmonary disease (COPD). People who suffer from COPD have similar but more severe symptoms than asthma. It was discussed that COPD patients (from the clinician's experience) were more willing to be involved with their treatment and self-manage their condition. There may be opportunities to extend this research outside of asthma and use the outcomes as a guideline to challenge future medical device designs using human-centred design approaches.

Design in the Medical Field

Medical device design requires more precise solutions than consumer devices as the resulting product should demonstrate significant dependability. It thus must follow more restrictive developments (Malhotra et al., 2005). For all approaches in medical design, patient safety is the primary concern. Other crucial considerations include product reliability and efficacy (Hercules et al., 2019; Tamsin & Bach, 2014). As with any technology, there is a risk of failure and technical or electronic difficulties, which would impact the device's usability for this project. For example, the battery might run out while the user cannot access the charger. Implementing a shared battery function like the Samsung Galaxy PowerShare (Samsung, 2022) was proposed, but this would only be possible with compatible phones and increase the cost. I considered the possibility of designing a mechanism that would allow the user to have manual control of the inhaler in case it short circuits or runs out of battery. It would be ideal for the user to not worry about such issues during emergencies. This may mean, however, that the device cannot track the usage until the battery is charged again.

Due to the scope of the project and the restricted timeframe, I was unable to conduct an in-depth examination of the more technical aspects and issues of the device. In future, healthcare and engineering fields will need to collaborate with designers to satisfy manufacturing specifications (Ciurana, 2014). I advocated for a human-centred approach and involving users throughout the research, and understand in reality that there is often a lack of collaboration and competing priorities. However, the nature of healthcare requires meticulous research and integration of both knowledge and skill between various disciplines for successful product development (Ocampo & Kaminski, 2019). A combination of quantitative and qualitative methods can encourage more collaboration between the researchers, clinicians, designers, patients, and their caregivers (Ku & Lupton, 2020).

Reflections as a Designer

I started this research journey with a keen excitement about wanting to improve and modernise asthma inhalers. With minimal prior background (formal education) in industrial design, my instinct was often to revert to an evidence-based approach when designing new concepts. I had to be more intentional in resisting this approach and rather tried to understand the problem context through the user's perspective first. On the other hand, a medical device still requires a certain degree of rigour, so I channelled my engineering thinking into feasibility analysis. Bringing in two perspectives from seemingly opposite epistemologies taught me to use each knowledge in various stages of the project.

Collaborating with end-users and healthcare professionals proved challenging in ways I did not expect. I knew COVID would present obstacles, especially in the participant recruitment plans. However, the delays and issues made me more aware of how complex an HCD problem could become. Considering the user can mean analysing the problem context past what is directly related to the research, to better understand their experiences. With no experiences being identical, this complicates the tension between finding a solution suitable for most people, or accommodating individualised needs and desires. The layered contexts perfectly represent the complexity of human behaviour, so it is crucial to work directly with primary users and supporting systems.

I learned to prioritise the users' underlying needs over my own biases and assumptions as best as I could. However, not all the requirements and stylistic requests from users can be met, hence the importance of learning how to determine certain features to include over others. As a designer, it was also vital to imbue my creative choices that would show my personality through this specific approach to a complicated problem. I gained a deeper understanding of what it means to advocate for users and design through empathy, thereby shaping my values as a designer.

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APPENDICES

Appendix A

Ethics Approval and Amendment
Ethics Application 21/282

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

17 February 2022

Stephen Reay
Faculty of Design and Creative Technologies

Dear Stephen

Re: Ethics Application: **21/282 Reimaging an Inhaled Experience: Improving the Design of Asthma Metered Dose Inhalers**

Thank you for your request for approval of amendments to your ethics application.

The amendments to the recruitment protocol (Asthma NZ Social media platforms) and data collection protocol (interviews via Zoom as approved in EA1) has been approved. The amendment to the research aim has been noted.

Non-Standard Conditions of Approval

1. Ensure that the comments will be disabled for the advertisements placed on social media so people who are interested in participating will contact the researcher directly.
2. In the Information Sheet - consistent use of the 1st and 2nd person.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval.

