Hidden In Plain Sight:

Encouraging Asthma Inhaler Usage in Public

Master thesis *Design For Interaction* - faculty of *Industrial Design Engineering*

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Abstract

In the Netherlands an estimated amount of 1.75 million people are suffering from asthma, from which an estimated amount of 300,000 are children. Even though the treatment of asthma has come a long way, nonadherence in asthma patients regarding their treatment remains high. This nonadherence is in part linked to the visual appearance of asthma inhaler devices and the ease of incorrectly interacting with these devices. The combination of using a metered dose inhaler (MDI) with a (valved) spacer chamber significantly decreases the likelihood of device interaction issues, but it worsens the visual appearance of the device, making it the least popular asthma inhaler device and also the least likely to be used in public.

A concept has been developed in order to make the combination of an MDI + spacer chamber more appealing to use amongst younger asthma patients (children), especially in public. This concept consists of a housing which can hold and disguise an MDI + spacer chamber whilst providing an outwardly appearance of a sports water bottle. Interaction with this concept also provides an outwardly appearance as a person who is drinking from a sports water bottle, as opposed to that of a patient who is inhaling from a medical device. This concept aims to provide the advantages of an MDI + spacer chamber whilst simultaneously decreasing factors of embarrassment and/or reluctance to use such a device in public.

Finally a usability study and a user experience (UX) study have been conducted in order to evaluate whether the developed concept performs as intended.

Foreword

This page marks the start of this graduation thesis. In actuality this page is amongst the very final to actually be written for this graduation project and marks to me the finalization of a long process that has consisted of many ups, downs, twists and turns.

First and foremost I want to thank my supervisory team consisting of Ruud van Heur and Iemkje Ruiter for their guidance in this process. I started this graduation project with the idea that it would be a matter of demonstrating my skills as designer (at the time), only to realize that I actually still had to learn quite a few more things if I wanted to successfully leave this university as a graduate. And in all honesty some of the things I still needed to learn were not necessarily related to me as a design student but to me as a human being. For this in particular I want to provide thanks for their advices, discussions and patience with me.

I want to provide thanks to my friends and family as well, in particular my parents and brother, for their support of me. At times the road has gotten quite rough and it made it easy to lose sight of the end goal. Sometimes a simple nudge or a pat on the back can mean the world and I want to thank them for that.

Finally I want to thank you for your interest in this project and for reading this. I hope that you may gain some insights from this thesis.

Rawien Motie

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1 *Introduction*

1.1. Preface

It is estimated that at the time of this writing about 235 million people are suffering from asthma. Amongst children asthma is a common disease and the most common noncommunicable (chronic) disease. Asthma is seen as a public health problem, regardless of country and socioeconomical status. Characteristics of asthma are recurrent attacks of breathlessness and wheezing, which can vary in frequency from patient to patient. Asthma cannot be cured, but it can be controlled through medicine. Appropriate management of asthma can enable patients to enjoy a good quality of life (Asthma, 2017).

In the Netherlands an estimated amount of 1.75 million people are suffering from asthma. From this amount an estimated 300,000 are children. 1 out of 10 children of school attending age are suffering from asthma (Astma | Cijfers & Context | Huidige situatie, 2018). In 2015 asthma related health care costs neared 422 million euros for the Netherlands alone, which is 0.5 percent of the total amount of health care costs in this country. 38 percent of these asthma related health care costs were dedicated to asthma medication and devices/delivery systems. The majority of the asthma related health costs were dedicated to patients in the age groups of 1 – 14 and 40 – 74 years old (Astma | Kosten | Kosten, 2018).

The above mentioned statistics provide an indication of the scope and impact of asthma on society. The treatment of asthma has improved over the course of years in order to make it more accessible and effective. However, articles and stories provided by various sources such as news outlets, documentaries and anecdotes from health care providers and patients themselves, depict that the current treatment of asthma is still sub-optimal at best. Asthma related health care costs could be decreased, whilst simultaneously improving the management and treatment of asthma. There are substantial resources dedicated towards this task from several fields of science, for example by improving the effectiveness of medicine and delivery systems. However, it seems that the skills and resources dedicated towards this task from the field of Industrial Design is minimal at best. There is still substantial room for improvement regarding the treatment of each individual patient, by focusing on issues that go beyond the physiological aspect of this global disease.
For example: even though there is medication available that will improve the physical condition and quality of life for an asthma patient, how can it be ensured that the patient is actually both able and willing to take in this medication when necessary?

1.2. Background

This graduation project is self-proposed, with additional help from Dr. Jean Driessen from the Center of Excellence (COE)*. It is in part a continuation on the results of the project Exploring Interactions* (2015-2016).

In Exploring Interactions an aesthetic redesign of an asthma inhaler was made, primarily targeted towards young exercise induced asthma patients, in order to allow the user to inhale asthma medication in public without attracting any undesired attention. The main reason for this is that (especially young) patients are self-conscious about their appearance and have a tendency to avoid the inhalation of asthma medication when surrounded by peers or in public, which may have a detrimental effect on their personal health.

An aerosol inhaler disguised as a sports bottle was designed and evaluated. This resulted in a positive response of the children and young adults the final concept was tested on, as well as their parents and Dr. Jean Driessen (who was involved during this project as an expert). Due to this a commercial potential in this concept was recognized. A desire to continue working on this project with the intention to bring a finished product on the market was born out of this.

**The Center of Excellence (COE) is a specialized laboratory based in Amersfoort (in the Netherlands) that caters to children and adolescents with respiratory problems. The COE is able to accurately find out whether an individual has a type of asthma or not.. Furthermore the COE is able to consult (in cooperation with the hospital/doctor that treats the patient) in how to progress further with the treatment of asthma. Aside from patients with an average lifestyle, the COE also specializes in the consultancy of asthma patients in the realm of sports and even young athletes.*

Fig.1. Official logo of the Center of Excellence

**Exploring Interactions (EI) is a mandatory design project for the Master study of Design for Interaction within the faculty of Industrial Design Engineering at the Technical University Delft. Each year the course has several topics, defined by faculty researchers with a consortium of stakeholders. Each studio works on one topic and each student defines her or his individual design goal within that topic. The aim of the course is to explore interactions and design interactions within the realm of the chosen topic and progressively find a design solution for the design goal by means of these interactions. Interactions can be found between humans, but also on a human-product level and interactions can be found on a personal and emotional level.*

The project is divided in three phases: in the first IDEATE phase a design goal is formulated and interactions related to the chosen topic are explored and researched. In the second ITERATE cycle a design concept is formed altogether with a rough design model. The design concept is to be evaluated by means of small tests within a certain context. In the final DEMONSTRATE cycle the design concept is to be finetuned and a detailed model is to be made and evaluated by testing it in field with the end user.

The writer of this report worked through the project in a sports related topic with the following design goal: "I want to design something that will help exercise induced asthma patients in team sports to choose a team role that they want to be in." During the project it was found out that there was a general reluctancy from asthma patients to inhale medication in the presence of peers. The end result of this project was a sports water bottle with an integrated asthma inhaler. The thought behind this concept was that a patient would be able to discreetly inhale medication during a team sport session (such as football or hockey) whenever necessary. This would motivate asthma patients to choose a team role as desired, instead of choosing a role that requires the least amount of physical effort by default due to this reluctancy of being seen using a medical/asthma device. A final prototype was tested during football practice with a team that contained several asthmatic players. The results of this evaluation supported the design concept.

Fig.2 (left) and fig.3 (lower left): photographs of a 3d-printed prototype of a sports water bottle with an integrated inhaler, together with a canister cotaining asthma medication.

1.3. What is asthma?

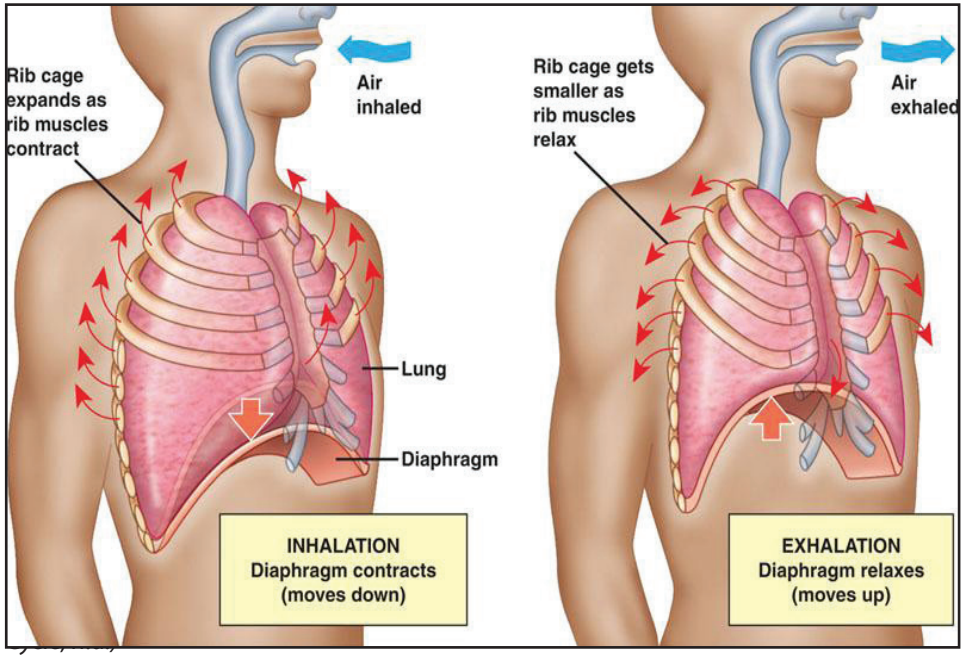
In order to be able to understand the essence of this graduation project, it is important to have a basic understanding of what asthma is. The Global Initiative for Asthma (GINA) is a network comprising of individuals, organizations, health care officials and asthma care experts from around the world and it has a main goal to globally improve asthma care/ treatment. According to GINA asthma is described as the following:

"Asthma is a common, chronic respiratory disease affecting 1–18% of the population in different countries. Asthma is characterized by variable symptoms of wheeze, shortness of breath, chest tightness and/or cough, and by variable expiratory airflow limitation. Both symptoms and airflow limitation characteristically vary over time and in intensity. These variations are often triggered by factors such as exercise, allergen or irritant exposure, change in weather, or viral respiratory infections.

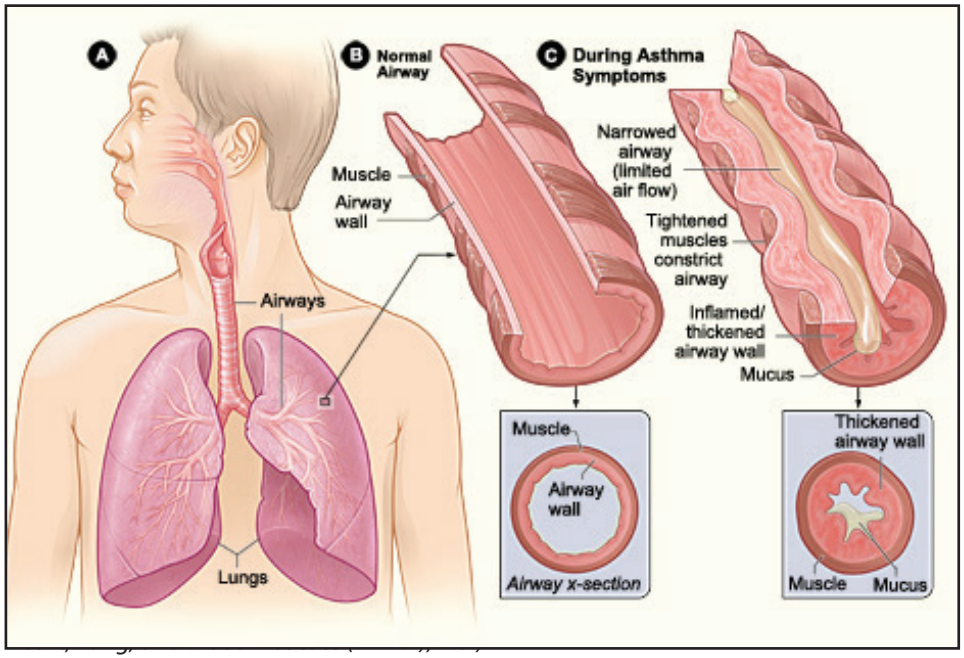
Symptoms and airflow limitation may resolve spontaneously or in response to medication, and may sometimes be absent for weeks or months at a time. On the other hand, patients can experience episodic flare-ups (exacerbations) of asthma that may be life-threatening and carry a significant burden to patients and the community. Asthma is usually associated with airway hyperresponsiveness to direct or indirect stimuli, and with chronic airway inflammation. These features usually persist, even when symptoms are absent or lung function is normal, but may normalize with treatment (Fitzgerald, 2015)."

The gist of what exactly asthma itself is can be explained by the following: In normal breathing, the diaphragm, a large muscle at the bottom of

the chest cavity, contracts, which in turn creates more space in the chest cavity. The increase in space results in the expansion of the lungs to fill in this space, which in turn draws in air through the mouth and nose. This process is known as inhalation/inspiration. Subsequently the diaphragm relaxes, which decreases the space in the chest cavity and forces air out of the lungs. This process is known as exhalation/expiration.



Air is both transported to and from the lungs through tubes/pipes called airways. The mouth, nasal cavities, larynx (voice box), trachea (windpipe) and bronchi (bronchial tubes) are all airways. These airways all contain muscles which control the flow through these passages by either constricting or relaxing. With the exception of the mouth and parts of the nasal cavities, the airways also contain cells that produce mucus. The purpose of this sticky substance is to trap germs and other foreign particles that enter the body together with the inhalation of air (How the Lungs Work | National Heart, Lung and Blood Institute (NHLBI), n.d.). Under normal circumstances the muscles around the airways are in a relaxed state. With asthma the airways are inflamed, which results in swelling and subsequently narrows the airways. Based on certain stimuli, the muscles around the airways constrict which further narrows the airways. On top of this, the production of mucus is also put into overdrive, which narrows down the airways even further (Asthma | National Heart, Lung, and Blood Institute (NHLBI), n.d.).



The diaphragm still works normally; when the lungs expand it gets filled with air. But when the diaphragm relaxes and subsequently forces air

out of the lungs, not all the air is able to escape from the lungs due to the narrowed down airways. Before all the air is able to escape, new air is forced into the lungs due to the constriction of the diaphragm and subsequent expansion of the lungs. This creates a chain effect in which the affected person will start breathing heavier and faster in order to be able to get enough new (oxygen-rich) air into the lungs. But in effect it only increases the amount of (oxygen-depleted) air that stays trapped in the lungs. This experience of shortness of breath or the sensation of not being able to remove the air from the lungs is known as an exacerbation (asthma attack). In severe cases and without treatment, an exacerbation has the potential to be fatal to the affected person. Asthma in general is treatable/manageable by means of asthma medication and therapy, but there is not a cure for asthma (Asthma | National Heart, Lung, and Blood Institute (NHLBI), n.d.).

There are various types of stimuli that can trigger inflammation and further effects of asthma on the airways and each stimulus corresponds to a type of asthma. Examples of more known types of asthma are:

- **Allergic asthma**: asthma triggered by allergic particles such as pollen, animal hairs or dust mites
- **Non-allergic asthma**: asthma triggered by particles such as those found within exhaust gases, perfumes, smoke or (cold) weather conditions
- **Exercise induced asthma**: asthma triggered by physical activity/ exercise
- **Severe/difficult asthma**: asthma from which the triggers or not known and which cannot be controlled through conventional asthma medicine and therapy (Soorten astma - Longfonds.nl, n.d.).

In the context of this graduation project there is not a focus put on a specific type of asthma. If a type of asthma is treatable/manageable by means of conventional types of asthma medication, and can be managed by the patient himself/herself without constant supervision, it qualifies for this project. With this rule in mind it can be said that this project focuses on the majority of asthma types. Conversely, this project does NOT focus on severe/difficult asthma.

1.4. Problem description

The treatment of asthma has come a long way. There is a wide variety of medicine available, together with devices to administer these medicine (asthma inhaler devices). The development of new types of medicine is ongoing, together with new devices. Yet most, if not all of these devices tend to follow certain archetypes, together with their advantages as well as their inherent flaws. And despite this ongoing development, there seems to be a significant problem that is being overlooked by most:

How can it be ensured that (prescribed) inhaled asthma medication actually reaches the lungs of an asthma patient whenever deemed necessary?

Nonadherence in asthma patients regarding their treatment is high and it has remained virtually unchanged during the last two decades (Bender, 2016). Within the context of this project it is identified that there are two main root causes of this nonadherence and both are directly related to the archetypes of these asthma inhaler devices:

1. The psychological aspect of inhaling asthma medication from a device

2. The physical interaction between patient and asthma inhaler device

First and foremost, the act of inhaling asthma medication from an inhaler device is quite visually distinctive; it is an obvious act once it is observed. There is an aspect of shame or embarrassment attached to the use of an asthma inhaler in public, especially amongst younger patients. This can lead to situations in which patients simply will not use their medication when necessary, which can have negative health consequences. An attempt has been made to disguise an asthma inhaler as a water bottle in the previously mentioned Exploring Interactions project, with promising results.

Second, a major problem with current (aerosol) asthma inhalers is that these are easily used incorrectly; it is crucial for the patient to inhale at the exact moment that the asthma inhaler is actuated. It is already quite difficult to achieve this precise timing under “normal” circumstances, it is severely worse during an exacerbation (Price, 2017).

A third problem is partly related to the previous problem is that asthma patients do not always inhale the correct (prescribed) dose of the asthma medication. A common mistake is that patients hold the inhaler at such an angle during use that the spray ejected from the inhaler directly hits the palate or the back of the mouth. Due to this less medication reaches the lungs (Price, 2017). A combination of incorrect use and the patient not always following the prescription leads to situations in which the patient can be either underdosed or overdosed on asthma medication. This can not only have effects on their personal health, but also on society, due to the costs of wasted medicine.

Finally, asthma patients can have a prescribed routine in when they should use their asthma medication. Currently it can be very easy to forget to take the medicine, especially when the patient does not experience any adverse effects at the moment. In the longer term health effects could occur, without the patient (and treating doctor) understanding how these effects are occurring.

It is believed that these problems can be overcome by addressing the two main root causes by designing a new type of inhaler that is more appealing to use and is more user friendly/less prone to user errors.

1.5. Project objectives

This graduation project is divided into the following objectives:

1. Getting to know the current asthma inhaler (archetypes) ; how do these devices work in terms of function and interaction, how do these devices contain the asthma medication etc. But also: what does the market around these devices look like?

2. Finding out for who to design: what are the the characteristics and needs of this target group and how can these catered towards to?

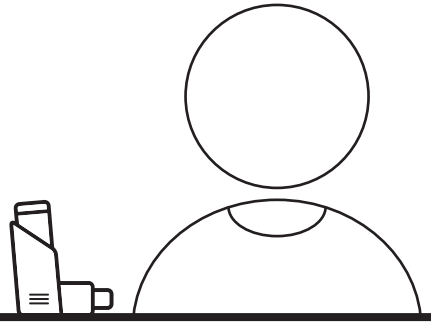
3. Generating ideas and concepts for a new asthma inhaler based on the findings of the previous objectives.

4. Develop a working prototype.

5. Evaluate the developed concept by means of the prototype.

The above mentioned objectives are generally completed in a linear manner and the completion of the objectives corresponds to the completion of one full design cycle.

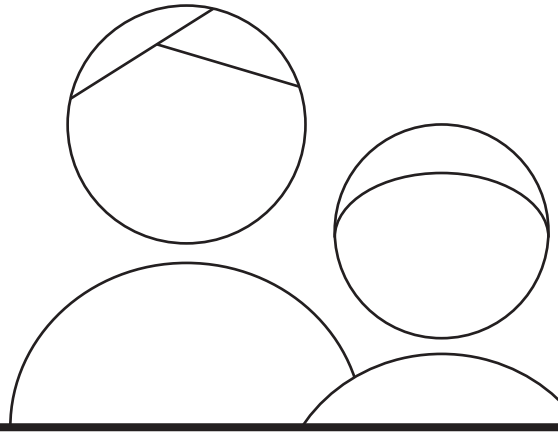
1.6. Stakeholders



The target user group:

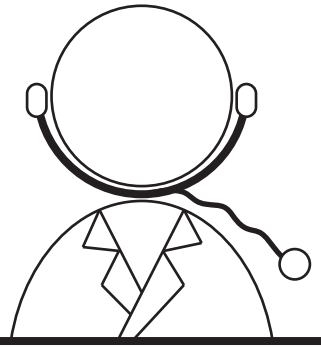
Asthma patients between the age of 6 and 18 years old.

These school-going children and adolescents are the primary users of the designed product. Depending on the age, this main user needs to at least understand how to use the primary functions of the product by him or herself. If the main user is of an older age, it is expected that he or she is also able to use any secondary functions without any supervision.



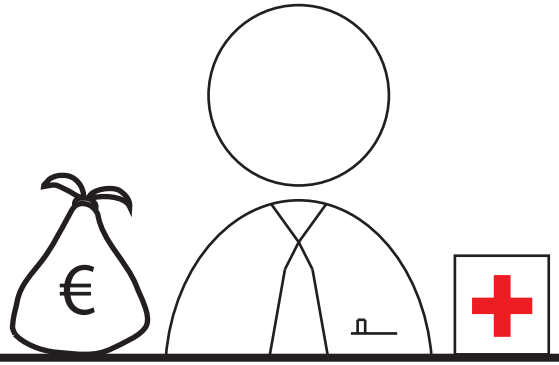
Parents/guardians of the target user:

They need to be able to provide additional guidance to the asthma patient in case of uncertainties regarding usage of the product. This means that they need to understand the workings of the designed product in both primary and secondary functions.
For example: perhaps a young asthma patient knows how to inhale from the product, but it is his/her parents who perform the maintenance related tasks, such as cleaning the product.



Health care providers:

These provide asthma patients with professional care, such as by formulating an asthma treatment plan and providing prescriptions for asthma medication.
Health care providers need to understand the designed product fully, as they need to be able to not only provide guidance to the patient regarding product usage, but also to their parents/guardians. Health care providers need to be able to answer questions regarding the product.



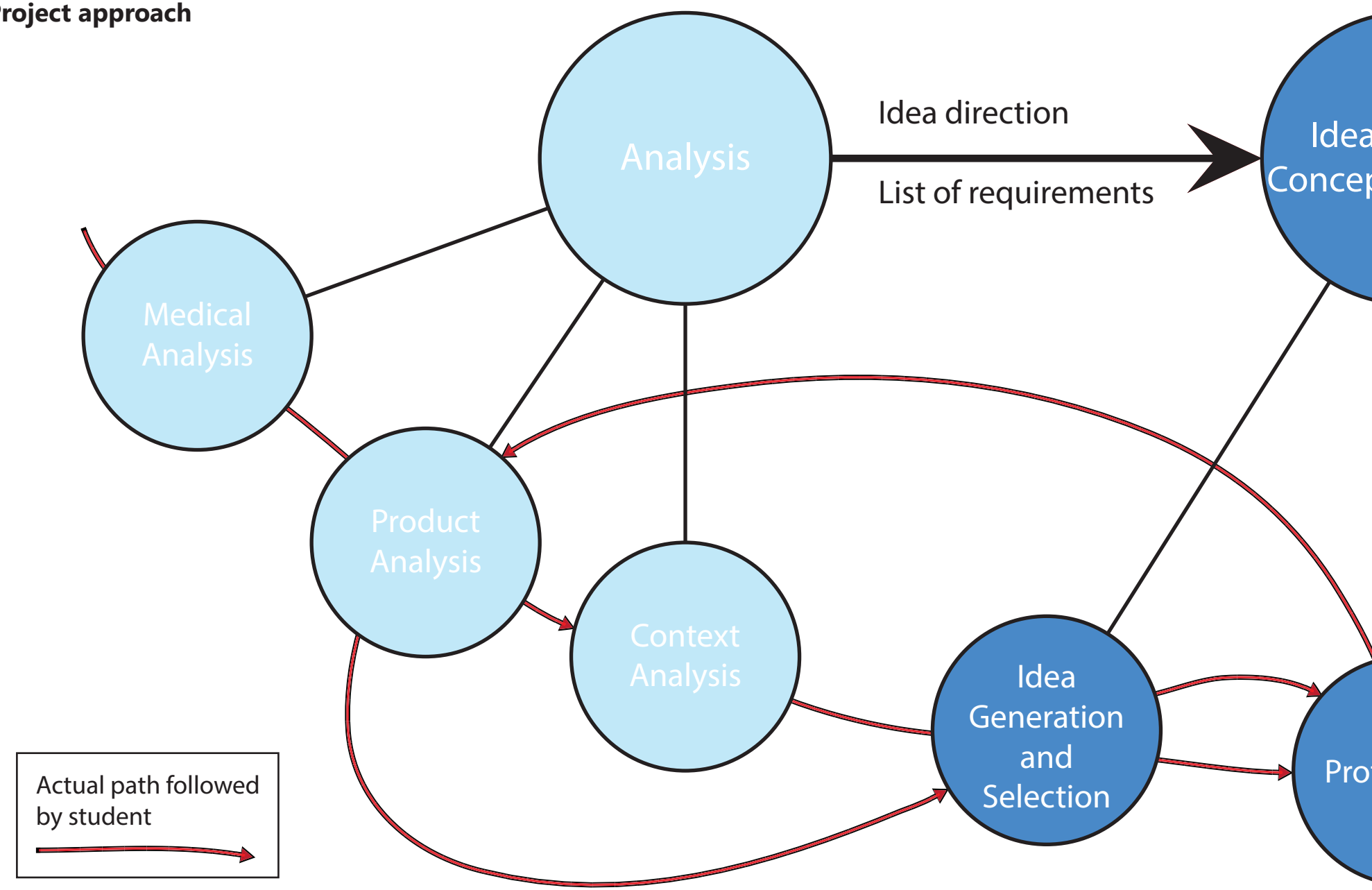
Health insurance companies:

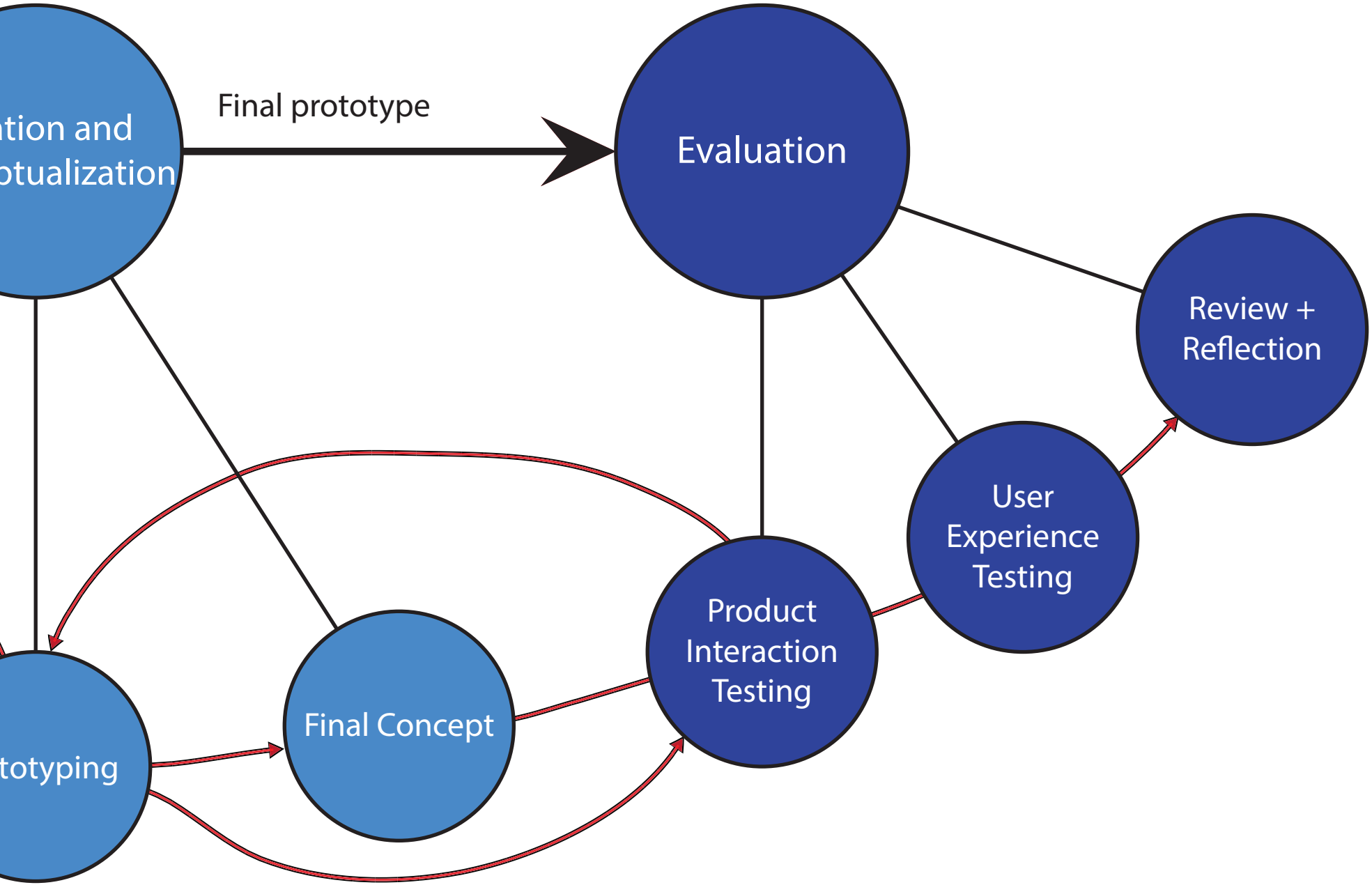
These companies provide financial compensation of insured medication and health aids. Health insurance is influenced by medicine and aid device costs. These companies could potentially have an interest in the designed product if it could be proven that it will lead to a lower overall cost of asthma medication due to less wastage of prescribed asthma medication.
An health insured product will be able to reach a wider audience compared to a private vendor selling the same product.

