Empower people's perception of air and their ability to

Improve indoor air quality

Master thesis
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EXECUTIVE SUMMARY

Air pollution is a widely accepted problem in today's world. Nine out of ten people does not breathe healthy air due to rapid urbanization and human activities that cause increased severe air pollution. Over the years people have had a tendency to comfort themselves with everything they need inside. However, they may not be aware that the amount of dangerous pollutants indoors is often 5 times higher than outside *(EPA, 2017)*. Since we spend 90% of our lifetime indoors, the impact of indoor air pollution (IAP) on our health is relatively high, especially for children. Their bodies and lungs are still developing what makes it very important to breathe safe air. When individuals deal with the risk of being exposed to IAP, they may have various beliefs about the impact it has on their health and the way of keeping indoor air quality (IAQ) levels within an acceptable range.

Since people are a valuable asset in buildings, it seems practical to make them able to manage their own air. In the recent years, filtration of air through the use of air cleaners for private use has been an upcoming technological trend. Together with TinyWolf, the startup I am part of, we develop an air purifier to provide various households with clean air where it matters most. For most people air purification introduces new ways of thinking how to improve IAQ.

To bridge the research gap of related work in the relationship between IAQ and human behavior,

my research aims to understand household members' perception of air and their related behavior in order to empower and design for their ability to improve the indoor air quality.

In order to deal with the complexity of human behavior I used a theory that has found its way from social science into design research. The social practice theory provides a framework to study family and individual life to create an insightful overview of understanding everyday habitual practices that are linked to IAQ.

I firstly evaluated the current situation in order to examine the challenges household members face when they want to improve indoor air quality. Findings show the importance of access to information and tools to reduce the exposure to indoor air pollution. Secondly, in the practice-oriented design approach I introduced three households with different versions of TinyWolf's purifier. The evaluations investigate the influence of the designed products on household members' perception of the impact of a purifier on the perceived air as well as their ability to adopt the product for use in existing daily practices, in particular the sleeping practice. Findings show that the product alone does not immediately lead to behavior change. It's meaning and a measure of skill are necessary. Research shows that the empathy between people and product can influence the way they act *(Aftab & Rusli, 2007)*. My project shows a way of how design could be used to empower people's ability to improve indoor air quality.

PREFACE

This work in front of you is the result of my great learning experiences of the last six months. This thesis has been written to fulfill the last requirements of the Master's degree in Design for Interaction at the faculty of Industrial Design Engineering at Delft University of Technology.

I would like to thank the following people for the guidance and contribution throughout my project.

Stella, thank you for being my chair. Thank you for trusting me in approaching my project in my own way. You encouraged me to make decisions by critically reflecting on my work and providing me with related articles and suggestions to enhance my progress. Tomasz, thank you for supporting me by sharing your ideas and vision. Your proactive feedback has inspired me to make new connections while maintaining the intrinsic value of my work. You learned me to structure my thoughts and keeping the overview.

This project would not have been a success without the honesty and kindness of the three families that have participated. Their enthusiasm throughout the research has motivated me to inspire them how to improve air quality.

I would like to thank Sten, Mikkel and Esben for their contribution to my project by always openly sharing their thoughts and opinions, that has been a great help throughout my process.

A special thanks to my family and friends who believed in me throughout the project. It has been a rollercoaster sometimes, therefore a big thank you for the advice, distraction, laughs and great help.

I am very excited to present you my master thesis.

Enjoy reading!

Annemijn Pille

Copenhagen, April 2019

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INTRODUCTION

CHAPTER 1

In this chapter the subject of my thesis project is introduced. This section starts with a broad perspective of the project's topic to illustrate the relevance of the thesis to everyday challenges in today's world.

1.1 Pollution alert!

Air pollution is among the largest worldwide environmental health risks. The World Health Organization (WHO) estimates that 7 million people die prematurely every year from air pollution-related diseases, of whom 4 million die from indoor air pollution (WHO, 2018). Polluted air is a mixture of natural processes and human activities. Presence of air pollution can interfere significantly with comfort, health and welfare of persons *(Brunekreef, 2002)*.

Very large parts of the population in urban areas breathe air that does not meet the European standards, let alone WHO Air Quality Guidelines *(WHO, 2005)*. The result of rapid urbanization consequently is increased severe air pollution. We occasionally experience smog hanging over cities when poor air flow and dispersal allows pollution to build up. Many cities face challenges in meeting the needs and demand of their own growing urban populations.

The lack of visible smog does not indicate healthy air. Residents are exposed to a variety of pollutants over their own lifetime. Understanding the types of pollutants is crucial for identifying the health impact and to help protect human health in the future *(Power, A. et al., 2018)*. The BreatheLife campaign developed a pollution meter for people to help them understand how polluted the air around them really is.

Technology plays a prominent role in conveying air quality information to people. Innovation and awareness of air pollution traveled outside of Asia to Europe, which has now the highest number of places reporting air quality data *(WHO, 2018)*. Technological air pollution interventions depend upon achieving a durable change in public attitude and behavior in a way that improves people's health as well as the quality of the air they breathe *(Kelly & Fussell 2015)*.