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: jfv6650@autuni.ac.nz; david.white@aut.ac.nz

Ethics Amendment 21/282

Auckland University of Technology Ethics Committee (AUTEC)

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6 September 2021

Stephen Reay
Faculty of Design and Creative Technologies

Dear Stephen

Re Ethics Application: **21/282 Reimaging an Inhaled Experience: Improving the Design of Asthma Metered Dose Inhalers**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 6 September 2024.

Non-Standard Conditions of Approval

1. Send through the updated version of the Consent Form for file.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: jfv6650@autuni.ac.nz; david.white@aut.ac.nz

Appendix B

Online Survey Invitation Poster

This poster was designed for a social media platform that Asthma NZ advertised on my behalf.

Appendix C

Expert Interview Indicative Questions

1. Clinician's role in asthma care.

2. What are the sorts of issues that patients generally have when they schedule in appointments specifically seeking asthma services?

3. What has been the most recommended form of asthma treatment - and why do you believe they are commonly prescribed or used?

4. How important would you say techniques are when using asthma inhalers?

5. What are your thoughts on inhaler technique education?
   a. In your experience either just in NZ or possibly working with others around the world, are the techniques standardised?

6. From previous studies conducted, it seems that patients have been concerned about techniques and the following aspects. What are your thoughts around them?
   a. Hand-breath synchronisation
   b. Keeping track of dosage
   c. Use or lack of use of spacers
   d. Disposal of inhalers

7. Regarding the spacer, I've only recently found out that by using the inhaler itself, only about 20% of the medication is going into my lungs, and that's with "perfect techniques". Using a spacer increased this to 40%.
   Are patients aware of how little medication they receive without a spacer?

8. Are different ages recommended different sized spacers?
9. From my own experience as an asthmatic, I tried to forgo using a spacer as I got older. Do you find your patients have done similarly? If so, what reasons were given?

10. Were there other comments or concerns made by patients about inhalers and spacers?

11. With newer developments of inhalers (dry-powder, soft-mist, breath-actuated) do you believe these products have solved some of the pMDI's issues? Or created more issues in your opinion?

12. If you could come up with an ideal inhaler, what improvements would you say should be made in terms of function and/or design?

Appendix D

Survey Questions

1. Looking back to when you can first remember, how did you feel about having asthma?

2. If you had been diagnosed with asthma as a child, how did you feel having to use an inhaler in those earlier years? Refer to some example situations below: a) Sports b) Other school activities c) Around peers d) Classroom surroundings

3. Were you recommended to use a spacer with your inhaler by a medical professional? If so, why do you think a spacer was recommended?

4. Do you currently use a spacer with your inhaler? If not, what age were you when you stopped using the spacer?

5. How were you taught to use your inhaler? (Tick options from list of instructions)

6. Did you understand why these techniques were recommended? Explain why/why not and what your medical practitioner's reasons were.

7. Over the years, were you taught different techniques by the medical practitioner? If so, what changed? This may also include changing inhaler type (e.g. from metered-dose to dry powder).