Pharmacies:

Pharmacies are distributors for various types of (prescribed) medicine and health aids.
Pharmacies could be a potential way to get the target user group in contact with the designed product, as many pharmacies do offer various types of asthma medicine and aids for asthma patients.

1.7. Project approach

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Product
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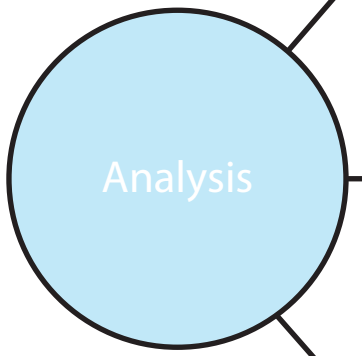
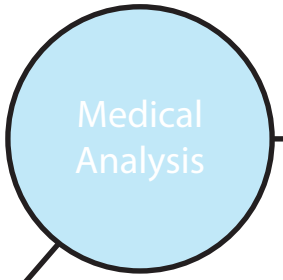
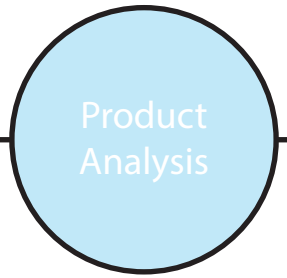
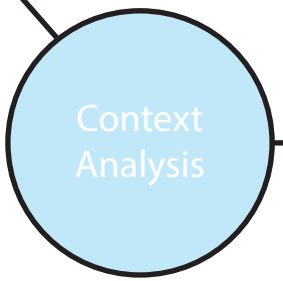
2 *Analysis*









What?

Analysis within a medical context; what are current treatments of asthma and approaches towards asthma treatments?

Why?

To find out what aspects of current asthma treatments and approaches are working, and more importantly: what can be improved upon?

What?

Analysis of (inhalation) products that are currently used for the personal treatment of asthma.

Why?

To find out what the pro et contra are for each type of product and to choose one of these types to improve upon by means of a (re)design.

What?

Analysis of the patient and his/her environment within the context of his/her personal treatment.

Why?

To gain a deeper understanding of the treatment of asthma from the perspective of the patient him/herself. This knowledge will be used to evaluate the initial design direction with and to explore other design opportunities.

2.1. Medical analysis

The medical analysis has been conducted by means of a literature research in order to find answers on the following questions:

- **How is asthma being treated?**
  What is the involvement of the patient within this procedure?

- **What are the components of an asthma treatment?**
  In which respects is the patient in control of reaching a successful treatment?

- **In what aspects is the current treatment of asthma in need of improvement?**
  How can the current treatment of asthma be improved regarding the involvement of the patient?

The answering on these questions will help in gaining a better understanding of the treatment of asthma , and more specifically, it will help in finding directions regarding the improvement of the current asthma inhaler that goes beyond the obvious.

The overall treatment of asthma

Worldwide there are different examples of strategies to systematically decrease the burden of asthma. The successful strategies generally boil down to one main strategy: the asthma treatment plan (Global Asthma Network, 2014).

The asthma treatment plan is a document tailored towards an individual asthma patient and serves as a guideline to which the patient should adhere to. The creation of this asthma treatment plan is a joint operation between the asthma patient, health care providers and possibly caretakers of the patient. This treatment plan contains several aspects, such as which types of medicine to use, which actions to undertake during emergency situations and contact data of health care providers for emergency purposes. But the treatment plan can also contain personal goals related to the lifestyle of the patient and how to work towards these goals (Long Alliantie Nederland, 2012).

Certain aspects of this treatment plan are beyond the control of the patient (e.g. the types of prescribed medicine), but to a certain degree the patient is able to exert control over this treatment plan and the subsequent success or failure of it. Within the context of this project, the asthma treatment plan can be seen as combination of two major components:

1. The medicinal treatment of asthma:

Medicine prescribed by healthcare providers to be used by the patient in order to combat the physiological effects of asthma and/or to (temporarily) prevent the occurring of physiological effect of asthma.

2. The self-management of the patient within the treatment of asthma:

The involvement of the patient in making sure that the prescribed medicine is taken in during appropriate times and situations. But also the personal involvement in minimizing the risks of exposure to asthma and the prevention of worsening of asthma.

Both components are of utmost importance for the treatment of asthma, but within the context of this project the self-management of the patient plays the most significant role and will be discussed more in-depth further in this chapter. For the sake of completion though, the medicinal treatment of asthma will be briefly explained.

Actieplan astma kinderen

Neem dit actieplan mee naar ieder bezoek aan de arts!

Naam:

Naam arts:

Noodnummer: [binnen kantooruren]

[buiten kantooruren of weekend]

Het gaat goed

Neem dagelijks

Ontstekingsremmer:

[naam en dosering]

Overige medicijnen:

[naam en dosering]

Voor het sporten of

Luchtwegverwijder:

[naam]

Neem ____ (blauwe) pufs

❑ Gebruik een voorzetkamer

Overige afspraken:
[bijv. bewegen, prikkels]

Het gaat minder

astmaklachten nemen toe

Actie

Luchtwegverwijder:

[naam]

Neem ____ (blauwe) pufs

❑ Gebruik een voorzetkamer

Kijk na 10-15 minuten hoe het gaat.

Astmaklachten weg
Ga naar **groen** - het gaat goed

Astmaklachten verbeteren, maar niet weg
Neem maximaal ____ (blauwe) pufs, per ____ uur.
Indien klachten langer duren dan
neem contact op met
Indien astmaklachten verdwijnen, ga terug naar **groen**.

Astmaklachten blijven bestaan
Ga naar **rood** - ernstige astmaklachten

Overige afspraken:
[bijv. medicijnen]

Het gaat slecht

ernstige astmaklachten

Actie

Luchtwegverwijder:

[naam]

Neem ____ (blauwe) pufs

❑ Gebruik een voorzetkamer

Neem direct contact op met:

Naam:

: [binnen kantooruren]

Naam:

: [buiten kantooruren of weekend]

Overige afspraken:
[bijv. medicijnen]

Het gaat goed

Symptomen:

❑ Geen benauwdheid / kortademigheid, piepen, hoesten overdag of 's nachts
❑ Kan normaal deelnemen aan activiteiten
❑ Geen klachten bij inspanning
❑

LONG FONDS
Voorheen Astma Fonds
Strijd mee voor gezonde lucht en gezonde longen

Het gaat minder

astmaklachten nemen toe

Mogelijke signalen:

❑ Benauwdheid / kortademigheid
❑ Piepen
❑ Hoesten
❑ Wordt 's nachts wakker door astmaklachten
❑

Het gaat slecht

ernstige astmaklachten

Mogelijke alarmsignalen:

❑ Verslechtering / achteruitgang van:
  ❑ Benauwdheid / kortademigheid
  ❑ Piepen, ook in rust
  ❑ Wordt 's nachts wakker door astmaklachten
❑ Toenemende snelle ademhaling
❑ Moeite met praten (korte zinnen) door benauwdheid
❑ Gebruik van hulpademhalingsspieren, zoals neusvleugelen, intrekkingen en/of opgetrokken schouders
❑ Luchtwegverwijder helpt niet of niet voldoende of korter dan ___ uur.
❑ Onrustig of angstig zijn van/door benauwdheid
❑ Opvallend stil bij benauwdheid
❑

vermijd prikkels

❑ Huisstofmijt
❑ Pollen
❑ Rook
❑
❑ Huisdier
❑ Parfum
❑ Mist
❑

Goed inhaleren
Bekijk op inhalatorgebruik.nl de filmpjes en de gebruiksaanwijzingen over goed inhaleren.
Deze zijn te downloaden of printen. Laat één keer per jaar controleren of het kind goed inhaleert.

Neem altijd de luchtwegverwijder mee!

Dit actieplan is gerealiseerd via een gezamenlijke werkgroep van Longfonds, NVK-SKL, CAHAG en Taakgroep kinderlongverpleegkundigen en Verpleegkundig specialisten kinderlongziekten en aanverwante aandoeningen. Longfonds ©2017

Fig.6 (left): Example of an asthma treatment plan for children (in Dutch). This treatment plan provides space for advice, information and agreements/personal goals for three types of scenarios; when there are no negative effects regarding asthma (green area), when there are some negative effects(orange area) and when there are severe negative effects (red area). The blue area provides space for information regarding allergies.

Medicinal treatment

The medicinal treatment of asthma has quite a few intricacies that go way beyond the scope of this project. On a very basic level only the following is relevant for this project:

Medicine is used to either **prevent** (or control) the physiological aspects of asthma from occuring, or to **counter** (or relieve) the physiological aspects of asthma that have occurred (e.g. exacerbation). Types of medicine that are used for the former are called **controller medication**, types of medication that are use for the latter are called **reliever medication**.
The primary means of administering these medicine are through inhalation, by means of an inhalation device (e.g. asthma inhaler).

Self-management

From a medical perspective self-management can be defined as *"the tasks that individuals must undertake to live with one or more chronic conditions. These tasks include having the confidence to deal with medical management, role management and emotional management of their conditions"* (Pinnock, 2015).

Based on the abovementioned explanation, self-management can encompass quite a wide range of topics. When applied within the scope of this graduation project, there are four specific areas of interest:

- **Health literacy**
- **Preventive measures**
- **Treatment plan adherence**
- **Inhaler technique**

Health literacy is a combination of three skillsets: (1) navigational skills, (2) literacy skills and (3) numerical skills (Rosas-Salazar, Apter, Canino, & Celedon, 2012). An adequate level of these skillsets in a patient increases the likelihood of successful decision making regarding medical situations. Examples of tasks related to these skillsets within the context of asthma are: (1) determining when and where to go in the case of an emergency, (2) understanding what is written in an (personalized) asthma treatment and how to utilize this information and (3) counting and/or estimating how many doses of asthma medication one has left so that a new supply of medication can be obtained in a timely manner.

Preventive measures are measures/actions undertaken to avoid stimuli that exacerbate the effects of asthma. The exact stimuli may differ per specific type of asthma, but in general examples are (cigarette) smoke, unhealthy weight gain, pollen/pet dander and cold weather (Long Alliantie Nederland, 2012).

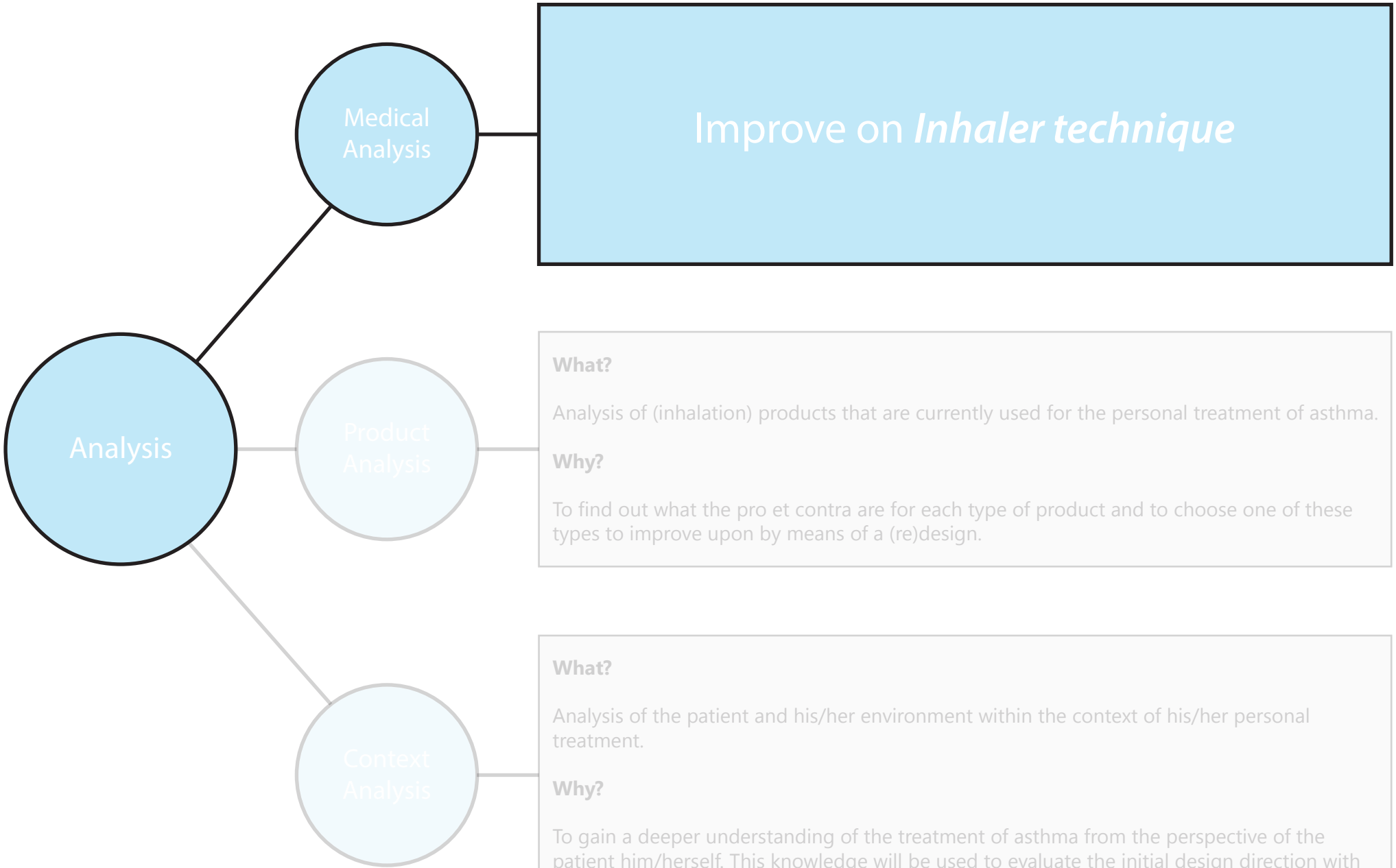
Treatment plan adherence refers to the patient's ability and willingness to comply with the guidelines and agreements as stated in their personal treatment plan. The benefits of this adherence is not only for the patient in that it provides guidance, but it is also for the health care provider. By monitoring the patient, the health care provider will be able to deduct what is working and what is not working as intended from the treatment plan. The health care provider will be able to adjust the treatment plan in order to achieve the desired effects.
Failure to adhere to this treatment plan may provide an incorrect image. In the case of less than desired effects in patients, the health care provider may incorrectly adjust the treatment plan under the assumption that the patient followed all the stated guidelines. This can lead to misdiagnoses and increased health care costs, due to for example increased prescribed medicine doses, whilst not necessary in reality. Non-adherence in asthma can be both non-intentional (e.g. forgetting to take a dose of medicine) and intentional (e.g. willfully not taking in medicine because the patient does not actively perceive its intended effects) (Lindsay & Heaney, 2013).

Inhaler technique is an important factor in whether a patient receives a sufficient or insufficient amount of medication per self-administered dose, as the primary means of medicating in asthma occurs through a type of inhalation device. Inhaler technique refers to the ability to properly use an inhaler device in order to self-administer a type of medication to their lungs.
The usage of an inhaler is a skill that must be learned and maintained in order for the medication to be delivered effectively (GINA, 2015). Improper inhaler technique can compromise the delivery of the inhaled medication to the lungs. Patients with incorrect inhaler technique are significantly more likely to have poorly controlled asthma and more emergency department visits (Carpenter, Roberts, Sage, George, & Horne, 2017).
Globally, up to 70-80% of asthma patients are unable to use their inhaler correctly. Most patients with incorrect inhaler technique are unaware that they have a problem (GINA, 2015).

Conclusion

The main opportunities for improvement are within the theme of self-management. In principle all four components of self-management (*health literacy, preventive measures, treatment plan adherence, inhaler technique*) could provide interesting opportunities for improvement from an industrial design perspective. However, health literacy, preventive measures and treatment plan adherence are components in which health care providers are already able to exert a certain amount of influence and awareness. Plus there are programs and campaigns from health foundations such as *Longfonds* which provide further awareness. Furthermore, the most obvious way to improve on these three components is by providing/increasing awareness in the patient.

Inhaler technique stands out for two main reasons; in contrast to the other components it demands physical interaction between product and patient and literature suggests that a large majority of patients is incapable of properly handling an asthma inhaler. The latter is surprising as the main method of asthma medicine administration is through inhalation. An improvement in this area could have major ramifications: it could significantly increase the quality of life for patients due to proper medicine administration and it could significantly decrease health care costs due to less wasted medicine due to improper medicine administration. Therefore the decision has been made to focus on the improvement of inhaler technique.


Analysis
Medical Analysis
Improve on *Inhaler technique*
Product Analysis
What?
Analysis of (inhalation) products that are currently used for the personal treatment of asthma.
Why?
To find out what the pro et contra are for each type of product and to choose one of these types to improve upon by means of a (re)design.
Context Analysis
What?
Analysis of the patient and his/her environment within the context of his/her personal treatment.
Why?
To gain a deeper understanding of the treatment of asthma from the perspective of the patient him/herself. This knowledge will be used to evaluate the initial design direction with and to explore other design opportunities.

2.2. Product analysis

The administering of asthma medication through an inhaler device is a major part within the treatment of asthma. As of this writing there is a substantial amount of asthma inhalers devices available on the market. These inhalers can differ widely based on the type of medication that is utilized through the inhaler, as well as in how the inhaler is designed in terms of form and interaction.
Despite the abundance of asthma inhalers currently on the market, there are still opportunities for improvement. Many inhalers are used sub-optimally, which in turn can result into uncontrolled asthma and increased health care costs (Price, et al., 2013).
The main aim of this product analysis is to find one type of inhaler to improve upon and to determine how to improve upon it. This is done by finding out which types of asthma inhalers are being used at the time of this writing, how these inhalers are supposed to be used and what the advantages and disadvantages of these inhalers are.

On an overall level asthma inhalers can be categorized into three distinctive groups (Hossny, et al., 2016):

- **Metered-dose inhalers (MDI),** which can be used as a standalone device or together with a **spacer chamber**
- **Dry powder inhalers (DPI)**
- **Nebulizers**

**There are asthma inhaler devices available which do not necessarily share the main characteristics of the above mentioned device groups, but these will not be discussed within this sub-chapter as the amount of these devices is too numerous to cover all.*

Fig.7 (right-top): Child using a MDI
Fig.8 (right-middle): Child using a DPI
Fig.9 (right-bottom): Child using a nebulizer

Metered-dose inhalers (MDI)

The generic MDI is a "L-shaped" device which exists out of three major physical components: (1) the canister or container containing a mixture of asthma medication and a propellant, (2) a metering valve attached to the canister and (3) an actuator through which the patient can eject and inhale the medication in the form of an aerosol by pressing in the canister (Newman, 2005).

There are several types of MDI's available on the market. Most use the design of a typical MDI, with the main (or only) difference between these MDI's being the medication stored inside the canister. However there are several other types of MDI's available from which the design does deviate from the typical MDI. Reasons for the change in design are mainly to improve upon the ease of use and to subsequently decrease the possibility of errors in usage. One such example is a breath actuated MDI, which ejects an aerosol by breathing in from the device as opposed to pressing in a canister. Still, the generic MDI remains to be the most popular type of inhaler to use for treatment (Sanchis, Corrigan, Levy, & Viejo, 2013)

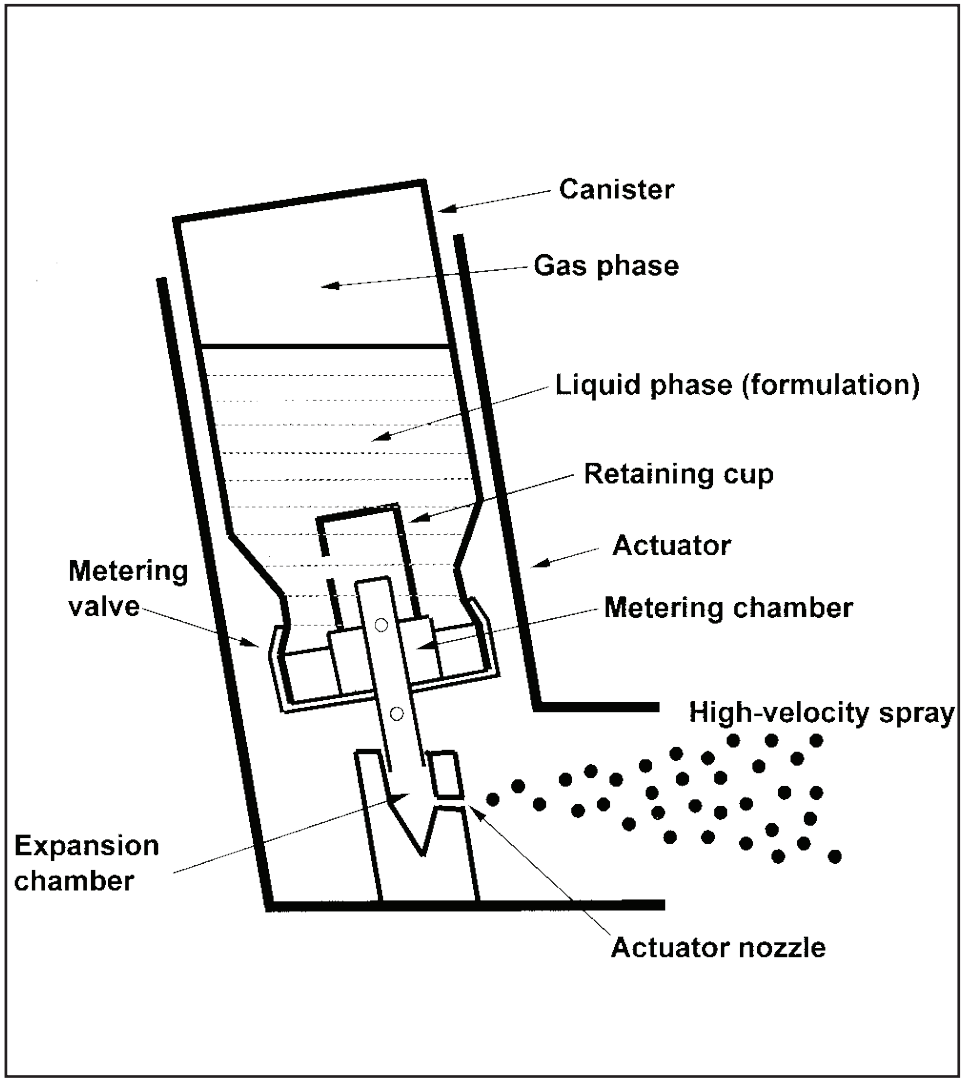


Fig.10. Schematic of a typical MDI (Newman, 2005)

Metered-dose inhaler + spacer chamber

Spacer chambers (also referred to as spacers/spacer chambers/holding devices) are add-on devices for generic MDIs, for which it serves as an external aerosol reservoir. Through the spacer chamber the velocity of the ejected aerosol is decreased and both the distance between the MDI and the patient's mouth and the transit time of the aerosol increased. This allows the size of the ejected particles to decrease and consequently increase the deposition of the aerosol particles in the lungs. Furthermore, spacer chambers trap large particles which can compromise up to 80% of the aerosol dose, which in turn significantly reduces the amount of the dose that is deposited on the patient's oropharynx. This in turn reduces side effects such as throat irritation, which is associated with drug delivery through the MDI alone (Lavorini, 2013).

Spacers chambers can be categorized in two groups: regular spacers and valved holding chambers. Despite the differences, both groups are frequently (and informally) referred to under the generic moniker of spacers or spacer chambers. Regular spacers are simple, open tubes that can be attached to the mouthpiece of an MDI. Valved holding chambers are spacers that contain a one-way valve that truly traps an aerosol plume after actuating an MDI and will only release the aerosol plume until the patient inhales (Lavorini, 2013). Valved holding chambers can be considered as superior to regular (non-valved) spacer chambers and are preferred over regular spacer chambers from a health care perspective (Nikander, Nicholls, Denyer, & Pritchard, 2014).

Size differences exist between spacers in terms of volume, in which larger volume spacers (750ml or more) are associated with a greater lung deposition. Ideally a compromise is needed between a volume that is large enough to improve lung deposition, and small enough to improve upon ease of use, portability and patient compliance (Nikander, Nicholls, Denyer, & Pritchard, 2014).
In the case of valved holding chambers alone, due to that an actuated aerosol plume is only released from the valved holding chamber if a patient inhales, it can be considered as a "breath actuated" device (Nikander, Nicholls, Denyer, & Pritchard, 2014). Because of this, valved holding chambers are one solution to overcoming the coordination issues between actuation and inhalation when using an MDI alone.

Fig.11. Child using an MDI with spacer chamber, or more specifically, a valved holding chamber

Dry powder inhalers

DPIs were designed with the aim to eliminate the coordination difficulties that were inherent with MDIs. Asthma medicine formulation is stored inside the DPI in a powdered form. This can be in single dose capsules, which need to be broken/punctured by the device before inhalation, or in blisters or powder reservoirs from which a metered dose is moved around inside the device (Fernández Tena & Casan Clarà, 2012).

Unlike with MDIs, there is not one typical version of a DPI as they can vary widely in design. There is one main characteristic though and that is the use of a powdered drug formulation instead of a drug formulation that is either dissolved or suspended in propellants in the case of an MDI. Instead of the drug formulation being ejected forcefully from the device by propellants as the result of one actuation (with an MDI), with a DPI the device is actually actuated by the respiratory flow of the patient, making the DPI a breath actuated inhaler device. This eliminates the issue of coordination which exists in MDIs (Lavorini, 2013). In contrast with the MDI, a DPI requires a forceful and deep inhalation in order to ensure that the drug formulation is actually delivered to the lungs (Lavorini, 2013).

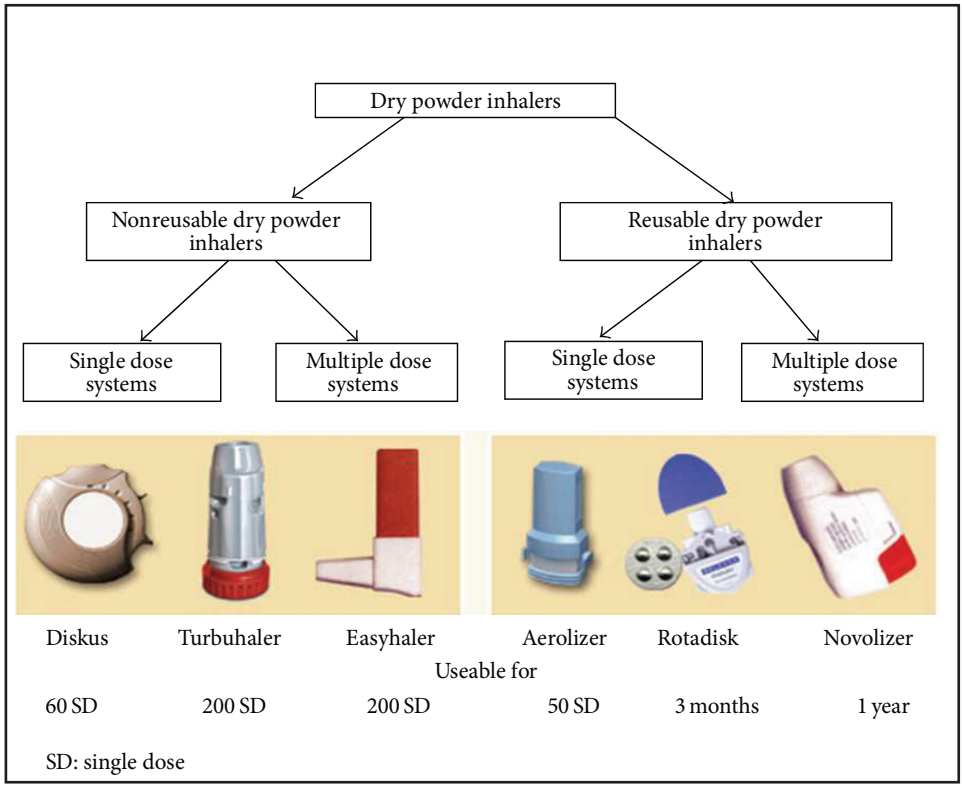


Fig.12. Overview of several "mainstream" DPI types (Lavorini, 2013)

Nebulizers

Nebulizers are devices which hold asthma medication in liquid form and turn this liquid into an aerosol using various techniques.
Currently there are three general types of nebulizers available; jet nebulizers, ultrasonic nebulizers and wire mesh nebulizers, with jet nebulizers being the most common type (Lavorini, Fontana, & Usmani, New Inhaler Devices – The Good, the Bad and the Ugly, 2014).

In general nebulizers utilize a larger volume of medication in comparison with MDIs and DPIs. The main difference between nebulizers, and MDIs and DPIs, is that nebulizers are able to deliver one single dose of medication over multiple breaths without the need of specific breathing techniques that are associated with the other inhaler devices. Typically a nebulizer takes 10-15 minutes to deliver a single dose of asthma medication to the patient (Dalby & Suman, 2003).

Nebulizers are significantly larger than MDIs and DPIs and require some sort of power supply. Together with other side effects depending on the type of nebulizer, such as noise generated by a compressor for jet nebulizers, nebulizers are more suited for home or hospital use and not so much for other environments due to a lack of convenience. Furthermore, it is suggested that nebulizers are no more effective than MDIs that are used in combination with spacer chambers, for both normal usage and during asthma exacerbations. This has clinical implications as the use of MDIs with spacer chambers during acute asthma results in lower hospital admission rates compared with nebulizer use. Besides this there are also significant cost savings possible for both individual patients as well as hospitals as the combination of MDI and spacer chamber is significantly lower than nebulizers (Mitselou, Hedlin, & Hederos, 2016).

Fig.13. Picture of a jet nebulizer.

Comparison of inhaler types

In order to be able to make a proper decision regarding which inhaler type to focus on, a comparison has been made between these types. Both the main advantages and disadvantages have been listed next to each other so that it is easy to see how each type compares to the others.

Metered-dose inhalers

+ *MDIs are generally inexpensive (Gupta, 2009)*

+ *MDIs are widely available for most inhaled medicines (Gupta, 2009)*

+ *MDIs are portable and compact (Chrystyn & Price, 2009)*

+ *The use of an MDI requires no preparation (Chrystyn & Price, 2009)*

+ *There is no contamination risk within MDI's (Chrystyn & Price, 2009)*

+ *MDIs carry a high amount of doses, with at least 200 metered doses (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)*

- *Coordination of breathing and actuation needed (Chrystyn & Price, 2009)*

- *Most patients inhale too fast (Chrystyn & Price, 2009)*

- *Inefficient lung deposition (Chrystyn & Price, 2009)*

- *High oropharyngeal deposition (Chrystyn & Price, 2009)*

- *The majority of traditional MDIs do not have a dose counter; the number of remaining doses can be difficult to determine (Chrystyn & Price, 2009)*

- *An estimated one in ten patients will stop inhaling (properly) due to a phenomenon called the "cold Freon" effect (Chrystyn & Price, 2009)*

MDI + spacer chamber

+ *Requires less coordination than an MDI alone (Chrystyn & Price, 2009)*

+ *Reduces oropharyngeal deposition compared with an MDI alone (Chrystyn & Price, 2009)*

+ *Spacer chambers are convenient for use during acute exacerbations (Chrystyn & Price, 2009)*

+ *Improves the lung deposition compared with an MDI alone (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)*

+ *Large drug doses are delivered more conveniently through a spacer chamber (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)*

+ *Device competence of spacer chambers is higher compared to both MDIs and DPIs (Brennan, Osman, Graham, Critchlow, & Everard, 2005)*

- *Spacer chambers are prone to static and require special washing instructions due to this (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)*

- *Spacer chambers are less portable than MDI's alone (Chrystyn & Price, 2009)*

- *Patient compliance for (continuous) spacer chamber use is low (Brennan, Osman, Graham, Critchlow, & Everard, 2005)*

Dry powder inhalers

+ DPIs are breath-actuated and therefore do not require any breathing related coordination (Chrystyn & Price, 2009)

+ DPIs do not use propellants which make these more environment friendly (Chrystyn & Price, 2009)

+ Most DPIs have built-in dose counters, eliminating the need to manually count the amount of left over doses (Chrystyn & Price, 2009)

+ DPIs are small and portable (Chrystyn & Price, 2009)

- Not all DPIs are multidose devices (Chrystyn & Price, 2009)

- The emitted dose from the DPI is dependent on the inspiratory flow of the patient/user (Chrystyn & Price, 2009)

- DPIs require a fast acceleration rate at the start of the inhalation (Chrystyn & Price, 2009)

- DPIs are unreliable for use during acute exacerbations (Chrystyn & Price, 2009)

- Usage can result in a high oropharyngeal deposition (Chrystyn & Price, 2009)

- DPIs are more expensive than MDI's (Chrystyn & Price, 2009)

- Most DPIs are sensitive to moisture (Fernández Tena & Casan Clarà, 2012)

- No advantage over MDIs in relation to amount of medication that reaches the lungs (Fernández Tena & Casan Clarà, 2012)

- DPI's provide no feedback to the patient in the instance of a successful inhalation (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)

- DPI's are prone to dose preparation related errors (Lavorini, The Challenge of Delivering Therapeutic Aerosols to Asthma Patients, 2013)

Nebulizers

+ Nebulizers do not require any patient coordination (Dolovich, et al., 2005)

+ It is possible to modify the dosage with a nebulizer (Dolovich, et al., 2005)

- Lack of portability (Dolovich, et al., 2005)

- Lengthy treatment time (Dolovich, et al., 2005)

- Requires device cleaning (Dolovich, et al., 2005)

- Requires device preparation before treatment (Dolovich, et al., 2005)

- Significantly higher cost compared to other types of asthma inhalers (Dolovich, et al., 2005)

- Depending on the type of nebulizer, requires either a pressurized gas source or an electrical power source (Dolovich, et al., 2005)

- There is a risk for contamination between uses (Dolovich, et al., 2005)

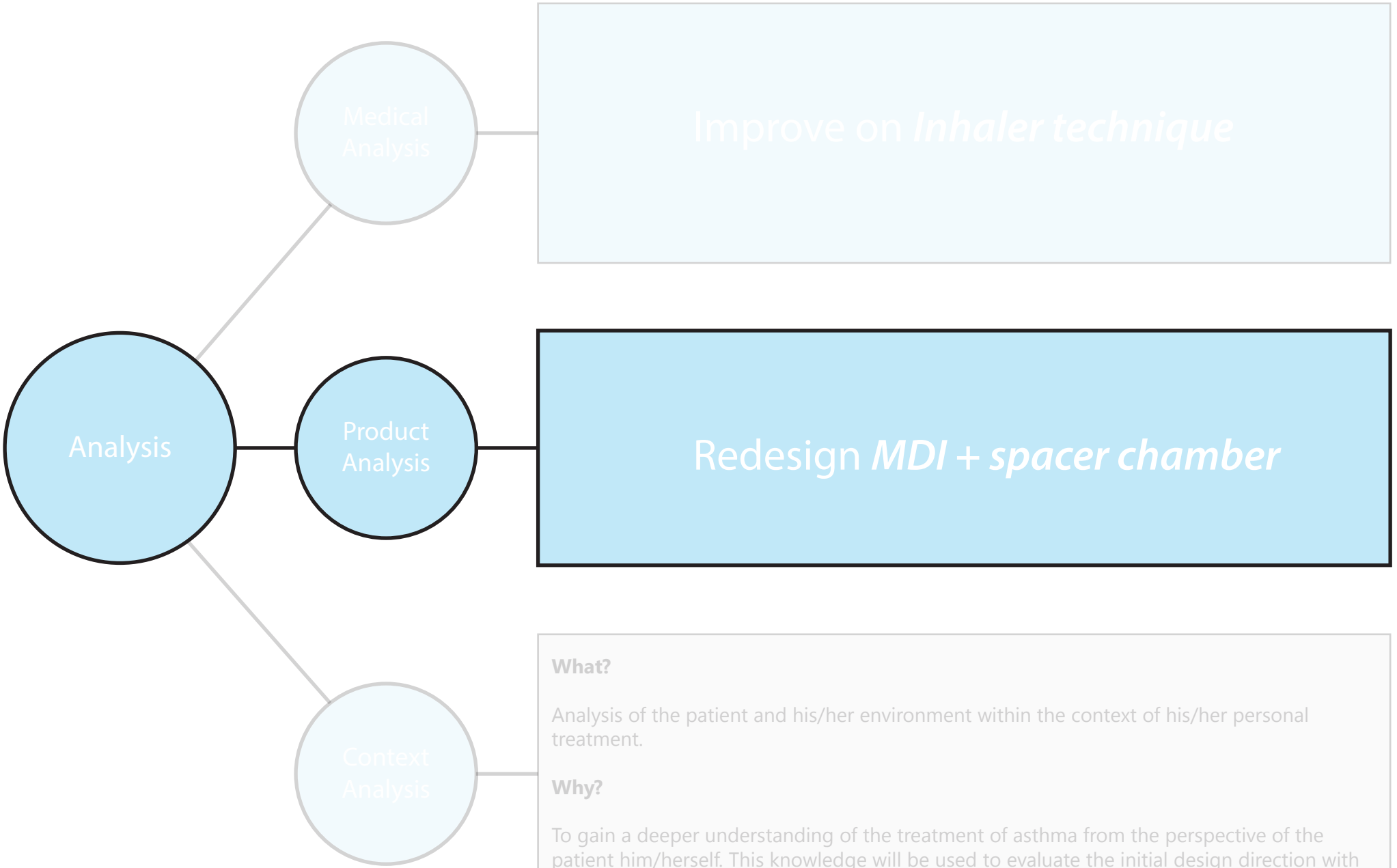
Conclusion

As can be seen in the comparison between the four inhaler types, MDIs and DPIs have clear advantages over nebulizers due their portability and for that these do not require an (external) power source. For these two reasons alone nebulizers are not suitable to focus on within the scope of this project.

Significant disadvantages are that MDIs require a strict coordination between actuation and inhalation and that DPIs require a firmer inspiratory flow in order to actuate the device. This means that a certain physical skill level/fitness is required for correct usage of these devices, regardless of any circumstances that the patient is in. Under "regular" circumstances correct usage may prove to be difficult already, especially for (young) children and the elderly. This difficulty of correct usage is increased during less than ideal circumstances, such as during an asthma exacerbation.

MDIs in combination with a spacer chamber have the same main advantages as MDIs and DPIs whilst it simultaneously negates the main disadvantages associated with MDIs and DPIs: coordination difficulties and requirement of a firm inspiratory flow respectively. On top of this the efficiency of the inhaled medicine is increased as well. There is one caveat; the compliance rate of spacer chamber usage is low compared to MDIs and DPIs. This low compliance rate is linked to the larger size and more obvious appearance of MDIs combined with spacer chambers. However, there is potential for a higher compliance rate by means of a redesign; the appearance of the MDI with spacer chamber can for example be made less obvious.

Because of the advantages MDIs combined with spacer chambers offer over standalone MDIs and DPIs and a lack of any true disadvantages on a usability or functional level, the decision has been made to focus on a redesign of the MDI in combination with a spacer chamber.


Analysis
Medical Analysis
Product Analysis
Context Analysis
Improve on *Inhaler technique*
Redesign *MDI + spacer chamber*
What?
Analysis of the patient and his/her environment within the context of his/her personal treatment.
Why?
To gain a deeper understanding of the treatment of asthma from the perspective of the patient him/herself. This knowledge will be used to evaluate the initial design direction with and to explore other design opportunities.

2.3. Context analysis

An analysis has been performed on the context of use as well. This has been done in order to gain insights from the perspective of the patient, regarding the use of asthma inhalers. Furthermore, this graduation project is based on certain findings which were found in the project Exploring Interactions prior to this project; this contextual analysis is in part performed to validate these findings. Finally, as this project started with an initial design direction (asthma inhaler designed as a drinking bottle), this analysis is also used to evaluate whether it is still interesting/ appropriate to continue with this design direction or if there are other interesting design directions to head into.
The contextual analysis consists out of two parts:

- **Interviews**
- **Context-mapping sessions**

Interview setup

Five patients from both genders have been interviewed in the range of 11-21 years old. A predefined set of questions has been formulated, with the option to deviate from these questions in the case of interesting/ noteworthy answers. This predefined set of questions can be found in Appendix A. The interviews have been conducted in person. The interviews were mainly formulated to gain an understanding about the situations in which asthma inhaler usage occurs in terms of both location ("where does the usage occur?") and people involved in these situation ("is the patient alone or not; who are also involved?"). Furthermore, the interviews explore the emotions that the patient experiences within these situations.

Interview findings

A summary of the most significant findings is presented here and is the following:

- 3 patients use MDIs (standalone) for daily usage, 2 patients use DPIs for daily usage.

- 3 patients use DPIs as rescue inhalers (inhalers for usage during emergency situations), 1 patient uses a standalone MDI and 1 patient uses a specialized MDI (Readihaler, breath-actuated MDI).

- 3 patients do not experience discomfort regarding inhaler usage in public, 1 patient experiences discomfort in inhaler usage within the presence of unknown people and 1 patient experiences discomfort in inhaler usage within the presence of any other people.

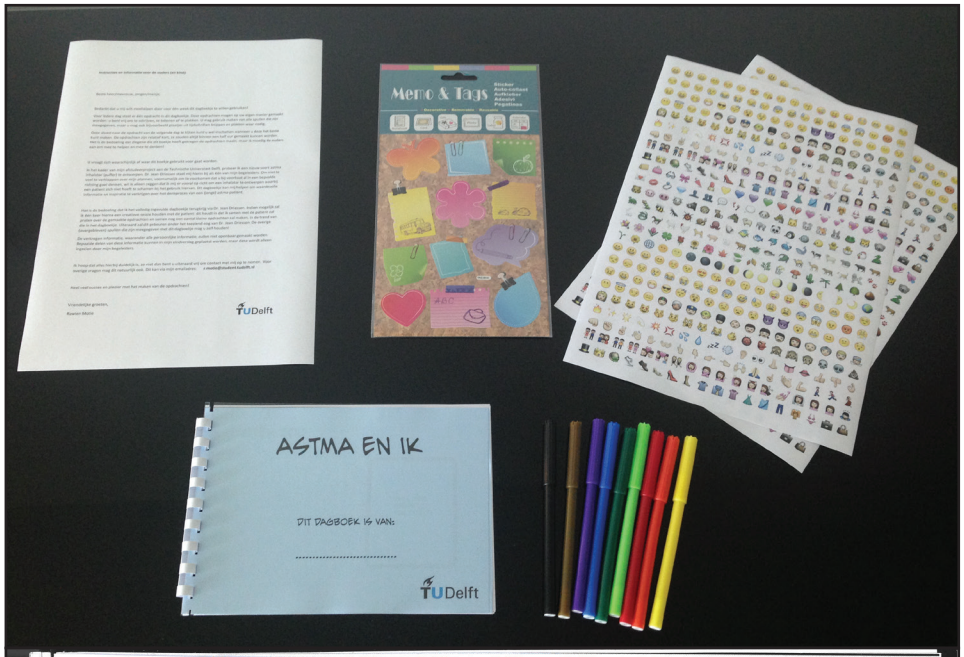
- 2 patients have a spacer chamber; both patients prefer not to use it in public due to the size of it and because they both feel that it attracts unwanted attention.

Context-mapping setup

Four patients (male, female) in the range of 11 to 14 years old have been involved with the context mapping sessions. The context mapping sessions as prepared in this project consists out of two parts; a sensitizing booklet which each patient had to use for one week and one follow up creative session.

Sensitizing booklet/toolkit

The sensitizing toolkit consists out of a booklet, various markers, stickers, sheets with various icons and emojis, a set of instructions and a consent form (to be filled in by the parents/guardians of the patient). The booklet contains exercises which are supposed to be completed by the patient over the course of one full week (one exercise per day, see Appendix B). The patient is allowed to do this at home and use the provided tools as he or she wishes to. The main purpose of the exercises is to bring the patient in a certain mindset; it primes the patient to think deeper about their daily interactions within the context of asthma. This priming will help to "open up" or make the patient think and express him/herself more freely for the follow up creative session.



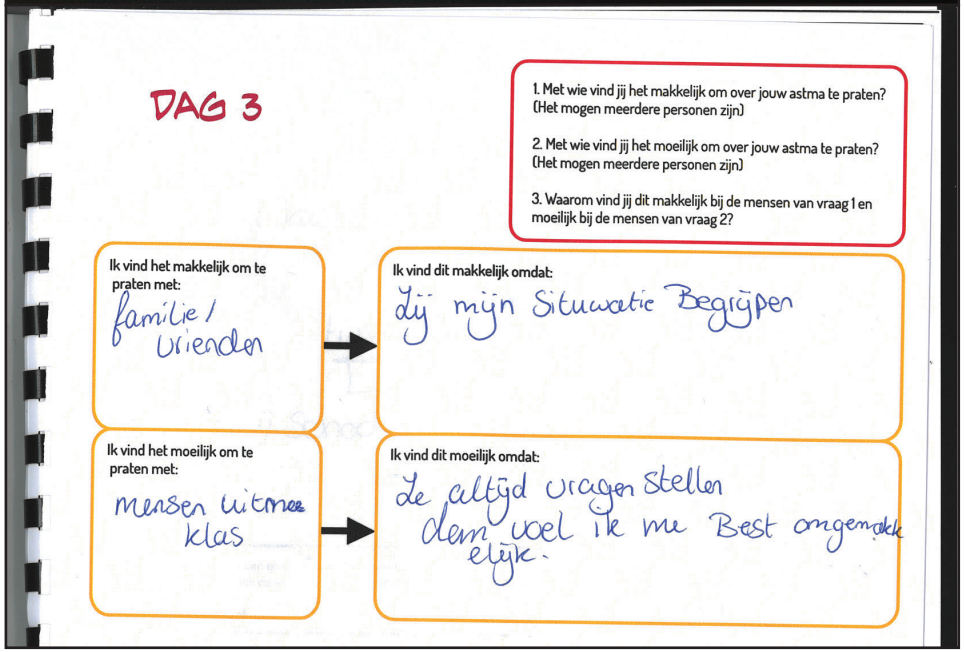


Fig.14 (top right). Picture of the contents of the toolkit as sent to each patient.

Fig.15 (bottom right). Picture of one of the exercises filled in by a patient.

Creative session

Four patients (male, female) in the age group of 11-14 years have participated with the follow up creative session. The sessions lasted for an overall duration of one hour and were conducted at either the home of the patient or in a private room in the library of Delft University of Technology.

The session consists out of a discussion, a brainstorm session and a "play session" in which the patient is allowed to reshape a 1:1 clay model of an MDI with spacer chamber. The purpose of this creative session is to gain an understanding of what a (young) asthma patient finds important or at least takes into consideration regarding the usage of asthma inhalers.

Creative session subtasks:

1. Brief discussion about the sensitizing booklet as filled in by the patient

2. Discussion about what the patient likes and dislikes about their currently used inhaler(s)

3. Brainstorm session about what type of object an inhaler could be disguised or hidden into

4. The patient gets to (re)mold an 1:1 scale clay model of an MDI with spacer chamber into a form/shape of the patient's liking

5. The patient is shown the initial idea of an inhaler disguised as a drinking bottle (by means of the final prototype from the project Exploring Interactions) and is asked for his/her opinion on the idea

Fig.16 (above). MDI with spacer chamber next to 1:1 scale clay model as used during the creative session.

Fig.17 (top right). Patient with a clay model of an MDI with spacer chamber disguised as a (toy) gun.

Fig.18 (bottom right). Spacer chamber and Diskus (DPI) reshaped into more desired shapes according to a patient.

Context-mapping findings

The most significant findings are the following:

- All patients use their asthma medication on a daily basis
- There can be a base routine observed for each patient regarding inhaler usage, such as where the inhalers are stored, where these are used and when these are used.
- There is no perceived discomfort regarding inhaler usage around people that the patient is close/familiar with. There is a perceived discomfort/reluctance to use inhalers around people that the patient is not familiar with.
- Main dislikes about their currently used inhaler(s) are the appearance/visibility of the inhalers, inability to see the amount of remaining doses and the need to drink water after inhaler usage.
- Main likes about their currently used inhaler(s) are the relatively low amount of actions needed to operate the inhaler and the high portability and storability of the inhaler.
- Initial ideas regarding the reshaping of the inhalers were based on the patient's hobbies and interests, disregarding that this new shape could potentially be very visible/stand out as unusual.
- The idea of an inhaler disguised as a water bottle was well received; all patients claimed that they would prefer this above current existing inhalers. Two patients mentioned that they already thought about a similar idea.