8. Do you find the inhaler/spacer easy or difficult to use? Why?

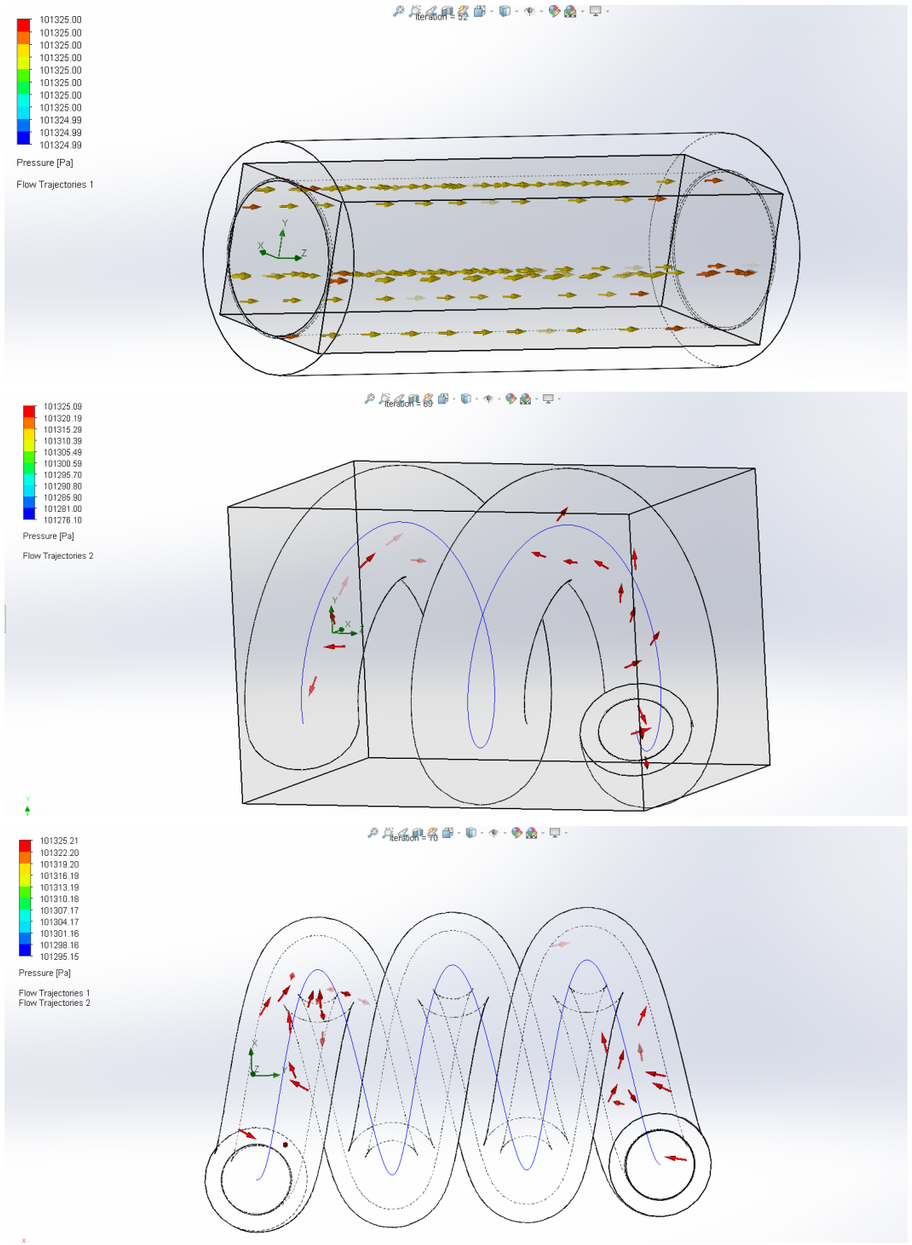
9. Has your experience having asthma and your use of inhalers changed since your diagnosis? Do you use your inhaler (and spacer) less, more, or the same? Explain your reasoning.

10. Do you feel that the inhaler (and spacer) are comfortable to use in public? i.e. in the workplace, at school, during social events, in front of peers or family.

11. Have you made any changes to your inhaler (and spacer) to accommodate your needs? If so, please describe these changes.

12. Draw or describe what you would like your ideal inhaler to look like and function. What are your reasonings behind your design?

13. Any other general comments about the inhaler (and spacer).



SolidWorks flow simulations - Straight pipe (like spacer) and experimentation on spiral forms.