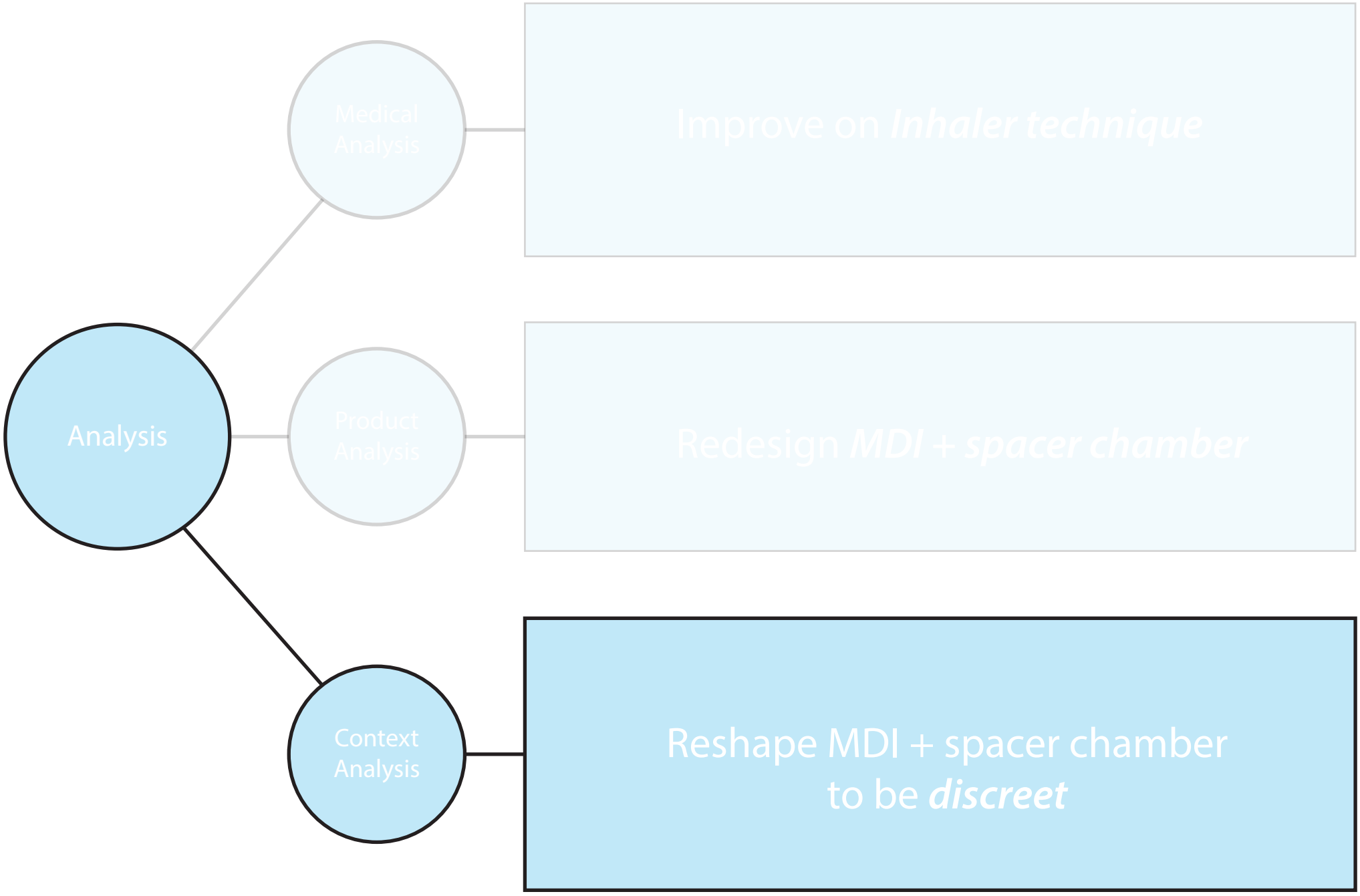
Conclusion

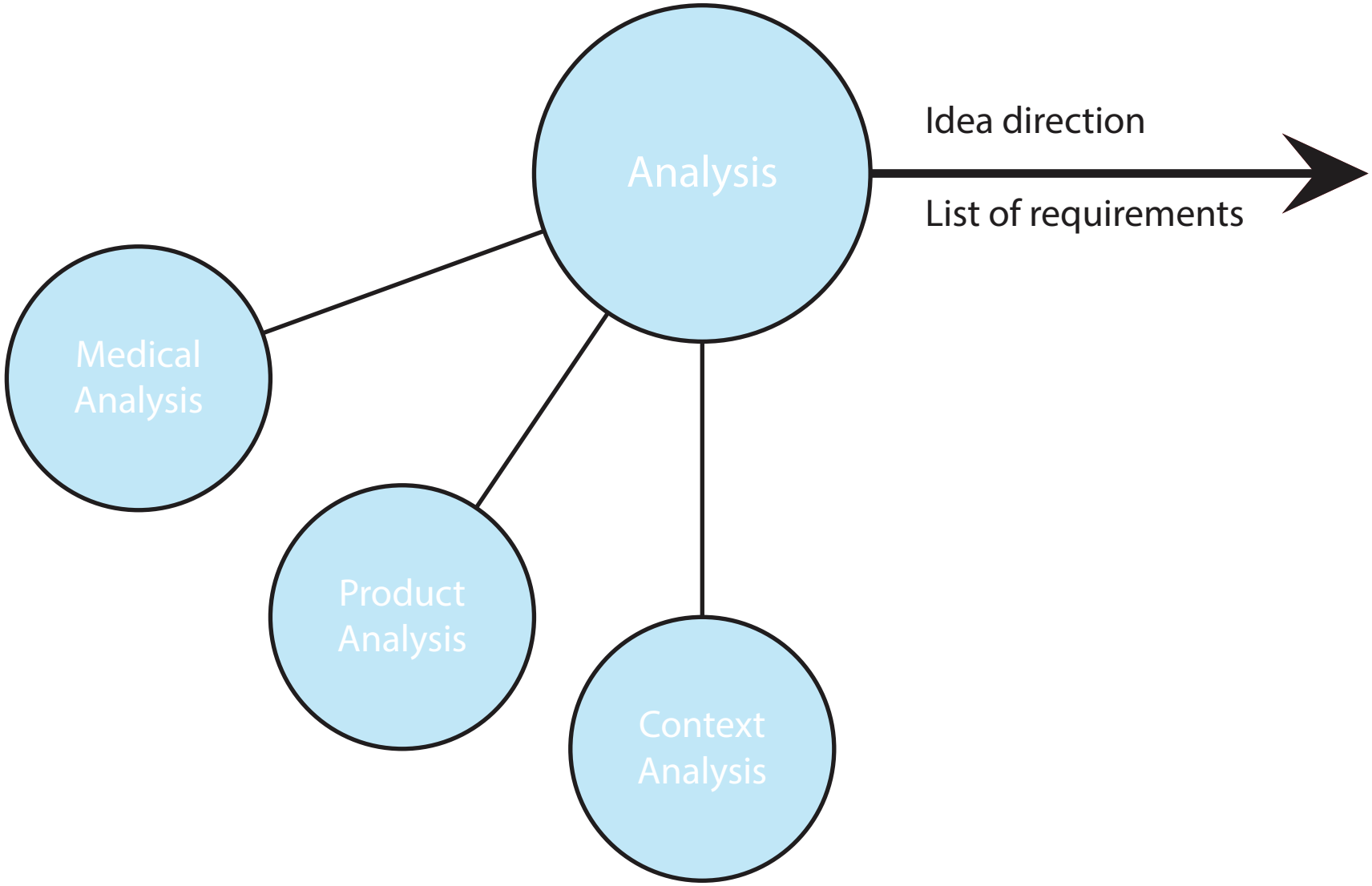
Standalone MDI's are the most common type of inhalers to be used, followed by DPI's. The most positively perceived trait of both inhaler types are their relatively small size and ease of portability. MDI's in combination with spacer chambers are both the least used and least preferred type of inhaler. This is mainly for its more obvious (medical) appearance and in part for being larger and less convenient to carry around in comparison with a standalone MDI or DPI.

A reluctance exists amongst younger asthma patients to us their inhaler in public areas or otherwise around people they are not familiar with. Even though this reluctance does not extend to all asthma patients, it still exists under a significant amount. This can potentially dissuade a patient from using their inhaler (properly) when in need while being in public situations, such as during a class. This effect is visible amongst all inhaler types, but is the most visible for MDI's in combination with spacer chambers.

The idea to disguise an MDI combined with a spacer chamber as another (non-medical) product is well received and shows the potential to make patients prefer the use of such an inhaler above the standalone MDI and DPI. The idea of an MDI with spacer chamber disguised as a water bottle is also well received, due to the natural looking action of drinking from it, while in actuality inhaling from it. It is also in part due to not looking out of place when carried by a patient, such as in a bookbag.

Based on the above stated the decision has been made to reshape the MDI with spacer chamber in order to make it discreet to use in public settings.


Analysis
Medical Analysis
Product Analysis
Context Analysis
Improve on *Inhaler technique*
Redesign *MDI + spacer chamber*
Reshape MDI + spacer chamber to be *discreet*


Analysis
Idea direction
List of requirements
Medical Analysis
Product Analysis
Context Analysis

2.4. Idea direction

This graduation project has been started with the drinking bottle idea as a basis. This idea is based on the results from the project Exploring Interactions. During that previous project the idea has been tested and evaluated with the help of asthma patients and experts involved with the project. Based on those evaluations the idea has been deemed as strong and worthy of a proper conceptualization cycle, which has resulted in this graduation project.

The option has been kept open to deviate from this drinking bottle idea, either by finding a more suitable idea or by finding out through the results of the analyses that the drinking bottle idea is not viable after all. Within the context analysis time has been spent to generate ideas by means of co-creation through the creative sessions, however the resulting ideas were not as satisfying. Furthermore the results of the medical, product and context analyses can be directly and appropriately connected with the drinking bottle idea. Therefore the decision has been made to continue with the conceptualization of this idea.

Fig.19. Prototype of drinking bottle inhaler from Project Exploring Interactions amongst "true" generic drinking bottles.

2.5. List of requirements

The conclusions from the medical, product and context analyses serve as the basis for the conceptualization of the drinking bottle idea. In addition a process tree has been made regarding the usage of the generic MDI + spacer chamber in order to gain a deeper understanding within the scope of usability (see Appendix C). From this a list of requirements has been compiled and a list of desires.

The list of requirements is quantifiable: the final concept/product has to adhere to these requirements. The list of desires is more flexible; while it would be desirable to have the characteristics mentioned in this list integrated in the final concept, it is not mandatory. Perhaps these desires could be integrated in a future design iteration.

Both the list of requirements and list of desires are broadly based on the following subjects: **patient adherence**, **product usage** and **medical requirements**.

List of requirements for new product

Usability

1. The user must be able to inhale asthma medication through the product
The main function of the product is to transfer asthma medication to the lungs of the user.

2. The user must be able to actuate the product
The user must be able to dispense medicine into the spacer chamber, and inhale from it at will.

3. The user must be able to hold the product in a correct way
In order for the medication to be dispensed correctly, the product must be held in such a way during use, that the internal medicine canister is positioned upright.

4. The user must be able to drink water through the product
According to the guidelines as proposed by GINA, a patient should rinse his/her mouth with water after inhalation of medicine, in order to reduce local side effects.

Functionality

5. The product must contain an adapter that is compatible with medicine canisters that are used in (generic) MDIs
The patient must be able to transition from using the "old style" MDI to using the new product, without the need to transition to another type of medication or administration of medication.

6. The product must contain a slot or compartment in which a spacer chamber can be fitted
The strength of the new product is that is allows for discreet inhalation through a spacer chamber, therefore the product must be able to contain a spacer chamber.

7. The product must contain an adapter that connects one medicine canister to the spacer chamber
The formulation contained with a medicine canister must be able to be ejected into the spacer chamber.

8. The product must contain one mouthpiece which connects to the spacer chamber
The user must be able to inhale from the spacer chamber; this can be either directly from the spacer chamber or through a connection piece.

9. The product must contain a water tank/container
The patient must be able to drink water through the product.

Performance

10. The amount of steps needed to actuate and inhale from the product cannot exceed the amount of steps needed to actuate and inhale from a typical MDI with a spacer chamber
In terms of usability the product must be more desirable than the currently used generic MDI with spacer chamber. This can be achieved by making the product more efficient to use in terms of the amount of steps needed for operation.

Maintenance

11. The product must be washable
The product must be washable for both hygienic and aesthetic purposes.

12. The user must be able to access, rinse and refill the water tank/container
The patient must be able to access and refill the water tank for obvious reasons, and be able to rinse/clean it for hygiene purposes.

13. The user must be able to access, remove and replace the spacer chamber inside the product
The user must be able reuse the product after eventual deterioration of the inside spacer chamber, by being able to replace this spacer chamber. Furthermore, the patient should be able to clean the spacer chamber for hygienic purposes and to reduce any static electricity that builds up over time.

Safety

14. The materials used in the product must be food safe
The patient must be able to safely drink from the product.

15. The product, including the spacer chamber, must comply with the European guidelines for medical devices*
The product must be safe to use by abiding to the European guidelines for medical devices. Furthermore, it must also be legal to purchase, own and use by all parties involved.

*(REGULATION (EU) 2017/745 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EEC and 93/42/EEC)

List of desires for new product

User experience

1. The product must be inconspicuous during use; the product must not draw unwanted attention
The user must feel comfortable to use the product without hesitation, regardless of the environment that the user is in.

2. The user must be able to actuate the product during an exacerbation
The user must be able to use the product during different situations, including less than ideal ones.

Usability

3. The product will be able to provide feedback to the user when it is time to replace the medicine canister
Ideally the user will be somehow notified to replace a (nearly) empty canister in a timely manner, in order to avoid situations wherin the user is out of medicine to directly use.

4. The user will be able to both inhale and drink water through the same mouthpiece
It is aesthetically more pleasing and in terms of usability more convenient to have one multi-functional mouthpiece for the product (no need to alternate between different mouthpieces).

Product properties

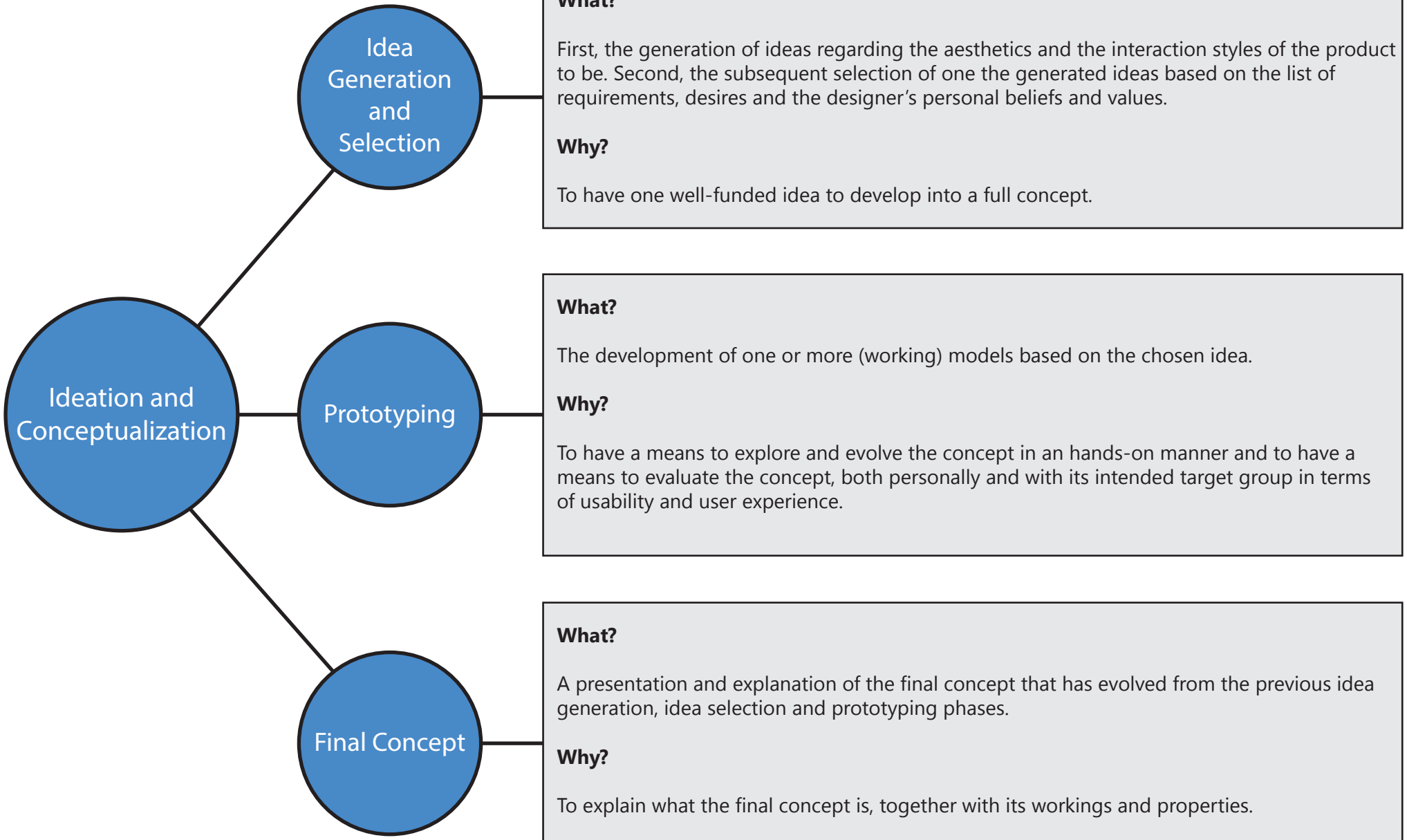
5. The product weight, including the spacer chamber, one full medicine canister and a completely filled water tank/container, will at most weigh similar to a fully filled drinking bottle
The product must be convenient to carry around in terms of weight; it must not feel like a burden to carry the product around. One generic water bottle (750ml) completely filled with water weighs around 805 grams.

6. The product must be able to fit inside of a backpack
In terms of size, the product must be in range with existing drinking bottles.

7. The water tank/container must hold enough water for at least one sip
The patient must be able to rinse his/her mouth after the inhalation of medicine with the amount of water that the product can hold.

8. The product will not contain any electronic parts
This makes the product more resilient against external factors, such as water, dust etc, and less prone to malfunctions. There is also no necessity for a power source.

3 *Ideation and Conceptualization*


Ideation and Conceptualization
Idea Generation and Selection
Prototyping
Final Concept
What?
First, the generation of ideas regarding the aesthetics and the interaction styles of the product to be. Second, the subsequent selection of one the generated ideas based on the list of requirements, desires and the designer's personal beliefs and values.
Why?
To have one well-funded idea to develop into a full concept.
What?
The development of one or more (working) models based on the chosen idea.
Why?
To have a means to explore and evolve the concept in an hands-on manner and to have a means to evaluate the concept, both personally and with its intended target group in terms of usability and user experience.
What?
A presentation and explanation of the final concept that has evolved from the previous idea generation, idea selection and prototyping phases.
Why?
To explain what the final concept is, together with its workings and properties.

3.1. Idea generation and selection

The idea generation within this graduation project uses the idea of an MDI + spacer chamber disguised as a drinking bottle as a baseline. The purpose of this idea generation is to give shape to this baseline; which aesthetics and which interaction styles are suitable for the final concept?

Idea generation - Cycle 1

A first idea generation has been conducted with the purpose of finding a main shape for the bottle. Subsequently this main shape will be used to build upon (or rather within) regarding the aspects as detailed in the list of requirements (water reservoir etc.).

Several shapes have been explored by means of sketching, subsequently these sketches have been grouped based on shared characteristics, as seen in Fig.20. These characteristics are the following:

- Group 1: Sharp + Symmetrical
- Group 2: Cylindrical + Sharp + Asymmetrical
- Group 3: Cylindrical + Organic + Asymmetrical
- Group 4: Organic + Symmetrical
- Group 5: Other

The exploratory sketching has been supplemented with foam modelling, in order to get an improved feel regarding possible shapes within a 3D space. The foam modelling has been performed using the characteristics as identified from the sketches as an input.

Fig.20 (right). Clusters of exploratory sketches, based on shared characteristics.

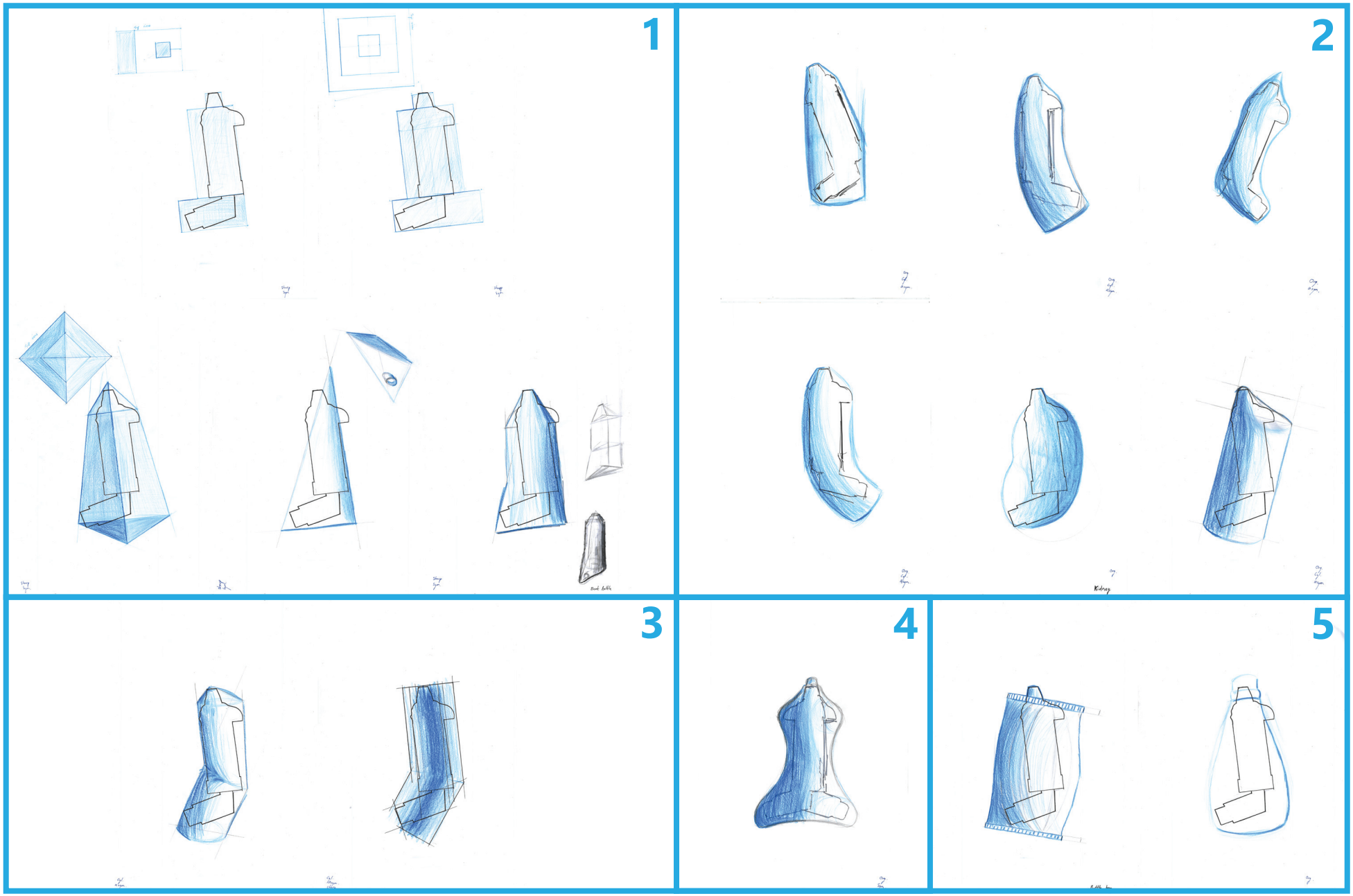

1
2
3
4
5

Fig.21 (left). Foam models of possible bottle shapes.

In this idea generation cycle the list of requirements has not been taken into account yet, due to most requirements being in the realm of practicality. Most requirements could have been implemented afterwards, in a defined shape. For example, the implementation of a water reservoir is possible in a predefined bottle shape, using this bottle shape to dictate the shape and form of the water reservoir. The only requirement that has been taken into account in this cycle, is that the bottle shape must always be held by the user in a specific manner, in order to ensure proper working of the MDI inside the bottle shape.

Based on this requirement and personal leanings towards sharp and symmetrical shapes, one of the foam models has been used as input for a 3D printed model. This 3D printed model has been used for a first evaluation regarding the orientation requirement. The results of this evaluation largely supported the appropriateness of the bottle shape regarding orientation (Appendix D).

However, due to using a predetermined bottle shape, there is no flexibility regarding the implementation of design features. This became obvious upon determining how to implement both mouthpieces for drinking and inhalation in the top of the bottle shape. It proved to be very difficult to implement these mouthpieces without either using overly complicated mechanisms for such a product, or drastically altering the bottle shape.

Due to this, the decision has been made to discard this idea in order to start a new idea generation cycle, albeit with a different approach.

Fig.22 (right). 3D printed model next to the foam model that it has been derived from.

Idea generation - Cycle 2

Another brainstorm has been conducted by means of sketching. This time however it has not been performed with the goal of already determining a definitive bottle shape, but rather to determine the positioning of the mouthpieces in relation to each other along with a matching interaction style.
After choosing one such design direction a follow up brainstorm has been conducted with the goal of finding a suitable bottle shape design that can contain all these key elements. This "form follows function" approach contrasts with the previous idea generation cycle.
The first round of sketches has been grouped together according to shared characteristics and have been identified as the following:

- Design direction 1 - "Classic bottle": Bottle shapes which contain both a mouthpiece for drinking and a mouthpiece for inhalation on the same side (e.g. top) of the bottle shape.

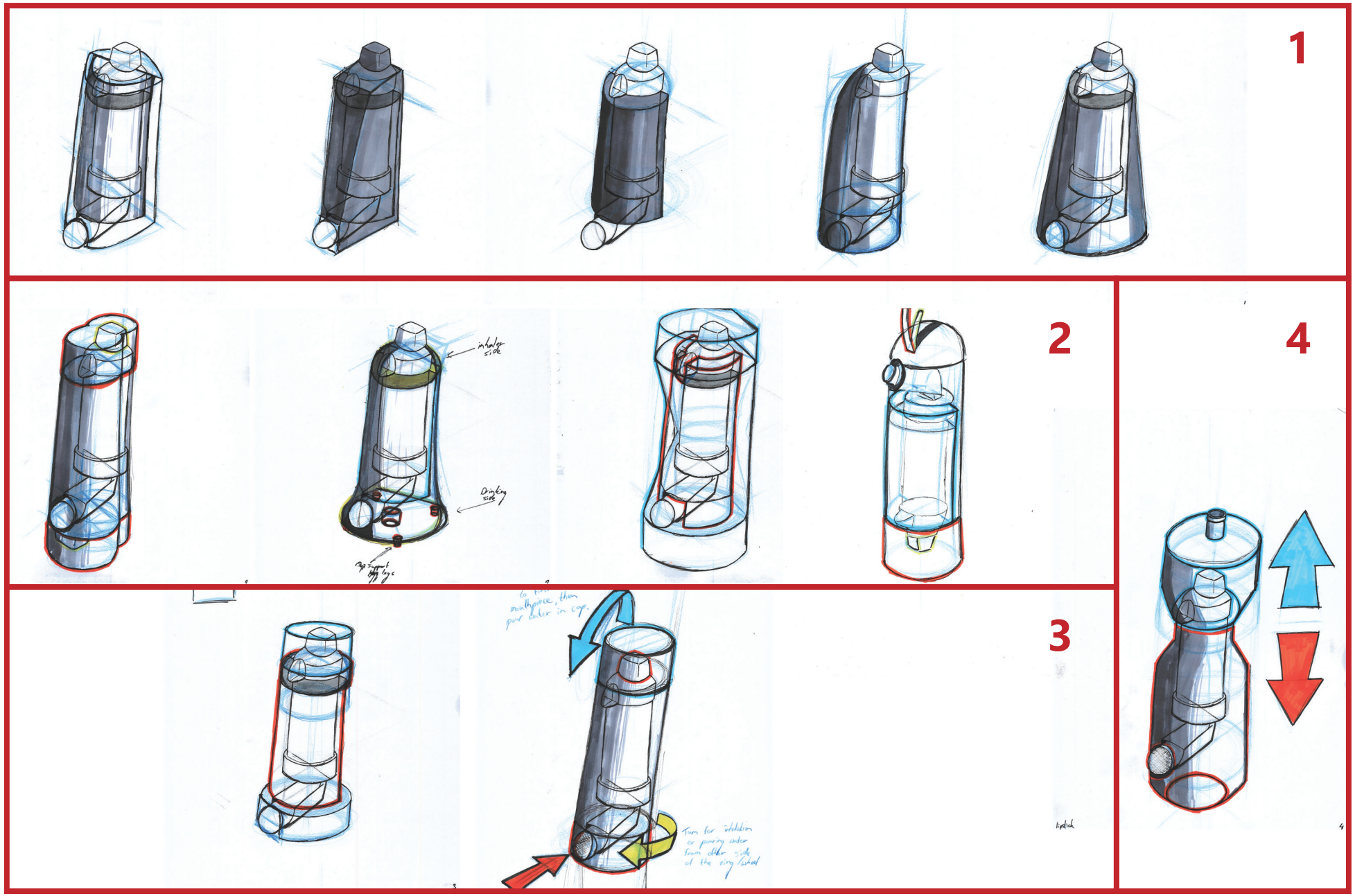
- Design direction 2 - "Battery": Bottle shapes which contain a mouthpiece for drinking and a mouthpiece for inhalation on opposite sides of each other (e.g. top of bottle shape for inhalation, bottom of the bottle shape for drinking).

- Design direction 3 - "Thermos flask": Bottle shapes that contain a mouthpiece for inhalation, but do not provide a method for drinking directly from the bottle shape. Instead it allows for the pouring of water from the product into another container such a cup. A real life product that can be compared to this is a thermos flask.

- Design direction 4 - "Lipstick": Bottle shapes that contain both a mouthpiece for drinking and for inhalation on the same side, however the mouthpieces are separated by means of a false lid. The lid itself contains a mouthpiece for drinking and a container for water storage and this whole part can be taken off in order to expose a mouthpiece for inhalation. The act of taking of a lid in order to expose the inhalation mouthpiece is reminiscent of taking off the cap of a lipstick.

One of these design directions will be chosen in order to generate a final set of ideas based on the properties of that direction. In order to be able to make a proper decision regarding which direction to focus on, a Harris profile has been made for each design direction. The Harris profile is a tool which allows for the graphic representation of the strengths and weaknesses against a predefined set of design requirements. By comparing the strengths and weaknesses of each design direction, a thoughtful decision can be made regarding which direction to focus on.

Fig.23 (right). Clusters of exploratory sketches, based on shared characteristics.


1
2
4
3
inhaler side
Dosing side
Turn for inhalation or pouring water from other side of the ring/lid

Design direction 1 – "Classic bottle"

	--	-	+	++
Usage				
Ease of actuation				
Ease of inhalation				
Ease of drinking				
Orientation clarity				
Distinguishability between inhaler mouthpiece and drinking mouthpiece				
Properties				
Aesthetics				
Target group compatibility				
Portability				
Sturdiness/fragility				

Ease of actuation: Actuating the inhaler requires the pressing in of the canister by means of an opening in the product. It is not necessarily more difficult, but also not easier then directly actuating an MDI + spacer chamber.

Ease of inhalation: Easy, as it is a matter of directly inhaling from an already exposed mouthpiece on top of the product.

Ease of drinking: Easy, as it is a matter of directly drinking from an already exposed mouthpiece on top of the product.

Orientation clarity: It is clear what the top and the bottom of the product are and which side contains the mouthpieces for both drinking and inhalation. With minor use cues in a follow up design it should also be relatively easy to make the user hold the product in such a way that the medicine canister in the product is correctly positioned during use.

Distinguishability between inhaler mouthpiece and drinking mouthpiece: It is not immediately clear which mouthpiece belongs to which function. Even with exaggerated use cues in a follow up design it is highly probable that there will still be a chance that mistakes will be made regarding which mouthpiece to use, especially during emergency situations.

Aesthetics: On itself this design direction will probably produce concepts that most closely resemble classic or generic style bottle shapes, albeit with two visible mouthpieces instead of one.

Target group compatibility: On itself this style of design will not necessarily stand out amongst the target group, which is not necessarily negative. This style of design is able to blend in with other bottle styles that might be carried by users that fit the target group.

Portability: It is probable that this design direction will produce relatively compact products, due to not requiring any special mechanisms. Sturdiness/fragility: On a basic level it is highly probable that a sturdy product could be derived from this design direction, due to not needing any type of special mechanisms. Less mechanisms will make a product less prone to breakage.

Design direction 2 – "Battery"

	--	-	+	++
Usage				
Ease of actuation				
Ease of inhalation				
Ease of drinking				
Orientation clarity				
Distinguishability between inhaler mouthpiece and drinking mouthpiece				
Properties				
Aesthetics				
Target group compatibility				
Portability				
Sturdiness/fragility				

Ease of actuation: Actuating the inhaler requires the pressing in of the canister by means of an opening in the product. It is not necessarily more difficult, but also not easier then directly actuating an MDI + spacer chamber.

Ease of inhalation: Relatively easy, as it is a matter of removing a lid/cap in order to expose a mouthpiece and then inhaling from said mouthpiece.

Ease of drinking: Relatively easy, as it is a matter of removing a lid/cap in order to expose a mouthpiece and then drinking from said mouthpiece.

Orientation clarity: Relatively easy, as it is clear that each side of the product contains a lid/cap that can be taken off. It will require additional use cues though in order to communicate which side of the product contains which type of mouthpiece. With minor use cues in a follow up design it should also be relatively easy to make the user hold the product in such a way that the medicine canister in the product is correctly positioned during use.

Distinguishability between inhaler mouthpiece and drinking mouthpiece: With any additional use cues that communicate the function per mouthpiece, it should be very clear to distinguish the mouthpieces from each other as these are literally positioned on polar opposites.

Aesthetics: On itself this design direction will probably produce concepts that resembles a more modern style of drinking bottles; sleeker type of bottle shapes.

Target group compatibility: On itself this style of design will not necessarily stand out amongst the target group, which is not necessarily negative. This style of design is able to blend in with other bottle styles that might be carried by users that fit the target group.

Portability: It is probable that this concept direction will produce relatively compact products, due to not requiring any special mechanisms.

Sturdiness/fragility: On a basic level it is highly probable that a sturdy product could be derived from this design direction, due to not needing any type of special mechanisms. Less mechanisms will make a product less prone to breakage.

Design direction 3 – "Thermos flask"

	--	-	+	++
Usage				
Ease of actuation				
Ease of inhalation				
Ease of drinking				
Orientation clarity				
Distinguishability between inhaler mouthpiece and drinking mouthpiece				
Properties				
Aesthetics				
Target group compatibility				
Portability				
Sturdiness/fragility				

Ease of actuation: Actuating the inhaler requires the pressing in of the canister by means of an opening in the product. It is not necessarily more difficult, but also not easier then directly actuating an MDI + spacer chamber.

Ease of inhalation: Relatively easy, as it is a matter of removing a lid/cap in order to expose a mouthpiece and then inhaling from said mouthpiece.

Ease of drinking: The drinking requires the removing of a lid/cap which also serves as a drinking cup. This cup then needs to be filled with water by means of some sort of tap that is integrated in the product. This procedure requires more time and effort compared to drinking directly from a bottle.

Orientation clarity: It is clear which side of the product contains a mouthpiece for inhaling and with an initial instruction it should be easy to determine how to hold to the product (using the tap/drinking mechanism as an orientation point).

Distinguishability between inhaler mouthpiece and drinking mouthpiece: There is a clear distinction between a mouthpiece to drink from and a mechanism that needs to be used in order to drink.

Aesthetics: This design direction could produce interesting looking concepts, however it is easy to deviate away from bottle shaped designs into more odd looking shapes. There is a possibility that it will produce more bulkier type of shapes due to that necessary mechanisms for drinking.

Target group compatibility: The use of thermos flasks is more associated with adult/elderly types of users than children/teenagers. The use of such (or similar looking products) amongst children/teenager will probably draw unwanted attention.

Portability: It is probable that this concept direction will produce a bulkier type of product; the product will still be highly portable, but perhaps less convenient to carry in comparison with other types of drinking bottles.

Sturdiness/fragility: Due to the inclusion of a more elaborate mechanism for drinking, there will be more parts that are prone to breakage. It is not farfetched to imagine that such a mechanism might be fragile, making the overall product too delicate to fit within for example the backpack of a high school student.

Design direction 4 – "Lipstick"

	--	-	+	++
Usage				
Ease of actuation				
Ease of inhalation				
Ease of drinking				
Orientation clarity				
Distinguishability between inhaler mouthpiece and drinking mouthpiece				
Properties				
Aesthetics				
Target group compatibility				
Portability				
Sturdiness/fragility				

Ease of actuation: Actuating the inhaler requires the pressing in of the canister by means of an opening in the product. It is not necessarily more difficult, but also not easier then directly actuating an MDI + spacer chamber.

Ease of inhalation: Relatively easy, as it is a matter of removing a lid/cap in order to expose a mouthpiece and then inhaling from said mouthpiece.

Ease of drinking: Easy, as it is a matter of drinking from an already exposed mouthpiece.

Orientation clarity: It is clear what the top and the bottom of the product are and which side contains the mouthpieces for both drinking and inhalation. With minor use cues in a follow up design it should also be relatively easy to make the user hold the product in such a way that the medicine canister in the product is correctly positioned during use.

Distinguishability between inhaler mouthpiece and drinking mouthpiece: With an initial instruction it should be clear which mouthpiece is for inhalation and which mouthpiece is for drinking, without causing any future confusion.

Aesthetics: On itself this design direction is open to several styles of drinking bottles; concepts that resembles a more modern style of drinking bottles can be produced, as well as concepts that would fit a more sportive style.

Target group compatibility: On itself this style of design will not necessarily stand out amongst the target group, which is not necessarily negative. This style of design is able to blend in with other bottle styles that might be carried by users that fit the target group.

Portability: It is probable that this design direction will produce relatively compact products, due to not requiring any special mechanisms.

Sturdiness/fragility: On a basic level it is highly probable that a sturdy product could be derived from this design direction, due to not needing any type of special mechanisms. Less mechanisms will make a product less prone to breakage.

Design direction conclusion

As can be seen from the Harris profiles, design directions 2 (“Battery”) and 4 (“Lipstick”) score significantly higher than design directions 1 (“Classic bottle”) and 3 (“Thermos flask”).

Design direction “Lipstick” scores highest overall, but the difference in scoring between “Lipstick” and “Battery” is minimal, warranting extra consideration before heading into one direction based on score only. Still, the decision is to use “Lipstick” as the design direction for follow-up ideas and concepts, due to being superior regarding the aspects of *orientation clarity* and *distinguishability between inhaler mouthpiece and drinking mouthpiece*. Due to these aspects the chance for incorrect usage is minimized as the mouthpieces for drinking and inhalation are positioned in a specific manner in relation to each other and it is clear that only one side of the bottle shape contains mouthpieces.

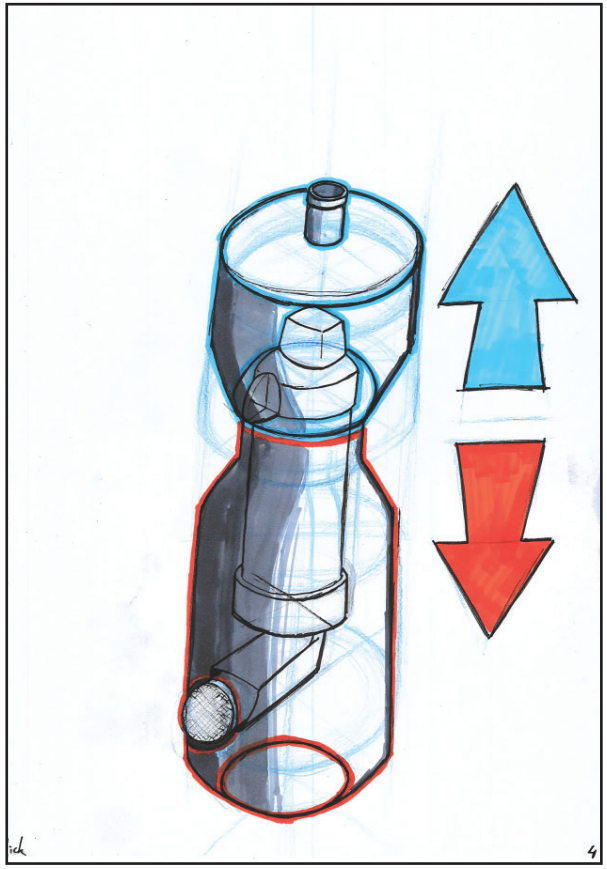
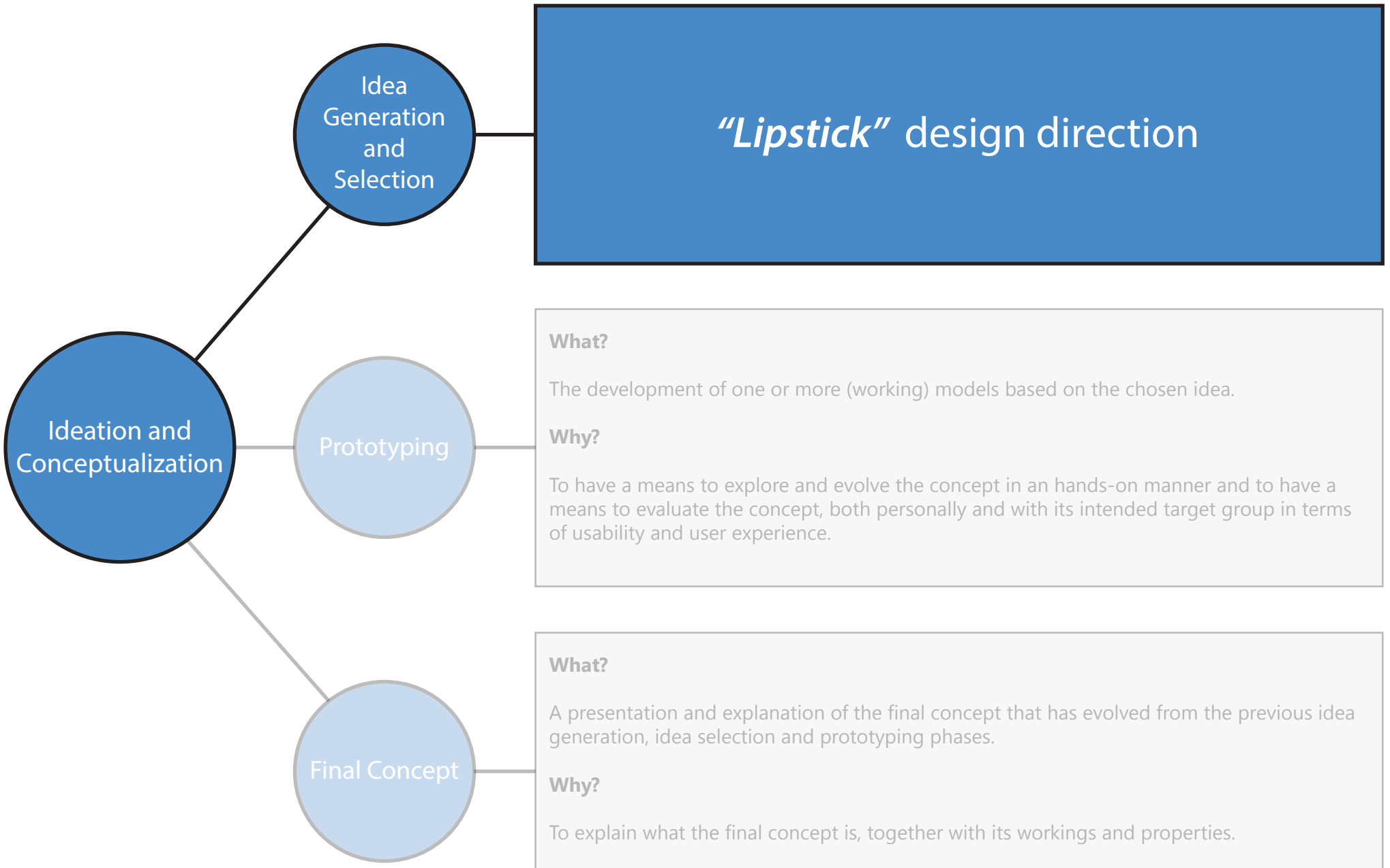


Fig.24. Sketch which showcases the “Lipstick” design direction.


Ideation and Conceptualization
Idea Generation and Selection
Prototyping
Final Concept
"Lipstick" design direction
What?
The development of one or more (working) models based on the chosen idea.
Why?
To have a means to explore and evolve the concept in an hands-on manner and to have a means to evaluate the concept, both personally and with its intended target group in terms of usability and user experience.
What?
A presentation and explanation of the final concept that has evolved from the previous idea generation, idea selection and prototyping phases.
Why?
To explain what the final concept is, together with its workings and properties.

3.2. Prototyping

Prototypes and prototyping (the creation of prototypes) can have various uses and purposes. In this graduation project the use for prototyping is twofold: the first is to have a means to bring 2d ideas and sketches into a three dimensional realm and the second is to have a tangible object that can be evaluated by not only the designer, but also by the end user.

In other words, instead of continuing the design exploration through sketching, here an approach was chosen to sketch in 3d instead. These 3d sketches can be held and tinkered with, providing an experience of what feels right and perhaps importantly, what does not feel right? This in turns leads to the questioning of how can this be improved upon. By continuing to find answers on these questions, new prototypes get created, each one (hopefully) an improvement on the previous one, until a satisfactory final model is reached.

The main technique used in this project for prototyping is by creating 3d CAD (Computer Aided Design) models and subsequently 3d printing these models. The 3d CAD modelling has been done in the program SolidWorks and the 3d printing has been done by means of an Ultimaker 2+ 3d printer and by using PLA (polylactic acid) filament as a print material.

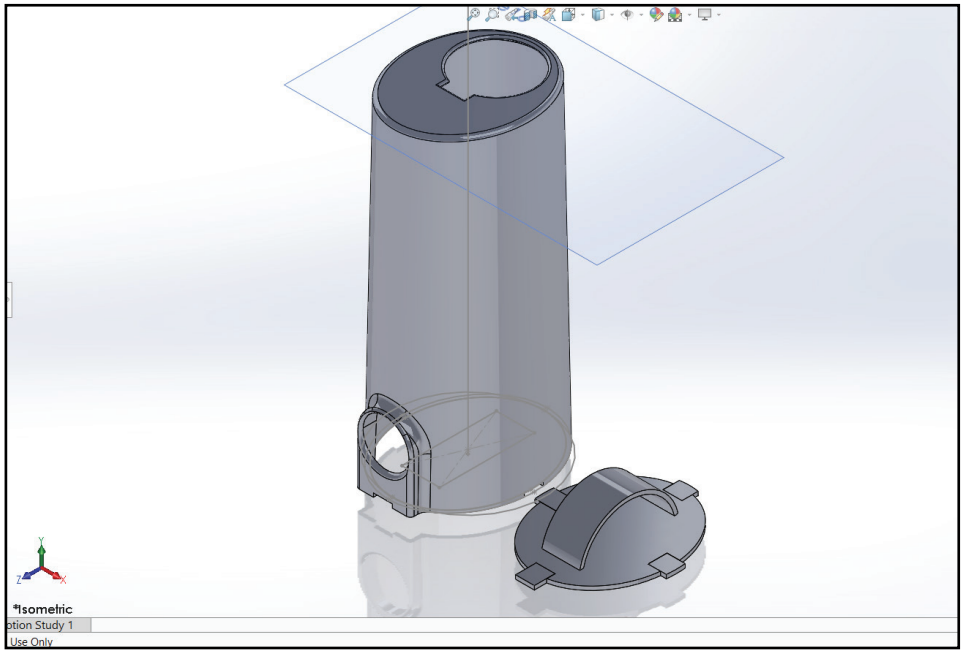


Fig.25. Partial screenshot of a 3d CAD model in process using the SolidWorks software.

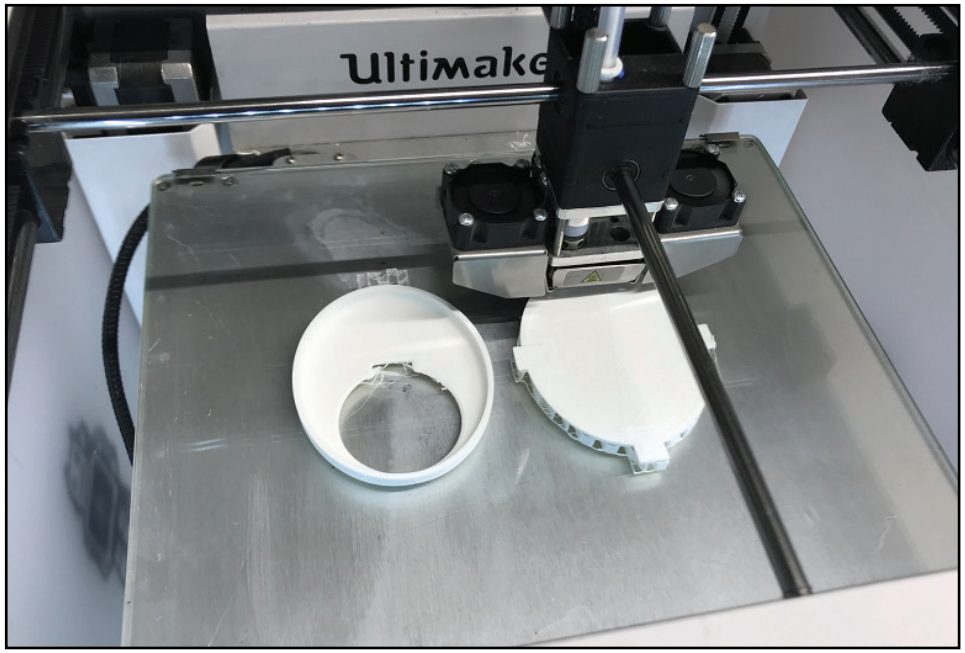


Fig.26. An Ultimaker 2+ 3d printer in the process of printing a prototype.

The produced prototypes have been pivotal in both the exploration of various design aspects as well as the evaluation of said aspects. The evaluation of a physical prototype can lead to the identification of various design flaws which may not necessarily be visible from a 2d drawing or a virtual 3d model. Addressing these design flaws in turn are likely to influence the design of the next model. By continuing the cycle of designing, producing, evaluating and redesigning, in the overall scheme the design flaws keep getting eliminated or diminished until a design model is reached that is on a satisfactory level.

In the following pages an overview of the produced prototypes is provided, which is followed up with details regarding points of improvement for each prototype.

Prototype 1

First prototype as a result of a shape driven design approach. Whilst it is aesthetically pleasing, upon evaluation it does not fit most design requirements.
As a result it was decided to restart the idea generation by using a more analytical design approach as opposed to try to "fix" this design.

Prototype 2

First prototype as a result of a more analytical design approach using the "form follows function" design philosophy, which in turn resulted in the "Lipstick" design direction. This is the first prototype in which a MDI and spacer chamber can be fitted in. This prototype only contains the lower half of the intended bottle shape.