Appendix E

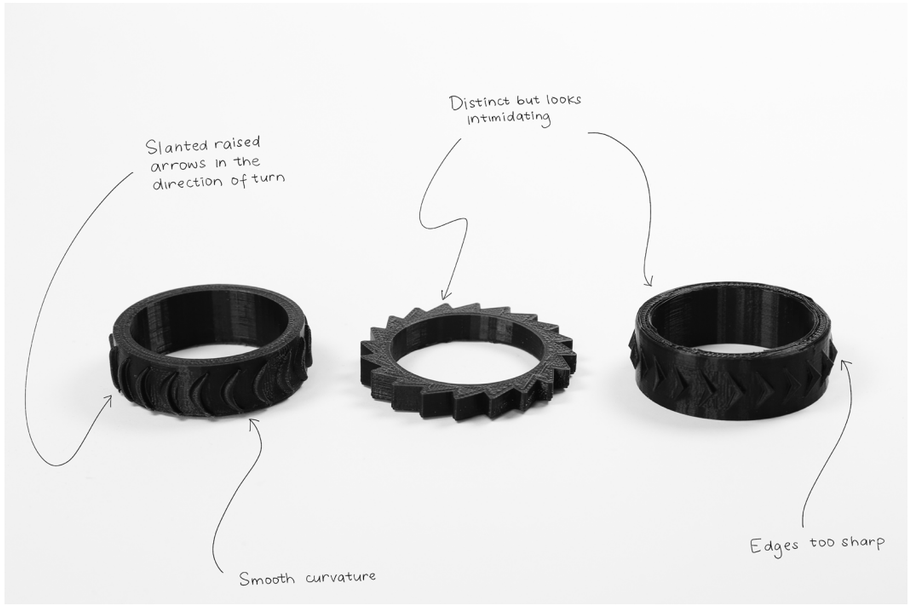
Solidworks Flow Simulations

Simulate Flow of MDI Spray After Dispensing

As one of my aims was to incorporate the function of the spacer into the inhaler itself, I decided to model the flow of the medicine through a spacer after it has been dispensed from the inhaler. I started with a basic cylinder and modelled airflow using the Solidworks Flow Simulation. In consideration of this project being a design project and not engineering-based, and my inexperience with the flow simulation software, I had to simplify the parameters including the medication mist and the 3D forms.

The arrows depicted consistent pressure in the inlet and outlet of the cylinder, since the diameters on both ends were the same. One of the most common methods of reducing the speed of flow is to increase the diameter (H2X Engineering, 2021) – consider flow in pipes, and hence one of the functions of the spacer. However, if the diameter were to increase, this would contradict the intended design as one of the issues was the size of the spacer. A spiral pipe is known to increase drag (Yanuar et al., 2015), thus decreasing the flow speed, and I also had in mind that increasing the length of the “pipe” would mean increasing the time between the medicine being dispensed and flow into the lungs. As a result, I wanted to try design a spiral shape for the inhaler.

It was brought to my attention that an Archimedes spiral model could be better to slow down the flow, while its changing direction would reinforce mixing. I was unsure about whether the Archimedes spiral would integrate well with the design of inhalers as it does not seem to be a discrete form, but it was fascinating to briefly explore the potential. At this point however, I had re-directed the project focus to DPIs, so a flow simulation for this type of spiral was not created.



Patterns on gears that would be rotated may give a visual and physical indication to users about the direction of turn.

Appendix F

Affordances

For Twist Mechanism

As a key part of “good” product design, I recalled affordances and signifiers needing to be considered as they can really improve or degrade the experience with a product. With the turning mechanism of the Turbuhaler, many comments were made in the interview and survey that users were often confused about which way to turn, because it was able to be turned both ways. Although I thought about incorporating a one-way ratchet mechanism into my concepts, it was brought to my attention that having a good signifier could better the product experience as the users will not have to turn both ways first to discover that it only turns one way.

I decided to explore the possibility of a turning mechanism to give the participants more option to select from before developing more refined concepts. 3D models were created on Rhino before they were 3D printed. I felt that the rotational motion for the user was still not an instinctive action compared to buttons, so I decided to develop a more linear mechanism.

Appendix G

Aesthetic Development

Consumer vs Medical Design

During the refinement stage, I sketched out rendered concepts that incorporate metallic elements as part of the inhaler's design. I quickly realised that they looked too much like consumer products, with a "luxurious" appearance, which was not my intention. From this tangent I learned how certain characteristics may only appeal to select audiences, so I needed to be more mindful of the embodiments created from chosen features.

Sketches of rendered concepts that seemed to be too consumer-like.

Laveda Pasang