Prototype 3

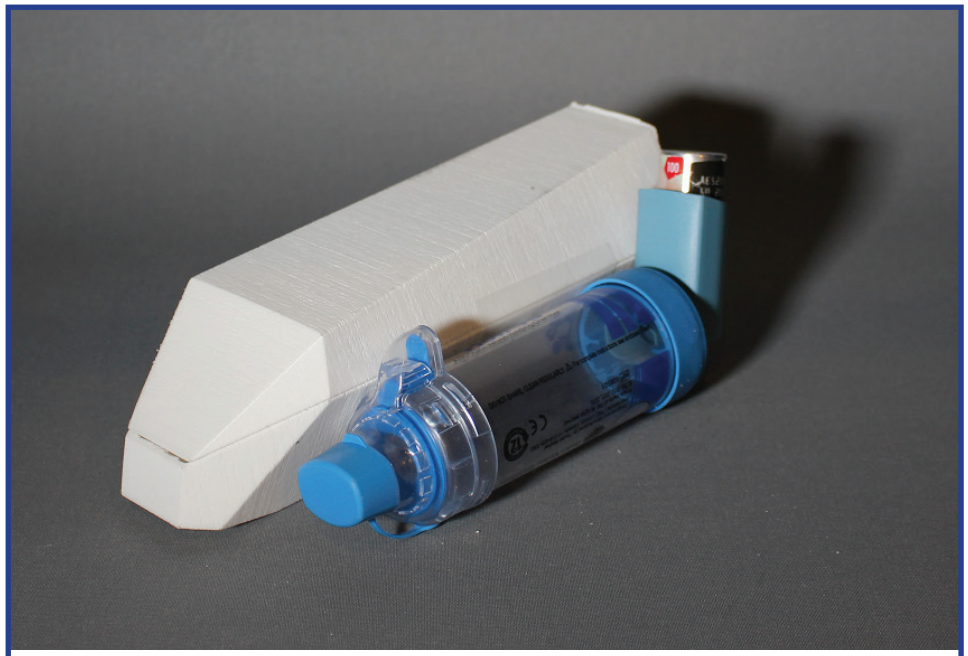
A result of various design changes in order to achieve a slimmer and aesthetically more pleasing model, whilst more convenient to hold and inhale from in comparison with the previous prototype. This has been done mainly by shifting from a circular cylinder shape into a elliptical cylinder shape and by lowering the overall height.

Prototype 4

First prototype to contain both a lower and upper halve. Several design changes have been applied in order to achieve a model that is suitable for production by means of injection moulding, most notably by tapering both bottle halves. The decision was made to leave the upper halve open in order to minimize risk of (3d) printing failure but still have a first impression regarding the overall size and shape of the intended bottle shape. An unintended consequence is that this prototype more so resembles a chalice instead of a bottle.

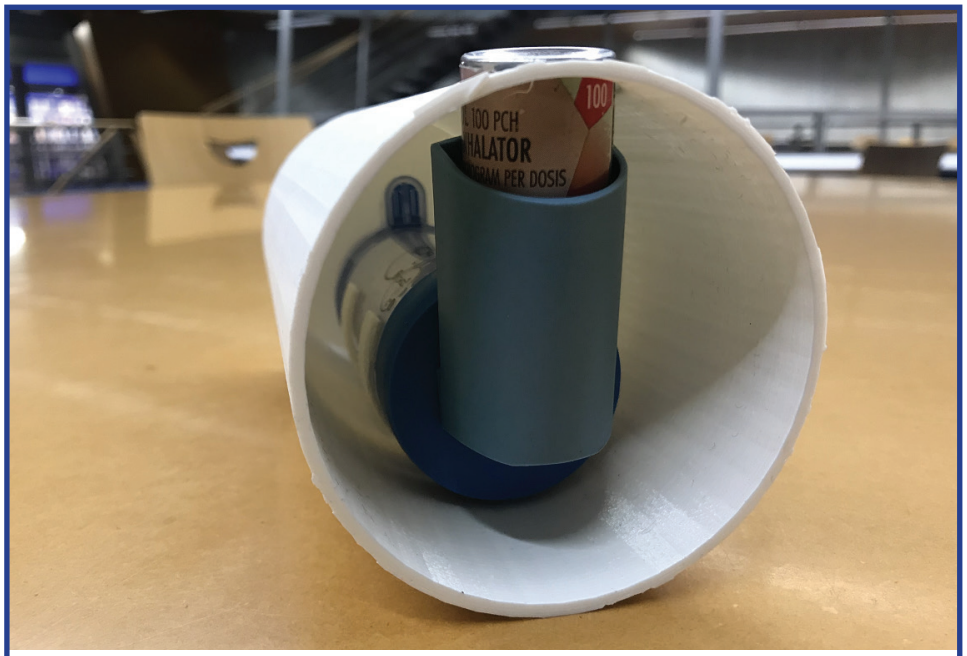
Prototype 5

First prototype to resemble a possible end model. Design changes have been applied to both slim down the model and to give the bottle a uniform appearance when closed as opposed to clearly indicating that it consists out of two separate halves. Whilst not completely functional, the upper halve now clearly resembles the top of a drinking bottle.



Points of improvement for Prototype 1:

- *This prototype does not meet most design requirements, most notably it is not able to fit in an MDI with a spacer chamber.*
- *Modifying this design in order to properly fit in an MDI with a spacer chamber will most likely lead to a model that is too bulky to comfortably hold and/or a shape that deviates too far from the original, already peculiar design. A restart of the design process is preferred over trying to find a solution to these major flaws.*



Points of improvement for Prototype 2:

- *The mouthpiece of the spacer chamber only protrudes minimally through the prototype, making it difficult to wrap ones lips/mouth around it and inhale from in a natural way.*
- *The canister protrudes from the prototype; it does not blend with the overall shape of it.*
- *The spacer chamber is not secured snuggly due to the positioning of the two ribs in the prototype; the spacer chamber is only held in place by the ribs and essentially "rests" on the MDI and canister that is partially sticking out of the prototype. Due to this it rattles upon any movement of the prototype.*
- *The canister cannot be comfortably pressed in. As the MDI itself is not secured it moves along with the canister due to the lack of an opposing force until the MDI is pressed against the inner wall of the prototype.*
- *The overall shape of the model is quite bulky due to it being a circular cylinder.*

Points of improvement for Prototype 3:

- *The lack of an upper halve makes that the model gives an incomplete impression.*
- *The MDI needs to be properly secured in order to be able to properly actuate it.*
- *Due to its straight (extruded) shape, this model is not suitable for mass production through injection moulding.*

Points of improvement for Prototype 4:

- *The prototype appears quite off due to the incompleteness of the upper halve.*
- *The overhanging walls of the upper halve can be shortened significantly.*
- *A better mechanism is needed to tightly fit the upper halve on top of the bottom halve.*
- *The elliptical disc used for closing the bottom of the lower halve needs a spring-like mechanism in order to provide enough upwards force for securing the MDI inside the model, whilst being flexible enough to not break. This is especially of importance since there are no ribs anymore inside of the model to hold the spacer chamber in place.*

Points of improvement for Prototype 5:

- *The protrusion where the canister fits through needs to be more closed off, in order to minimize the chance for accidental actuation of the MDI.*
- *The bottom of the lower halve needs some type of foam or spring in order to keep the MDI in place during actuation.*
- *The area that connects the lower halve with the upper halve needs some type of material (such as rubber) in order to keep these together during normal use.*
- *The upper halve needs a base for an "off the shelf" drinking mouthpiece to fit/screwed on. This is not necessary for the prototype itself but it provides implications for the future consumer model.*

The points of improvement for Prototype 5 are more focused when compared to those of the previous prototypes. By starting with a relatively rough sort of prototype as a starting point, the points for improvement started on a broader level as well. However by addressing these, the points for improvement have started to become more specific. This progress is visible by comparing the prototypes side by side, as it is visible how the models are starting to become more refined.

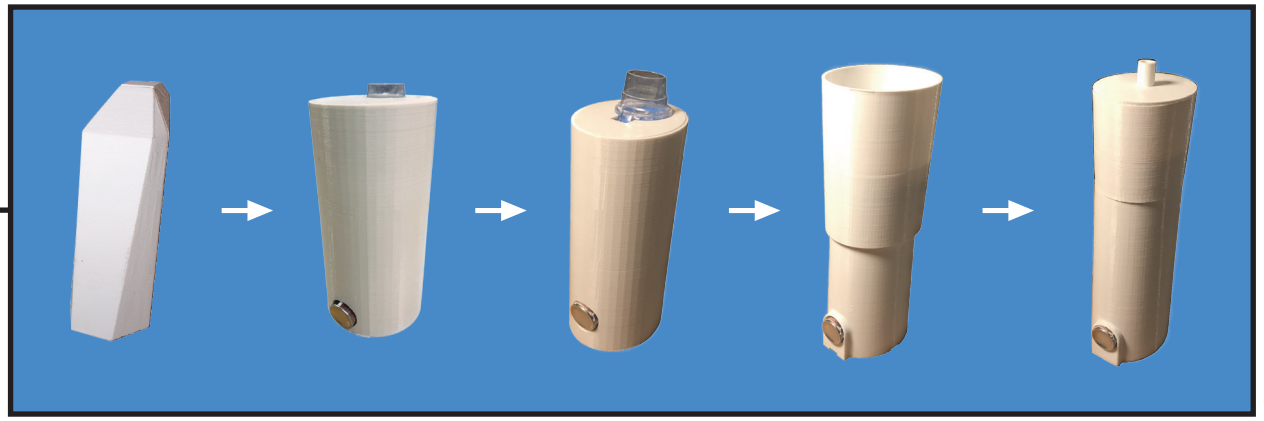
By addressing the points of improvement for Prototype 5, a model should be reached that meets all design requirements and is of a satisfactory level in order to pass as a final concept for this project. The process towards this final model as well as details around the final concept itself are presented in the up following sub-chapter.

Ideation and Conceptualization

Idea Generation and Selection

"Lipstick" design direction

Prototyping



Final Concept

What?

A presentation and explanation of the final concept that has evolved from the previous idea generation, idea selection and prototyping phases.

Why?

To explain what the final concept is, together with its workings and properties.

3.3. Final concept

Final prototype

The final prototype has been improved from the preceding prototypes in the following areas:

- The top of the prototype now contains an adapter on which existing bottle mouthpieces can be screwed on

- The top of the prototype can now be comfortably taken off from the base while combined both parts are held together by means of friction, also during motion.

- The MDI is held in place during actuation by means of a support in the bottom cap of the prototype.

- It is now more difficult to accidently actuate the MDI due to a smaller opening in the prototype, which prevents the medicine canister from protruding though the prototype.

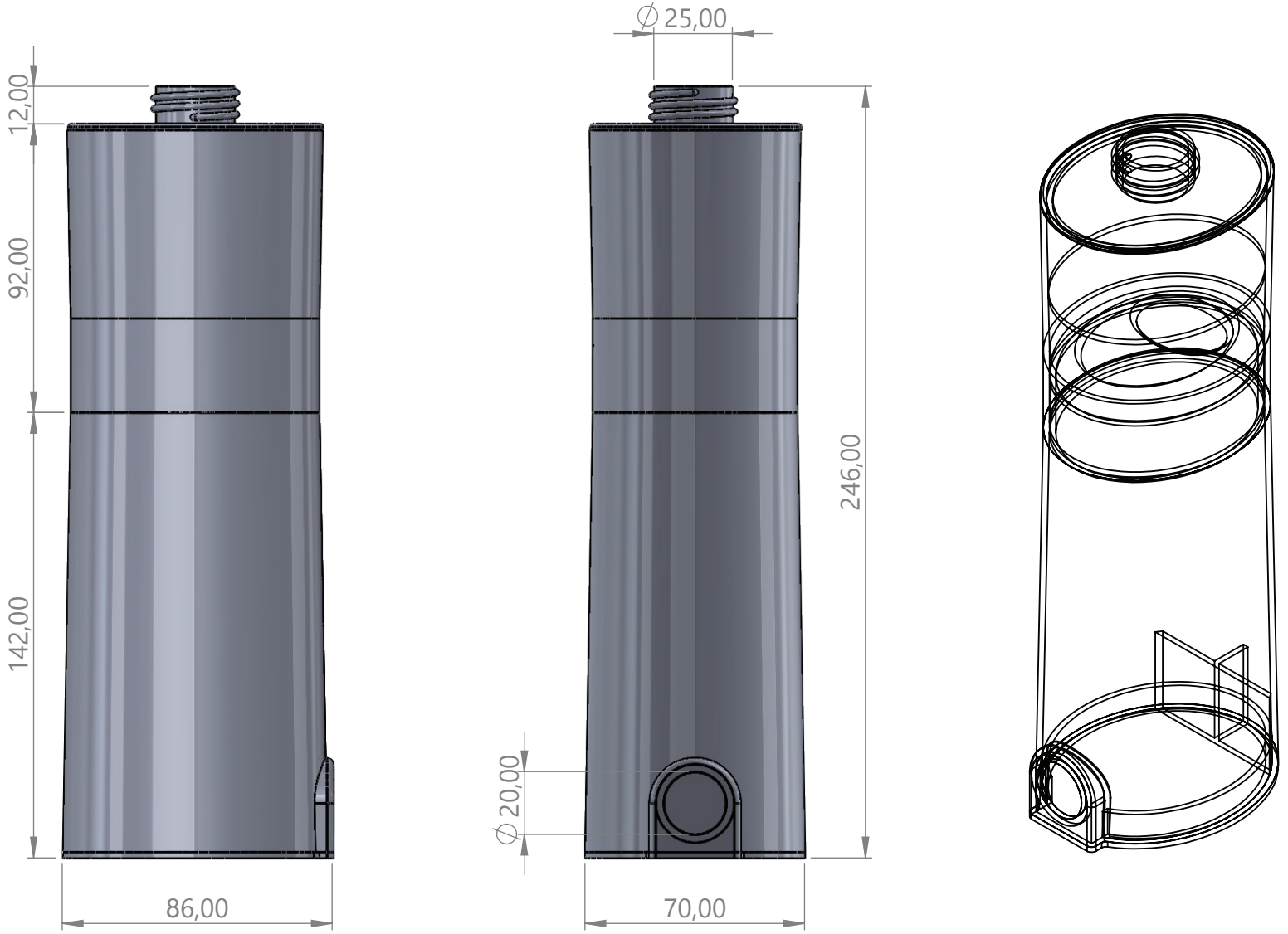
- Several versions of the final prototype have been 3D printed in different colors. The amount of colors and available material was severely limited, resulting in colors that were not necessarily of first choice. Nevertheless, it does give the final prototype a more finished product like appearance.

Properties final prototype

Material:	PLA (polylactic acid)
Weight (dry):	170 gr
Weight with MDI + spacer chamber and filled with water:	330 gr
Water capacity:	100 ml
Wall thickness:	2 mm

Fig.27 (top right). Four versions of the final prototype, each in a different color combination

Final prototype dimensions (mm)



Product materialization

Material

For a future production model the decision is made to use polypropylene (PP). PP is a commonly used thermoplastic in a wide range of consumer products, such as plastic bottles and synthetic clothing. PP can also be medically graded and used in medical products such as syringes.

Advice for which material to choose was provided by means of a consultation by Dr. ir. Erik Tempelman, associate professor in the fields of Design Engineering and Advanced Manufacturing. Regarding the use of plastics, the first criteria for which type of plastic to use are the thermal properties of it. Since the thermal requirements for the product are related to regular daily activities, PP is a suitable choice due to a melting point starting from 160 °C, depending the specific type of PP. Under normal use the product should not be exposed to temperatures exceeding 80 °C, which is the temperature that can be reached inside of a running dishwasher. PP can become brittle when exposed to temperatures below 0 °C. The product however was not designed for (prolonged) exposure in subzero conditions.
The product is of minimal mechanical complexity and does not require extreme accurate tolerances, which makes it reasonable to assume that the product can be manufactured at the majority of (local Dutch) injection moulding manufacturers. On top of this, PP is of a relatively low cost compared to other types of plastics.
Since the product is used for medicinal inhalation and drinking, it is important that the PP used for production is medically certified. This is of importance since this has consequences on a business level. It requires extra financial investments and it is not unusual to have a time span of two years before the PP is production ready due to the process of testing.

Fig,28 (left). Final prototype with the spacer chamber mouthpiece exposed.

Production method

The prototypes made during the later stages of this project have been designed with an end production in mind. The chosen method of production here is injection moulding, which is suitable when using PP as a production material. In order to facilitate the process of injection moulding, both the base and the top of the final prototype have an incorporated draft angle of 2°. The product has a uniform wall thickness of 2 mm and the product is devoid of ribs or other parts that protrude from or within the product. These choices were made to facilitate the process of ejecting the produced parts from the injection moulds.

Prototype ergonomics

The ergonomics of the final prototype are in part responsible for how well a user is able to interact with it. Here this is partially complicated due to the age range of the target group (ages 6-18). The physical differences between a 6 year old and 18 year old person are significant in relation to hand size, (pinch) grip span and the maximum amount of force that can be exerted by means of a (pinch) grip.

In order to examine whether the final prototype is appropriate for the full range of the target group, a closer look is taken on the aspects of hand span and grip circumference (for holding the prototype), and grasp and pinch grip strength (for actuating the MDI through the prototype). This is done by focusing on these aspects in relation to a 6 year old person, since this age from the target group has the lowest physical capabilities in relation to the other ages up until the age of 18.

The full circumference of the bottom of the base of the prototype is 250 mm. The mean grip circumference of a Dutch 6 year old child (both male and female) is 87 ± 8 mm (DINED, 2020). This is slightly over one third of the base circumference of the prototype (83,33 mm). This implies that it will be difficult for a 6 year old child to hold/grip the prototype one handed. A two handed grip will have a combined grip circumference that is larger than half of the base circumference of the prototype (125 mm), implying that the prototype can be comfortably held with two hands. However this in turn will make certain product specific interactions more difficult to perform, such as removing the top of the prototype in order to inhale from it. This interaction would require the user to hold/grip the base with one hand whilst using the other hand to remove the top part. From the same database it can be found that the mean grip circumference of a Dutch 12 year old child (both male and female) is 113 ± 11 mm (DINED, 2020), which is significantly closer to half of the base circumference of the prototype. This makes it more likely that children starting from this age are able to comfortably hold the prototype.

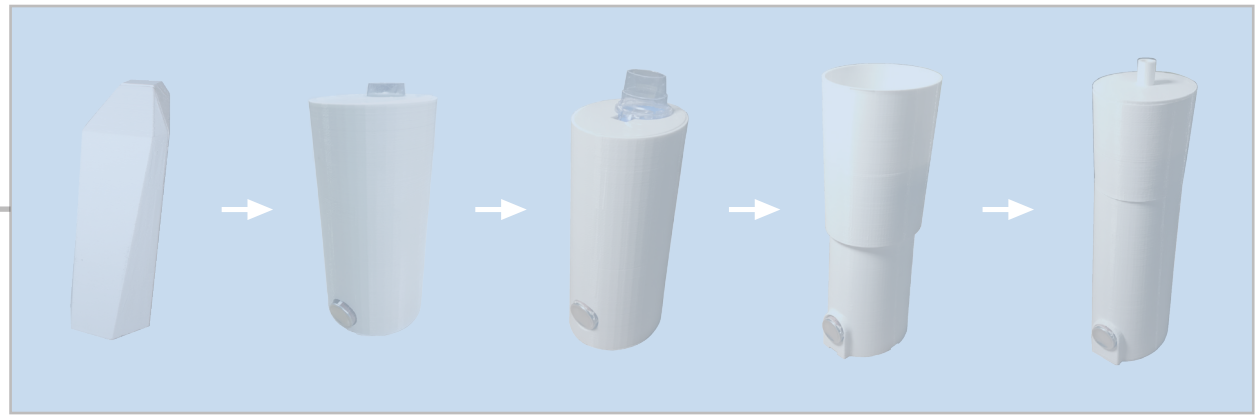
The actuation of a standard MDI requires a mean force of 37 ± 1.2 N whereas the mean maximum force applied during a standard MDI actuation as measured from a study group of children aged 5-17 (n=20) is 46 ± 20 N (Ciciliania, Langgutha, & Wachtelb, 2019). Based on this standard deviation compared to the age differences within this study group it is reasonable to suggest that children closer to age 6 can have a lower maximum force than the required mean force of 37 N.
This is supported by data from a different study which focuses on different types of hand grip strengths in relation to age. By focusing on lateral pinch strength, with this type of grip force exertion being the closest approximation to the actuation of an MDI, it can be seen that the mean force exerted by 6 year old children (both male and female) is insufficient for proper actuation; 4.5 lbf (≈20 N) for females (n=31) and 6.2 lbf (≈ 27.6 N) for males (n=34) (Ager, Olivett, & Johnson, 1984). Based on this study, male children starting from the age of 8 (n=28) and female children starting from the age of 9 (n=29) should be able to properly actuate from the prototype, with the exerted mean force of the former being 9.5 lbf (≈ 42.3 N) and of the latter being 8.4 lbf (≈ 37.4 N) (Ager, Olivett, & Johnson, 1984).

Ideation and Conceptualization

Idea Generation and Selection

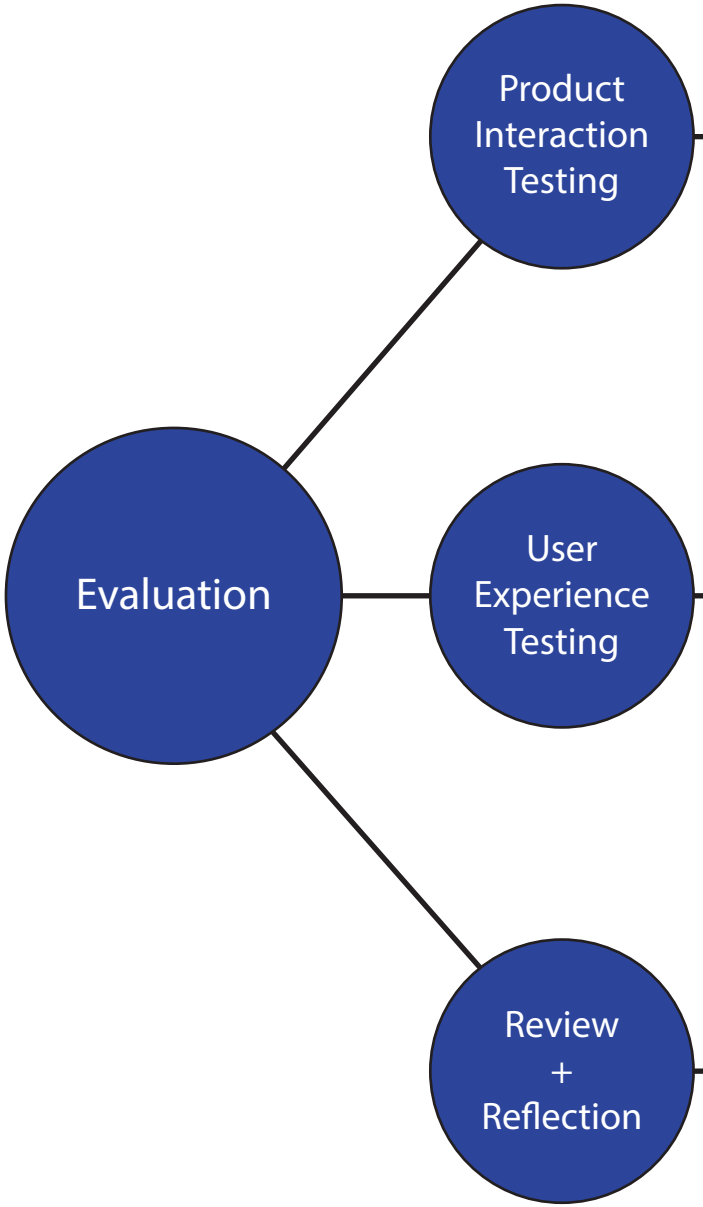
"Lipstick" design direction

Prototyping



Final Concept

4 *Evaluation*



What?

The testing of the final concept in terms of usability by means of the final prototype.

Why?

To evaluate if the target group is able to interact with and use the functions of the product as intended by the designer.

What?

The testing of the final concept in a real world setting in by means of the final prototype. Here the testing is focused on the experiences of the target user whilst using the product.

Why?

To evaluate if the target group has a positive user experience whilst using the product.

What?

A final review of the final concept regarding the design brief and design requirements, along with recommendations for a future model, as well as a reflection on the overall graduation project.

Why?

To complete the design process and to gain an insight regarding the personal growth as a designer during this graduation project.

4.1. User scenarios

Before starting with the evaluation of the final concept, it can be convenient to have various user scenarios as intended by the designer. These scenarios can serve as a script; it can provide a guideline for the steps that the target user has to take regarding interaction with the product.
But it can also provide a role as a reference point; are the steps that the target user takes equal to the steps that the designer has projected for the product? If not, where and why does the target user deviate from these steps and what are the consequences for this?

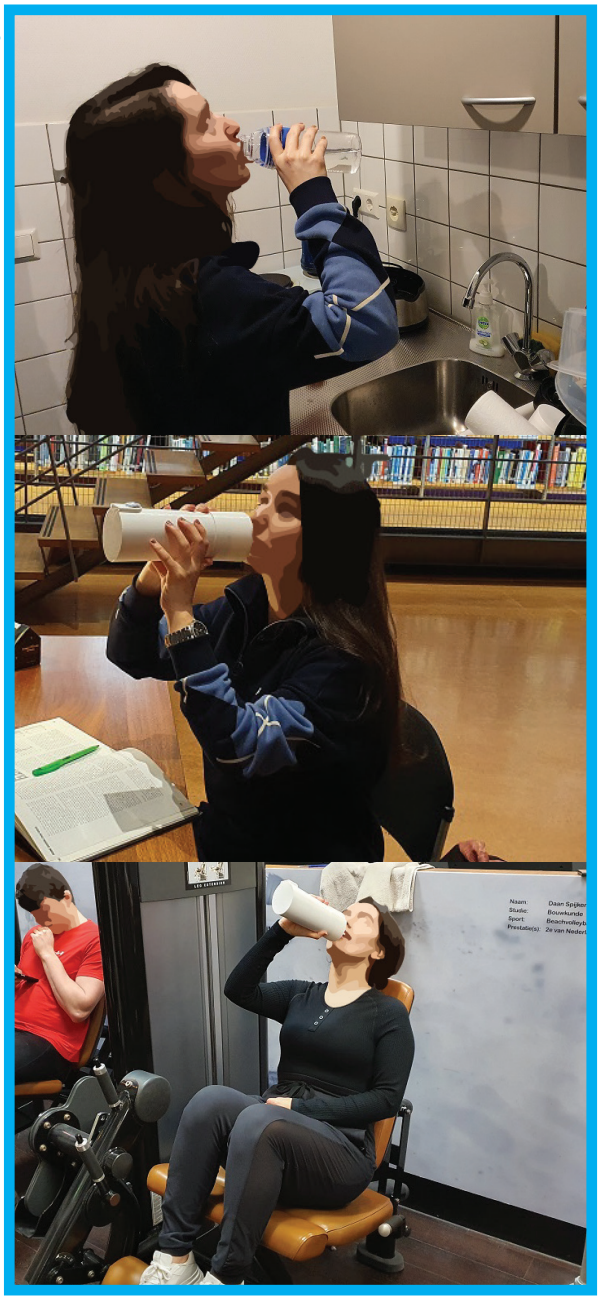
In order to have a reference point for the evaluations in this chapter, the following user scenarios are depicted in the following pages:
The use of an MDI and spacer chamber in a home setting and the use of an MDI and spacer chamber by means of a prototype in two public settings (a library and a gym).

Please note that the following user scenarios do not depict all possible steps, instead these depict usage starting at the point of retrieving the device for inhalation.

1.

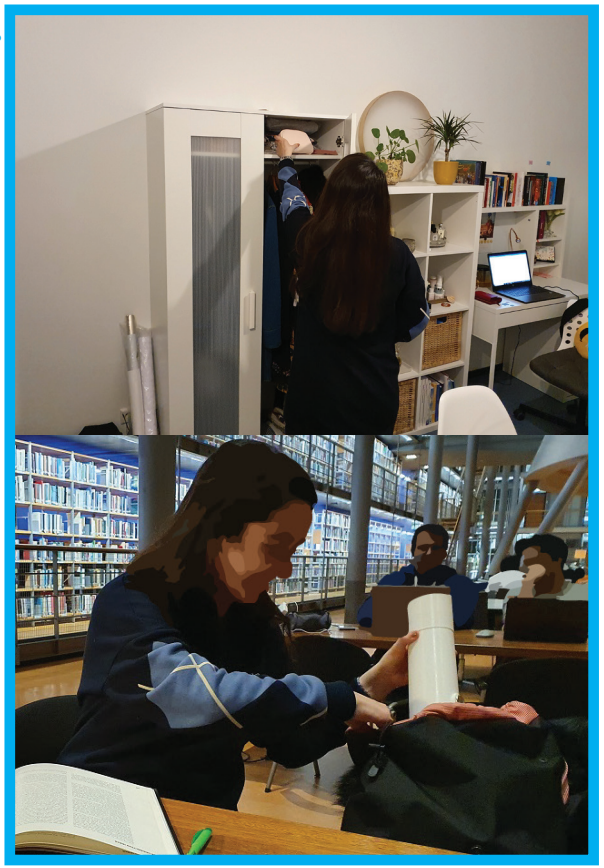
2.

3.



4.

5.



Depicted from left to right:

1. Preparing the device for inhalation
2. Inhaling from device
3. Rinsing mouth with water
4. Writing down the amount of doses left in device
5. Storing device in place of preference

** Please note that in the gym scenario the target user did not have a notepad present to write down the amount of doses left in the device.*

4.2. Product interaction testing

Usability study - Introduction

The concept has been developed with certain user-product interactions in mind. However this does not automatically guarantee that these interactions will perform as intended by the designer. In order to find out how the concept will be interacted with it was decided to conduct a usability study. During a usability study participants are asked to perform specific product related tasks with a concept prototype. From the observations of these it can be deduced if these interactions work as intended. If not, a decision can be made to change aspects of the concept in order to facilitate the actual occurring interaction with the product or in order to try and change the occurring interaction into a different direction.

The goal for this usability study is to determine if a participant is able to autonomously perform tasks with the prototype as intended in relation to product usage and maintenance.

At the moment of this writing the COVID-19 situation is still unfolding. Due to this it was decided to loosen the requirements of the participants in relation to the intended target group of this project. This was done in order to be able to work with the social distancing guidelines surrounding the pandemic and to still actually find participants for this study in a timely manner; it would have been difficult to find actual asthmatic patients willing to participate altogether with consent from a legal guardian. However since the intended product interactions should be clear to anyone wanting to use the product, the usability study could also be conducted with non-asthmatic participants somewhat close to the intended target age.

Method

A meeting is scheduled with each participant with the time and location at the choice of the participant. The participant is met in person altogether with the concept prototype. A brief explanation about the MDI and spacer chamber is provided as not all participants are familiar with these products and the usage of these. The participants are then asked to perform four specific tasks with the prototype, without any prior demonstrations regarding product usage. This is followed up with one open question.

The tasks and open question are the following:

1. (Simulate to) actuate and inhale from the prototype
2. (Simulate to) drink from the prototype
3. (Simulate to) empty and refill the prototype with water
4. Remove the MDI and spacer chamber from the prototype, then place the MDI and spacer chamber back into the prototype
5. How would you clean the prototype? (Open question)

Results

Nine participants in the age range of 19-31 years have participated in this study with the following results:

1. With the exception of one participant, it is understood how to actuate and inhale from the prototype whilst using a proper orientation. One participant tried to inhale from the mouthpiece used for drinking.

2. All participants tried to drink from the mouthpiece intended for drinking.

3. Eight participants screwed off the drinking nozzle and pretended to empty and refill the prototype from the opened bottleneck. One participant initially tried to pry off the whole top of the prototype before understanding that the drinking nozzle can be screwed off.

4. All participants would take off the bottom lid of the prototype and remove the MDI + spacer chamber through it, while the prototype is in a closed state (both prototype halves connected). Four participants have tried to put the MDI + spacer chamber back into the prototype with it still being in a closed state, making it difficult to properly align the spacer chamber mouthpiece with the opening for it in the prototype. The other five participants would remove the top halve of the prototype after initially keeping the prototype closed, exposing the opening for the spacer chamber mouthpiece and making it significantly easier to align these.

5. Seven participants guessed that they would completely open the prototype and clean each part both inside and outside by means of hand washing. Two participants guessed that they would only clean the exterior of the prototype by means of hand washing.

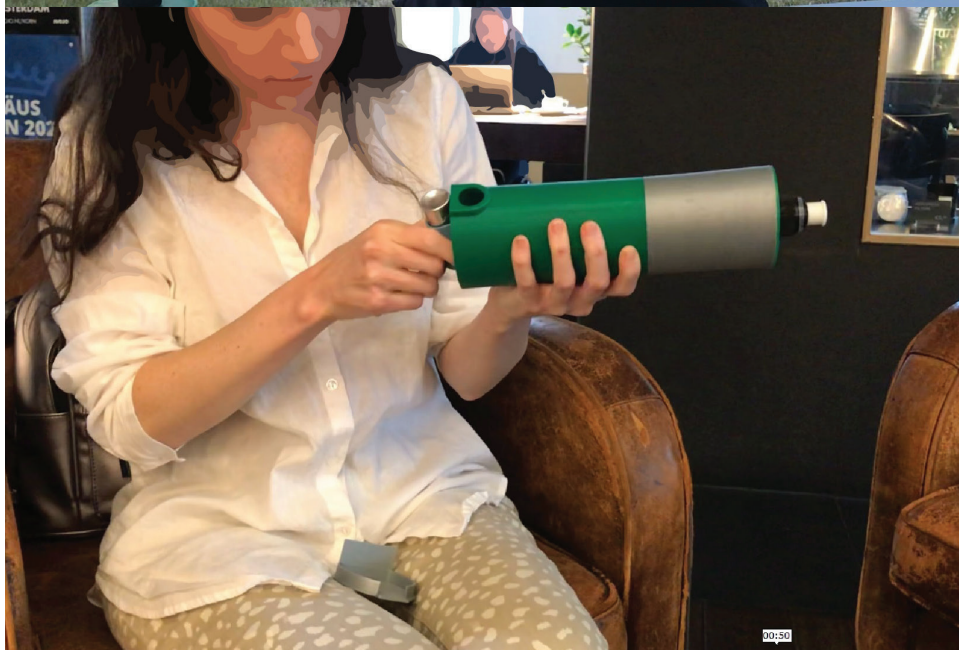


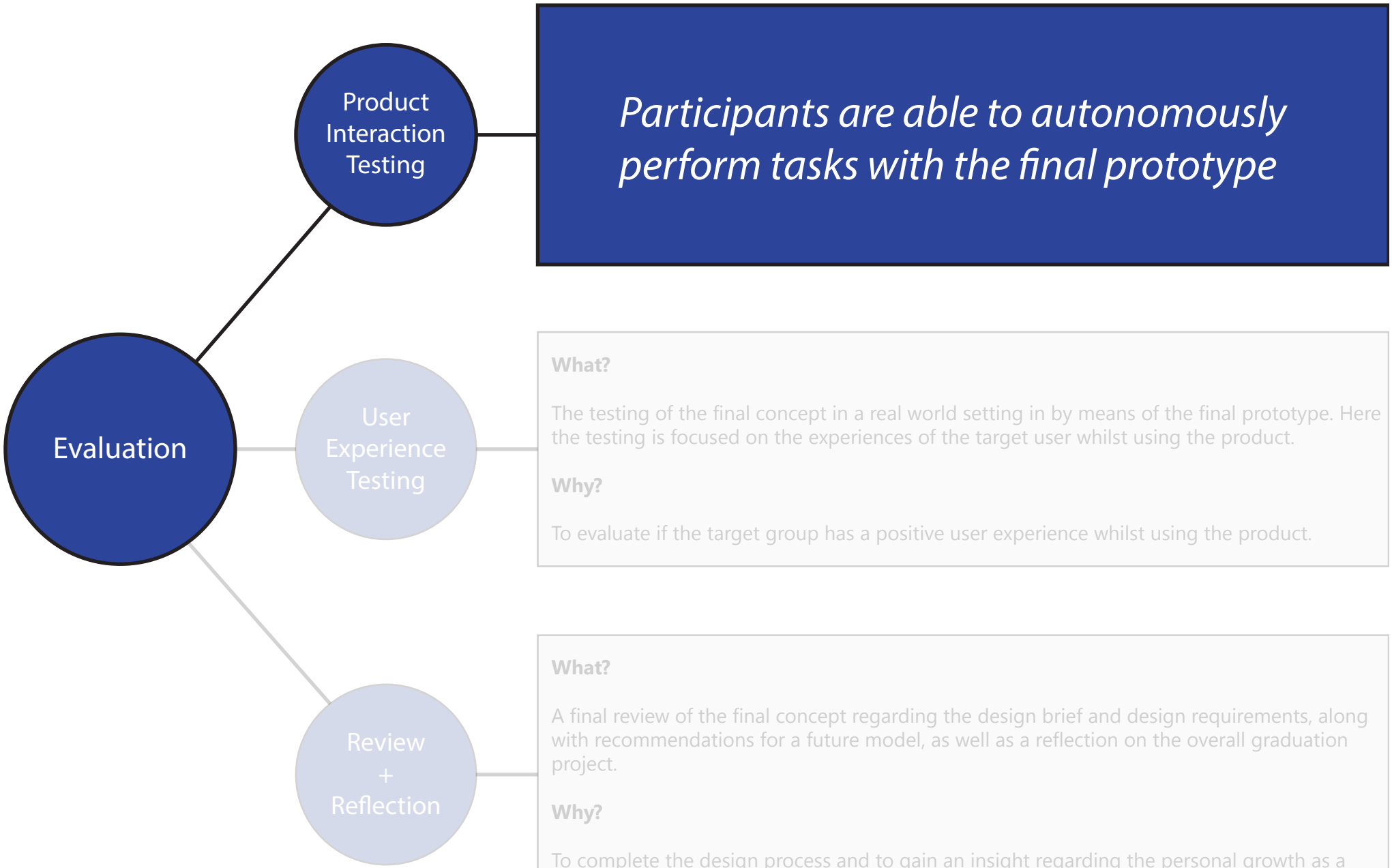
Fig.29 (top right). A participant simulating inhalation from the prototype

Fig.30. (bottom right). A participant placing the MDI + spacer chamber back into the prototype.

Discussion

The findings of the usability study indicate that there are minimal difficulties regarding the product related tasks. This is of interest as only one of the participants was (a former) asthmatic patient and all participants had no prior experience in using a spacer chamber. A reasonable explanation for this is due to simplicity of the prototype. There are no complex mechanics involved and the product interactions consist of basic physical actions, such as pressing an object (actuating the MDI) or pulling two parts apart (uncovering the spacer chamber mouthpiece). Notably a significant amount of participants experienced difficulties in placing (back) the MDI and spacer chamber during the first try. Whilst this can be considered as a design flaw, this product interaction is easy to overcome with instructions and since it is a part of product maintenance it is not a primary product interaction that is encountered on a daily basis.

The results of this study do not indicate that all potential users from the intended target group will experience similar results, as both the physical and mental capabilities differ during developmental ages. A separate usability study targeting younger participants from this group is recommended in order to be able to conclude that the product interaction is satisfactory regarding product usage amongst the complete range of the target group.


Evaluation
Product Interaction Testing
Participants are able to autonomously perform tasks with the final prototype
User Experience Testing
What?
The testing of the final concept in a real world setting in by means of the final prototype. Here the testing is focused on the experiences of the target user whilst using the product.
Why?
To evaluate if the target group has a positive user experience whilst using the product.
Review + Reflection
What?
A final review of the final concept regarding the design brief and design requirements, along with recommendations for a future model, as well as a reflection on the overall graduation project.
Why?
To complete the design process and to gain an insight regarding the personal growth as a designer during this graduation project.

4.3. User experience testing

User experience study - Introduction

In the previous subchapter the focus was on the ability of the user to properly interact with the final concept regarding specific tasks, which is an important aspect to question as a designer. Based on the conducted usability study this does seem to be true. However, this does not automatically indicate that a user is also willing to actually interact with the final concept. In order to find out if a user is willing to interact with the final concept privately, a study has been conducted with the focus on user experience (also referred to as UX).

Again, due to the COVID-19 situation access to participants directly related to the target group was made difficult. In order to still gain useful information, the decision was made to conduct an online study by means of social media (Facebook and Instagram) and an online survey platform (Google Forms). Every person encountering upon this study was allowed to participate, meaning that both asthmatic and non-asthmatic people could respond. This is valuable as asthmatic people should feel comfortable using the final concept and non-asthmatic people should not be able to recognize the final concept as (part of) a medical device, which in turn should make asthmatic people feel comfortable to use the final concept. From a UX study it should be able to find out if this is true.

The goal for this UX study is to determine if a participant is willing to use the product in a public setting (1), and determining if the product does not attract any unwanted attention when used in a public setting (2).

Method

Two series of photos have been taken with the first series depicting the designer drinking or inhaling from the prototype of the final concept whilst being in a public setting. These photos envision how a person using this product could be seen by someone else. The second series of photos are almost similar to the first series with one main difference being that the designer is now inhaling from a “naked” MDI and spacer chamber. These photos are posted on both Facebook and Instagram in the span of two posts, with each post asking viewers to respond to the photos by commenting on what draws the most attention on each photo.

The first series of photos (depicting the prototype) are posted on both Facebook and Instagram, with each platform having a different photo (different public setting). The following day the second series of photos (depicting a MDI and spacer chamber) are posted on both Facebook and Instagram, with each platform again having a different photo (different public setting). At the end of the second post a link to an online survey is posted which contains six statements to be rated by the participants and one final open question.

The six statements and final open question are the following:

1. During an exacerbation (asthma attack) while being in public, I would prefer to inhale from this product over any alternatives (such as inhaling from an MDI only or not taking any inhalation).

2. I feel confident that I will not attract any unwanted attention by inhaling from this product while being in public.

3. I can imagine myself drinking from this product while being in public.

4. I feel confident that I will not attract any unwanted attention by drinking from this product while being in public.

5. This product will make me feel confident to first inhale and then drink from it while being in public.

6. I feel confident that I will not attract any unwanted attention by first inhaling and then drinking from the product while being in public.

7. Would you like to use the product in the future? If yes, why would you like to do so? If not, why so and what would you like to do instead?

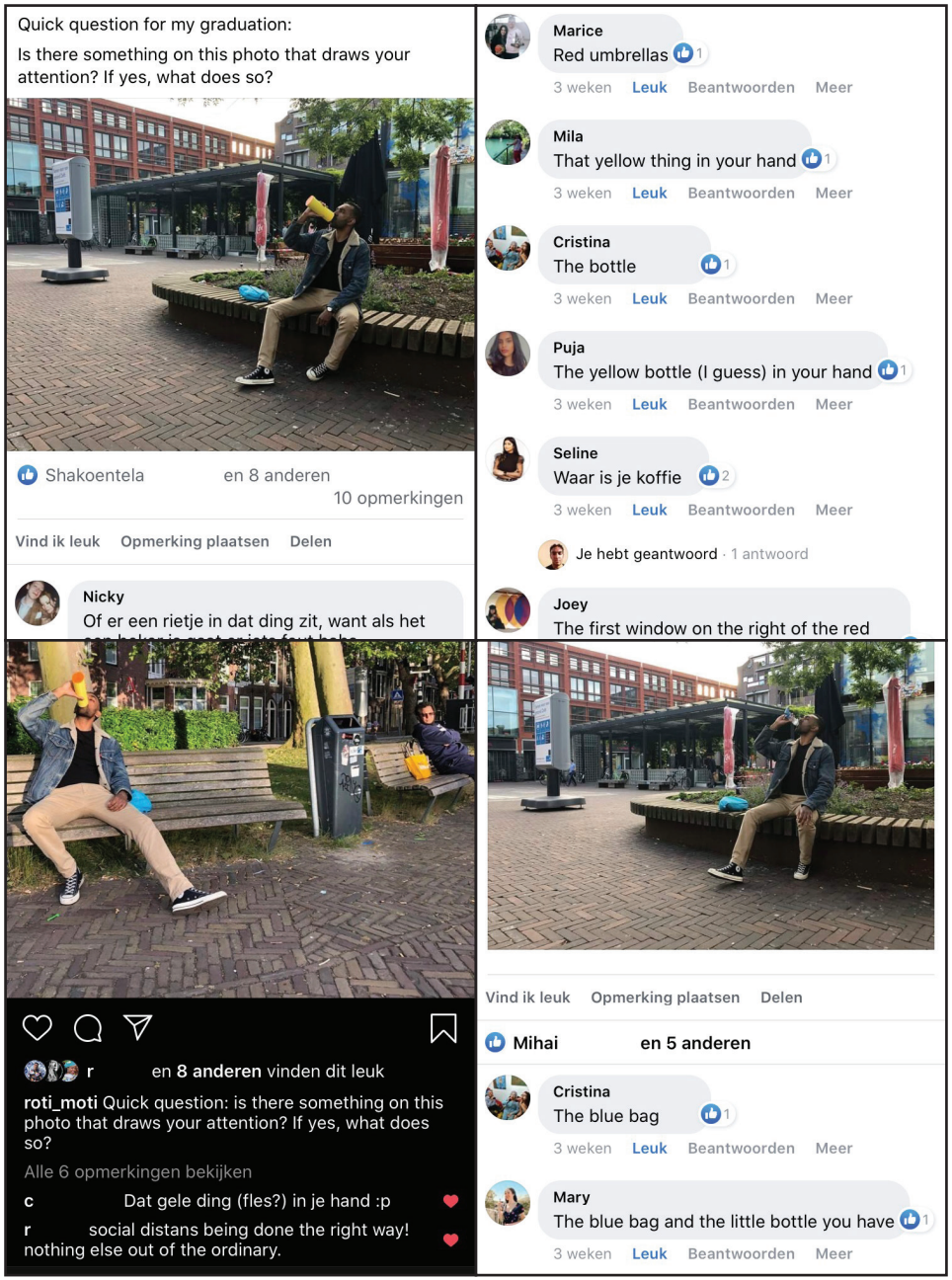


Fig.31 (right). Series of screenshots depicting the social media posts and several comments as provided on these posts.

Results

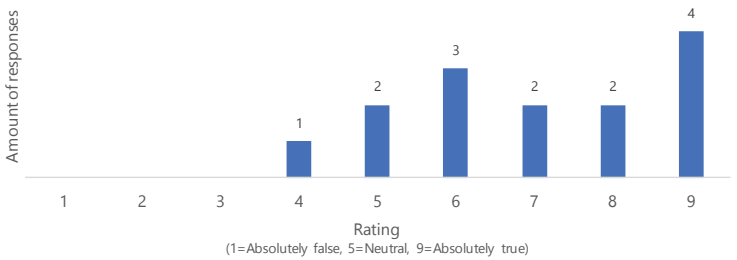
A total of 20 participants have responded on the social media posts and 14 participants have participated in the online survey.

From the social media posts six participants have indicated that the concept prototype draws the most attention on the first set of photos. From these six participants, five participants identified the prototype as a bottle and four participants explicitly mentioned the yellow color of the prototype.

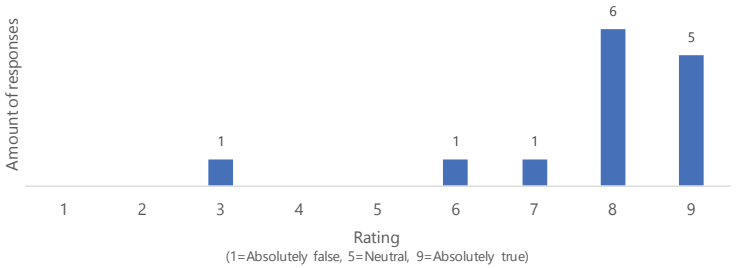
From the second set of photos two participants have mentioned the MDI + spacer chamber as the most attention drawing aspect on the photos.

The results of the online survey are the following:

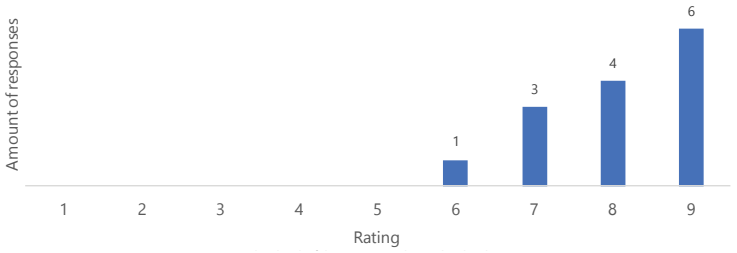
1.During an exacerbation (asthma attack) while being in public, I would prefer to inhale from this product over any alternatives (such as inhaling from an MDI only or not taking any inhalation) .



2.I feel confident that I will not attract any unwanted attention by inhaling from this product while being in public.

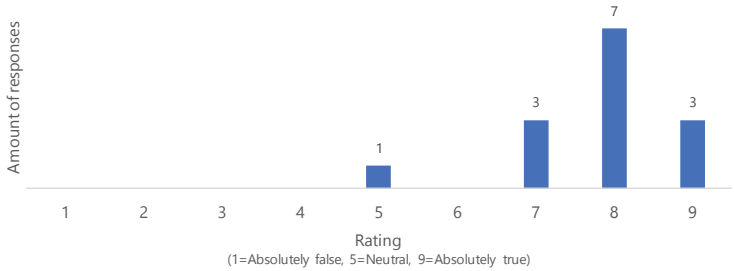


3.I can imagine myself drinking from this product while being in public.

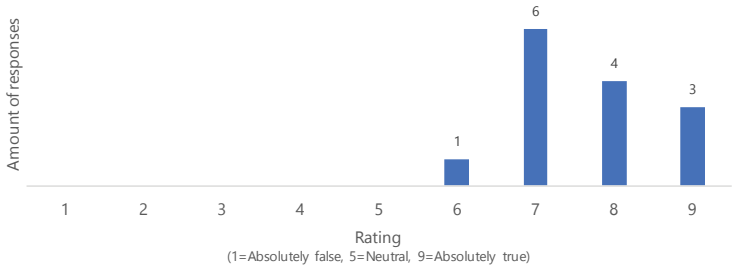


4.I feel confident that I will not attract any unwanted attention by drinking from this product while being in public.

5.This product will make me feel confident to first inhale and then drink from it while being in public.



6.I feel confident that I will not attract any unwanted attention by first inhaling and then drinking from the product while being in public.

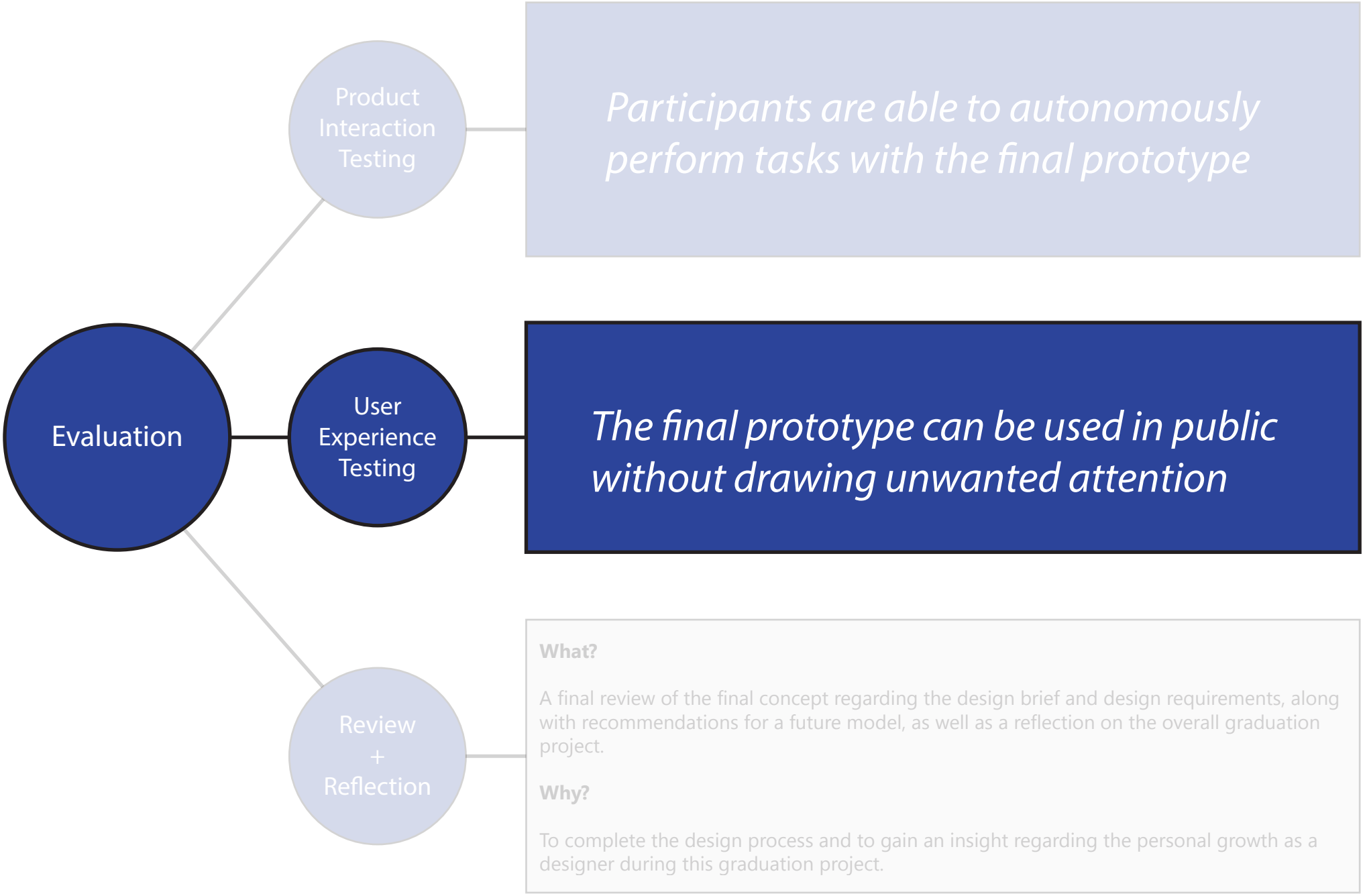


11 out of 14 participants would want to use the product themselves in the future or recommend it to friends with asthma. The foremost reason provided for this is that the product blends in with the environment due to visually appearing as a drinking or sports bottle.

One participant would like to use it in the future, but expresses concern that the product may be too large to comfortably carry around. One other participant expresses concern about the product color (yellow) and would feel more comfortable with a more subtle color that is less likely to draw attention.

Discussion

Both the results from the social media study and the online survey support the notion that the prototype could be used comfortably in public without drawing unwanted attention (or providing unwanted attention as an onlooker) due to the resemblance of a drinking bottle. One caveat to this is that the prototype used in the photos is bright yellow. Due to this it starkly contrasts with everything else on the photos. The results could have been more convincing if a prototype with a more neutral color was used and if more participants would have commented on the social media posts, most notably on the second set of photos.


Evaluation
Product Interaction Testing
User Experience Testing
Review + Reflection
Participants are able to autonomously perform tasks with the final prototype
The final prototype can be used in public without drawing unwanted attention
What?
A final review of the final concept regarding the design brief and design requirements, along with recommendations for a future model, as well as a reflection on the overall graduation project.
Why?
To complete the design process and to gain an insight regarding the personal growth as a designer during this graduation project.

4.4. Review + Reflection

Review

A final evaluation is made by measuring the final concept against the list of requirements and list of desires that has been compiled at the end of the analysis phase of this project. Both the list of requirements and the list of desires can be found on the following pages in the form of a checklist.

As can be seen from these lists, all the requirements are met and most of the desires are met. The only truly missing desire is the desire to provide automatic feedback in case the canister is running low on medicine and is in need of replacement.

Based on the user studies it can be in part concluded that the final prototype is suitable for use in terms of both usability and user experience. It must be noted though that both conducted studies were targeting older participants. In order to be able to conclude that the final concept is appropriate for the complete target group, it is recommended to replicate both the usability study and user experience study with younger aged participants. This was initially planned to do, but due to practical issues it was not able to do so in a timely manner.

Reflection

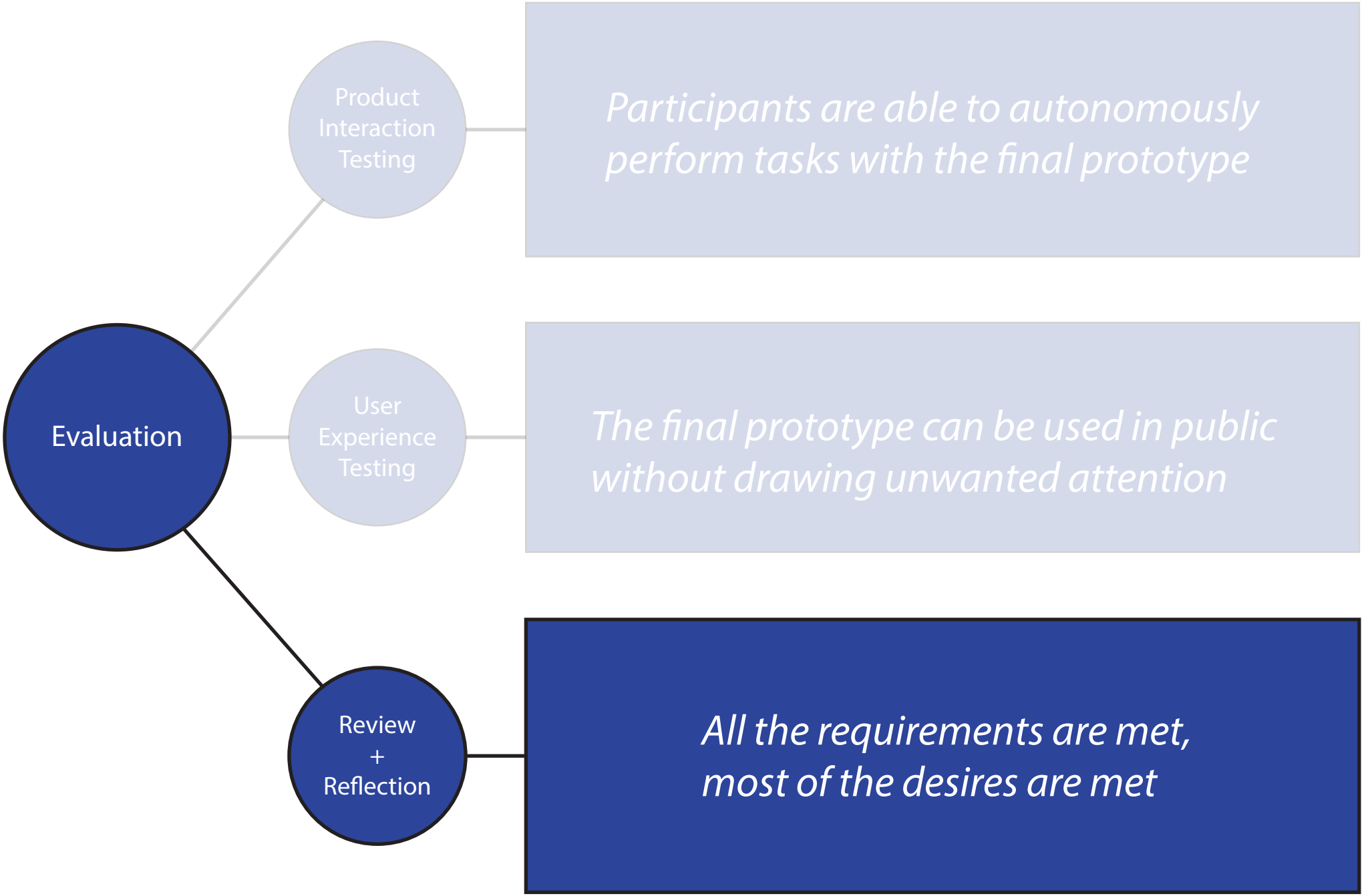
Upon reflecting this graduation project was quite interesting and challenging at the same time. Due to the self-proposed nature of this project, personal responsibility was extra emphasized upon. Since there was no "higher-up" in charge of this project a certain degree of freedom was experienced. However this is a double edged sword, as on one hand there was the freedom to do and work as desired, on the other hand this freedom can backfire, most notably in terms of planning. Working on this graduation project with this freedom whilst working close to full time aside from this project was a prime example how this can lead to a graduation project duration that extends beyond the average. Nevertheless, since the desire remains to continue working on this project with the intention to start a business from it, this experience is and remains very valuable in order to avoid future pitfalls regarding this freedom of time and responsibility.

During the process of this project, the realization was made that several skills needed to be improved upon and this has lead to a learning curve as opposed to solely demonstrating existing skills prior to graduating. Most notably prototyping skills, manufacturing knowledge and the combination of both needed to be improved upon in order to realize a suitable final concept.

For most (if not all) projects It is inevitable that if things could be redone, that this would be done so. In the instance of this project it is not different. Whilst there are quite a few things that could be improved upon, the aspects that wholeheartedly could be changed would mainly be time based. Most notably the overall planning of this project and the timely acquisition of participants for the user studies, given the age range of the target group.

List of requirements	Requirement met?	Additional information
1. The user must be able to inhale asthma medication through the product	*Yes*	
2. The user must be able to actuate the product	*Yes*	
3. The user must be able to hold the product in a correct way	*Yes*	*The orientation of the canister serves as a usecue*
4. The user must be able to drink water through the product	*Yes*	
5. The product must contain an adapter that is compatible with medicine canisters that are used in (generic) MDIs	*Yes*	*The product makes use of a standard MDI*
6. The product must contain a slot or compartment in which a spacer chamber can be fitted	*Yes*	
7. The product must contain an adapter that connects one medicine canister to the spacer chamber	*Yes*	*By means of a standard MDI*
8. The product must contain one mouthpiece which connects to the spacer chamber	*Yes*	*By means of the mouthpiece of the spacer chamber itself*
9. The product must contain a water tank/container	*Yes*	
10. The amount of steps needed to actuate and inhale from the product cannot exceed the amount of steps needed to actuate and inhale from a typical MDI with a spacer chamber	*Yes*	*The amount of steps needed is equal to the amount of steps with a standalone MDI +spacer chamber*
11. The product must be washable	*Yes*	
12. The user must be able to access, rinse and refill the water tank/container	*Yes*	
13. The user must be able to access, remove and replace the spacer chamber inside the product	*Yes*	
14. The materials used in the product must be food safe	*Yes*	*By means of medical grade polypropylene*
15. The product, including the spacer chamber, must comply with the European guidelines for medical devices	*Yes*	

List of desires	Desire met?	Additional information
1. The product must be inconspicuous during use; the product must not draw unwanted attention	*Yes*	*As long as attention drawing colors (e.g. bright colors) are avoided for the appearance of the product*
2. The user must be able to actuate the product during an exacerbation	*-*	*Not tested, but likely to be true due to the use of a standard MDI + spacer chamber*
3. The product will be able to provide feedback to the user when it is time to replace the medicine canister *Ideally the user will be somehow notified to replace a (nearly) empty canister in a timely manner, in order to avoid situations wherein the user is out of medicine to directly use.*	*No*	
4. The user will be able to both inhale and drink water through the same mouthpiece	*No*	*For safety reasons it is undesirable to use one mouthpiece for both drinking and inhaling*
5. The product weight, including the spacer chamber, one full medicine canister and a completely filled water tank/container, will at most weigh similar to a fully filled drinking bottle	*Yes*	*The final prototype weighs 330 grams, including 100 ml water, MDI and spacer chamber*
6. The product must be able to fit inside of a backpack	*Yes*	
7. The water tank/container must hold enough water for at least one sip	*Yes*	*The final prototype has a water capacity of 100 ml*
8. The product will not contain any electronic parts	*Yes*	


Evaluation
Product Interaction Testing
User Experience Testing
Review + Reflection
Participants are able to autonomously perform tasks with the final prototype
The final prototype can be used in public without drawing unwanted attention
All the requirements are met, most of the desires are met

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6 Appendices

Appendix A

What information do I want to gain from the interview?

1. When does the patient use his/her inhaler during one day?

2. How or what looks the situation like during each use of the inhaler?

3. What emotions does the patient experience during each inhaler use?

4. Is there a relation between the situation around each inhaler use and the emotions that are experienced during the inhaler use?

Introductory questions:

1. Hi, what is your name?

2. What is your age?

3. What is your current occupation (elementary school, high school etc.)?

4. What kind of hobbies do you have?

5. Do you play any sports, if so, which?

Questions about asthma:

6. What type of asthma do you have?

7. What type of inhaler(s) do you use?

8. What type of medication do you use?

9. Do you use a spacer? If yes, why, if not, why?

10. How often do you take your medication on a daily basis?

11. Is this amount always the same or can this differ per day?

12. Do you experience asthma attacks? If so, how often?

13. Do you know what can trigger an asthma attack for you? What are these triggers?

Questions about impact of asthma and inhaler use:

14. Can you describe to me where you are when you use your inhaler on a weekday? Can you describe this to me for each time that you use your inhaler on one weekday?

15. For each time that you use your inhaler on this one day, are you alone or are there other people around you? If so, who are these other people?

16. For the times that you are alone during inhaler use, how do you feel? (Happy, strong, confident, unhappy, embarrassed etc.) Can you explain to me why you feel like this?

17. For the times that you are not alone during inhaler use, how do you feel? Can you explain to me why you feel like this?

18. In the instances that you are not alone during inhaler use, does it matter to you which people are around you? If so, why, if not, why?

19. In the instances that you are not alone during inhaler use, do you sometimes receive questions from other people? If yes, what kind of questions? How do you feel receiving these questions?

20. If you could disguise your inhaler, so that it looks like sometime that is not associated with asthma and/or medication, would you like to use that instead of your current inhaler? If yes, why, if not, why?

21. If you could disguise your inhaler, so that it looks like sometime that is not associated with asthma and/or medication, and it also contains a spacer, would you like to use that instead of your current inhaler? If yes, why, if not, why?

Thank you for your time and answers!

Appendix B

ASTMA EN IK

DIT DAGBOEK IS VAN:

.....

TU Delft

OVER JOU

PLAK HIER
EEN FOTO
VAN JEZELF!

Er zijn een paar dingen die ik graag van jou zou willen weten:

Wat is jouw leeftijd? -

In welke groep/klas zit jij nu?-

Welke sporten beoefen jij nu?-

Wat zijn jouw hobbies?-

Waar ben jij goed in?-

Waar zou jij beter in willen worden?-

DAG 1

1. Geef op de tijdlijn aan wanneer jij jouw puffer hebt gebruikt vandaag. Schrijf er bij hoe laat dit was of ongeveer was.

2. Waarom moest je toen jouw puffer gebruiken?

3. Waar was je toen jij de puffer gebruikte?

OPSTAAN

GAAN SLAPEN

DAG 2

Tijd voor foto's!

1. Maak een foto van jouw puffer(s).

2. Maak een foto van alles wat je naar school meeneemt.

3. Als je een sport beoefend: maak een foto van alles wat je naar het sporten meeneemt.

4. Welke spullen op de foto's zijn belangrijk voor jou? waarom zijn deze spullen belangrijk voor jou?

Tip: Je mag de foto's uitprinten en op deze bladzijde plakken of bijvoegen, maar je mag ze ook via whatsapp/messenger sturen, of gewoon mailen naar:

r.motie@student.tudelft.nl

DAG 3

1. Met wie vind jij het makkelijk om over jouw astma te praten? (Het mogen meerdere personen zijn)

2. Met wie vind jij het moeilijk om over jouw astma te praten? (Het mogen meerdere personen zijn)

3. Waarom vind jij dit makkelijk bij de mensen van vraag 1 en moeilijk bij de mensen van vraag 2?

Ik vind het makkelijk om te praten met:	Ik vind dit makkelijk omdat:
Ik vind het moeilijk om te praten met:	Ik vind dit moeilijk omdat:

DAG 4

Het is weer tijd voor foto's!

1. Liggen jouw puffers op verschillende plekken gedurende één dag of liggen ze telkens op dezelfde plek?

2. Maak foto's van waar jouw puffers liggen. Maak ook nieuwe foto's van dezelfde puffers als deze op andere plekken liggen gedurende één dag.

Tip: Je mag de foto's uitprinten en op deze bladzijde plakken of bijvoegen, maar je mag ze ook via whatsapp/messenger sturen, of gewoon mailen naar:

r.motie@student.tudelft.nl

DAG 5

Omschrijf drie activiteiten waar jij het moeilijker mee hebt door jouw astma.
Hoe zorg jij ervoor dat jij die activiteiten toch kunt doen?

activiteit:	→	oplossing of hulpmiddel:
activiteit:	→	oplossing of hulpmiddel:
activiteit:	→	oplossing of hulpmiddel:

DAG 6

1. Hoe voel jij je als je jouw puffer moet gebruiken wanneer jij thuis bent?

2. Hoe voel jij je als je jouw puffer moet gebruiken wanneer jij op school bent?

Je mag dit hieronder allemaal opschrijven, tekenen of knippen en plakken!

thuis

school

DAG 7

Als jij iets aan jouw puffer(s) zou mogen veranderen, wat zou jij dan willen veranderen?
Je mag dit hieronder opschrijven, maar ook tekenen. **Alles mag!**

ASTMA EN IK

DIT DAGBOEK IS VAN:

.....

TU Delft

Appendix C

1. Get product in house
2. Get medicine canister in house
3. Insert canister in product
4. Store product inside storage space (e.g. backpack)
5. Take product out of storage space (e.g. backpack)
6. Inhale from product
7. Drink from product
8. Clean product
9. Maintain product

1.1. Transport (car, bicycle, delivery etc.)
1.2. Carry
1.3. Unpack

2.1. Retrieve MDI (with canister) from pharmacy
2.2. Carry
2.3. Unpack

3.1. Remove canister from MDI
3.2. Open product
3.3. Place canister in compartment for canister
3.4. Close product
3.5. Prime the product

5.1. Open backpack
5.2. Find product
5.3. Take product out

6.1. Hold product
6.2. Actuate product
6.3. Put lips around mouthpiece
6.4. Inhale from product
6.5. Remove lips from mouthpiece
6.6. Repeat from step 6.2. when more doses are prescribed
6.7. Rinse mouth with water

7.1. Hold product
7.2. Turn/press switch
7.3. Put lips around mouthpiece
7.4. Drink from product
7.5. Remove lips from mouthpiece
7.6. Turn/press switch back to original position

8.1. Open product
8.2. Remove spacer chamber
8.3. Handwash spacer chamber
8.4. Airdry spacer chamber
8.5. Rinse mouthpiece product
8.6. Rinse water reservoir
8.7. Airdry open product
8.8. Place back spacer chamber
8.9. Close product

9.1. Replace canister
9.2. Replace spacer chamber
9.3. Refill water reservoir

9.1.1. Receive feedback
9.1.2. Open product
9.1.3. Remove empty canister from compartment
9.1.4. Place new canister in compartment
9.1.5. Close product
9.1.6. Prime the product

9.2.1. Open product
9.2.2. Remove spacer chamber
9.2.3. Place new spacer chamber inside cavity/slot
9.2.4. Close product
9.2.5. Prime the product

Appendix D

Appendix E: IDE Graduation Assignment

IDE Graduation Assignment

CONTENT

Introduction

Give a sketch of the context of your assignment. Historical developments, if applicable relevant published scientific research results, new trends, status quo; materials, technologies, usage, etc. If it is a faculty project: describe how your assignment reflects the research portfolio of the IDE Faculty. If it is a company project: provide Company information. If other, e.g. entrepreneurial: describe your future enterprise and how your assignment will be of value to the enterprise.

This graduation assignment is self-proposed, with additional help from Dr. Jean Driessen from the Center of Excellence (COE). It is in part a continuation on the results of the project Exploring Interactions.

In Exploring Interactions an aesthetic redesign of an asthma inhaler was made, primarily targeted towards young exercise induced asthma patients, in order to allow the user to use asthma medication in public without attracting any undesired attention. The main reason for this is that (especially young) patients are self-conscious about their appearance and have a tendency to avoid using medication when surrounded by peers, which may have a detrimental effect on their personal health.

Due to the very positive response of the children and young adults the final concept was tested on, as well as their parents and Dr. Jean Driessen (who helped during this project as an expert), a commercial potential in this was recognized. A desire to continue working on this project with the intention to bring a finished product on the market was born out of this.

Current asthma inhalers that are on the market work fine on a functional level; i.e. the administration of asthma medication to the user. But as mentioned above the appearance of the inhaler could be improved upon in order to avoid the stigma of inhaler usage in public.

In terms of functionality there is also room for improvement (see Problem definition). By means of a feedback system it could be possible to aid patients in both proper usage of the inhaler and reminding the patient when to use it for prophylactic purposes.

The intention is to both create a prototype of this new inhaler and to create a business that can sell this new inhaler. For this a business plan will be made, parallel to the designing of this new inhaler. The prototype can be used as a proof of concept and in turn a means to attract investors for this new business. According to *Stichting Longfonds*, currently there is an estimated amount of 565.000 people living in the Netherlands who have a form of asthma and the prediction is that this group will keep growing. Around 103.000 people of this group are children. Based on these numbers the impression is that it can be commercially interesting to cater to this group of people.

Problem definition

Indicate clearly, what is should/could be improved in the present situation. When executing a research project: indicate the knowledge gap. What opportunities exist, what contradicting demands should be addressed, etc.

First and foremost, mostly in the case of younger asthma patients (children, teens, young adults) there is a stigma attached to the use of an asthma inhaler, especially when in public. This leads to situations in which patients simply will not use their medication when necessary, which can have negative health effects. As demonstrated during Exploring Interactions, it is possible to overcome this stigma by altering the shape of the inhaler as to imitate the shape of a completely different product, such as a bottle. This effect has not been tested on adults yet, but it is likely that it can affect at least some of them, in for example work environments (such as in an office shared with co-workers).

A major problem with current (aerosol) asthma inhalers is that it is very easy to use incorrectly; a common mistake is that users hold the inhaler at such an angle during usage that the spray from the inhaler directly hits the palate or the back of the mouth. Due to this less medication reaches the lungs.

A third problem is partly related to the previous problem in that asthma patients do not always get the correct (prescribed) dose of the asthma medication. A combination of incorrect use and the patient not always following the prescription leads to situations in which the patient can be either underdosed or overdosed on the asthma medication. This can both have effects on their personal health, but also on society, due to the costs of wasted medicine.

Finally, asthma patients can have a prescribed routine in when they should use their asthma medication. Currently it can be very easy to forget to take the medicine, especially when the patient does not feel any adverse effects of this at the moment. In the longer term health effects could occur, without the patient (and treating doctor) understanding how these effects are occurring.

Assignment

Briefly and to the point, describe the assignment to solve (part of) the problem for your 'client', i.e. Company of Faculty.

Design a new (aerosol) asthma inhaler that asthma patients are willing to use in public without fearing negative experiences such as shame or embarrassment anymore; there is no reason for an asthma patient to not use this new asthma inhaler when necessary.

This new inhaler will help the user to hold the inhaler in a correct way during usage, provides the user with a correct dosage of asthma medication and alerts the user to when it should be used whilst providing healthcare providers with valuable information on medication use.

Approach

What will be the approach to deal with the complexity of the assignment? What has to be done to meet the challenges? Indicate the steps within your project. If one or more extra parties are involved in your project, indicate which role they play.

There are four main steps that will be taken:

- Getting to know the original product; how does it work, what kind of canisters are being used, but also what does the market around it look like?
- Finding out for who to design, what their characteristics and needs are and how to cater towards these characteristics and needs.
- Generating ideas and concepts for a new asthma inhaler based on the findings of the previous steps. Also generating ideas in how to sell this new asthma inhaler.
- Developing a fully working prototype along with a business plan

Graduation Project results

Describe the expected results or outcome of your Graduation Project for your (imaginary) 'client', i.e. the Company or the Faculty. Describe what you intend to design, create and generate. E.g. a product, a product-service combination, a strategy illustrated through product or product-service combination ideas.

The expected outcome will be a fully working prototype along with a business plan. This prototype will be used as both a proof of concept and as a means to attract investors for a business.

Deliverables

List the mandatory graduation deliverables here, being the thesis report, annexes if any, the poster and the representative pictures. Furthermore, you may want to mention specific deliverables, such as a working prototype or a paper.

- Periodic report updates
- Final report
- Final presentation
- A1 poster
- Working prototype
- Business plan
- Repository uploads

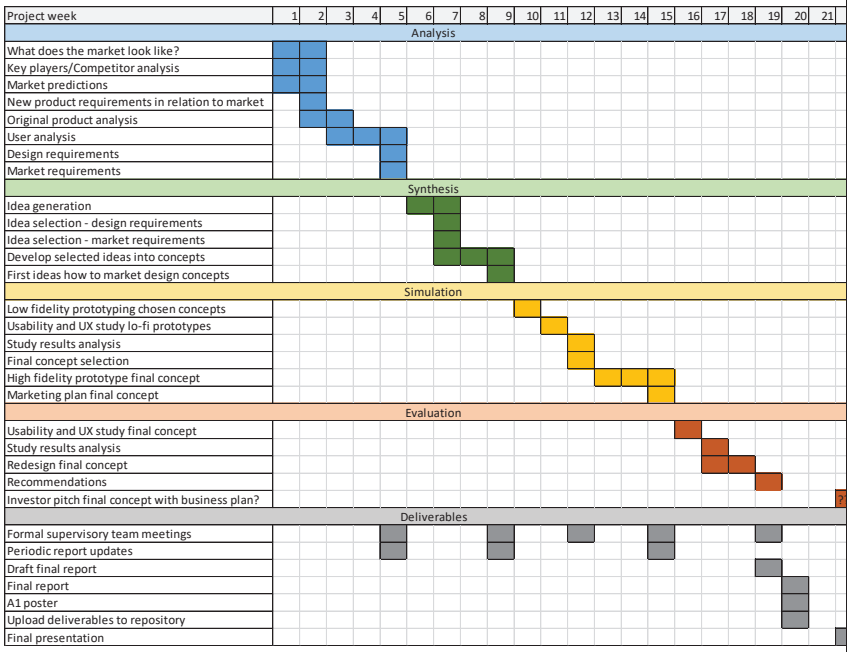
Relation and relevance to the domain of Industrial Design Engineering and the chosen master direction

Explain (as indicated/required in the graduation manual): 1) What is the relation of your project with the domain of Industrial Design Engineering and your master direction? 2) What is the relevance of your project to the mission of the IDE faculty? and 3) Explain the touching points of your project with each of the pillars of the triangle Human-Business-Technology. Indicate the scientific and/or societal significance of the outcome of your project.

The focus on improving upon the original product in the areas of usability and UX coincides with the chosen master of Design For Interaction. By designing for asthma patients I am also satisfying the requirements for a graduation project for a Medisign student.
This project makes use of the opportunity provided by the IDE faculty to create a startup business. The potential outcome of this project is that a successful business could be launched that can improve the lives of asthma patients regarding their medicine usage, while at the same time reducing the waste of medicine.

Planning

Present your planning in a Gantt Chart, which can easily be made in Excel, see example underneath. Make sure a print in black and white is still readable.
Mention the main phases of the project + number of weeks. Indicate only main activities, milestones, meetings.
Take notice: 33 EC = 22 full-time weeks! 30 EC are to be gained in the fulltime semester 4, 3 EC in the previous semester (part-time). Indicate periods of part-time graduation project activity and/or periods of not spending time on your graduation project, if any, e.g. because of holidays.



Brief explanatory remarks on the planning, if any.