1.2 Bringing attention to indoor air pollution

Despite the attention for outdoor air pollution, indoor air pollution (IAP) can often be overlooked, because gases and particles inside buildings remain invisible for occupants. Nevertheless, the risk of exposure to IAP is relatively high because of the high amount of time spent indoors *(US EPA, 1989)*. Moreover, most people are not aware of the higher number of dangerous particles indoors than outdoors *(US EPA, 1987)* and don't know how to improve the air quality most effectively.

In order to help people understand what factors of indoor air quality they specifically should pay attention to when trying to achieve a healthy indoor environment, it should be stated clearly what is meant by indoor air quality.

1.2.1 Defining indoor air quality

Indoor air is in principle an extension of the outdoor air. According to the U.S. Environmental Protection Agency (2017) the indoor air quality (IAQ) can be defined as the air quality inside and around buildings and structures, especially as it relates to the health and comfort of building occupants. This definition is used for the purpose of my research, because it includes the health and comfort of residents as well as aspects of the environment, which both are important elements within my research.

Air quality consists of various factors, such as the temperature, humidity, pollutants and also air movement. Within my research I am focusing on the quality of the air that represents a concentration of pollutants that can affect human health. Hereby, good IAQ can be defined as clean and unpolluted air. Whereas poor IAQ indicates a concentration of pollutants in the air that can endanger people's health and the environment.

A pollutant in the air is a substance that can have many forms, different sizes and either come from indoor or outdoor sources. The determination of types of pollutants can be categorized in three main groups: biological pollutant sources, chemical pollutant sources and physical pollutant sources.

Appendix 1.A: Explanation of different pollutant sources

INDOOR AIR QUALITY

''The air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.''

- US EPA (2017) -

1.2.2 Indoor air quality and human health

The exposure to air pollutants indoors plays a significant role in human health, especially because we spend 90% of our time indoors *(EPA, 1989)*. Exposure to particulate matter (PM) and allergens can trigger common diseases as allergic reactions, asthma symptoms, airborne respiratory infections or other sensory irritation. These symptoms are a result of pollutants that enter our lungs and find their way straight into our bloodstream.

In fact, people are human air purifiers who filter the air in a natural way. With 23.000 breathes a day it is important for everyone to breathe safe air. In our lives we already face a lot of health risks, some we choose to accept and some we choose to avoid. Poor indoor air quality due to high concentrations of indoor air pollutants is a risk to our health we can do something about, if we have access to the right information and understanding to make an informed decision.

The exposure to concentrations of pollutants varies and depends on factors such as individual behavior, activities, the type of pollutant sources and building conditions. My research will focus especially on the influence of people's perception of IAQ factors in relation to their ability to take the required action for air quality improvement.

1.3 How people behave, perceive and sense

1.3.1 Defining human perception and behavior

Perception occurs as a result of information in several kind of systems of our body. One of these systems is the sensory system which includes five senses: taste, smell, sight, touch and sound. Information is perceived by a sensory experience of the world around us. It involves a cognitive process that is required to process the information of our surroundings followed by our actions.

The array of every physical action and observable emotion associated with individuals and/or groups refers to human behavior. Our behavior is a response to internal and external stimuli we perceived.

Building a behavior consists of two parts, initial and habitual behavior. When building an initial behavior change it turns into a habitual behavior. Including a behavior change is crucial, but sustaining the behavior as a habitual action is also important.

PERCEPTION OF AIR

''The awareness of indoor air quality factors through senses.''

1.3.2 Perception of indoor air quality

As mentioned before, the definition of indoor air quality is defined as the awareness of indoor air quality factors through senses. Everyone has different receptors in their body for reception, transmission and perception of airwaves, sight or smell. When an odorant is breathed into the nose, which is an area of the body rich with odor receptors, the translated messages tell you it is a smell of for example of food or traffic.

People's response to indoor air quality factors can modify the pollution levels and effects. The active registration of sensory input makes us able to understand and interact with our environment. In order to improve IAQ, behavioral changes of an individual may be required, because each person may be forces to develop action to adjust the indoor air quality levels.

How attitudes towards the environmental stimulus develop depends on several factors to the individual, the context and the perception of risks to be exposed to poor IAQ. For more detailed information about a person's perceptual process see appendix 1.B.

Appendix 1.B: The perceptual process

1.4 Partner of the project: TinyWolf

An important stakeholder of my project is the startup I am part of named TinyWolf. If you mirror 'Wolf' it stands for flow, a tiny flow.

1.4.1 About TinyWolf

TinyWolf is a spin-off of DTU (Denmark Technical University) developing a product to improve indoor air quality for various households with children. Together with our team of four we have been working on the development of our air cleaning technology over the last year. Our development process has been funded by various Danish funds.

1.4.2 TinyWolf's vision

The vision of our startup is to help children with respiratory related problems by creating better air quality. Hereby TinyWolf is now in process of technical development and validation of our product that gives individuals clean air to breathe. The goal is to improve the daily quality of life and health through an innovative approach to health technology, so that new technology for a better life reaches far more. To reach our goal a next step for TinyWolf is optimization of the product's design through involvement of the end-users.

1.4.3 Why TinyWolf is part of my project

A main reason why TinyWolf adds value to my thesis project is because this collaboration enables me to evaluate the users' perspective of how the use of the provided air purifier influences their perception of air and perception of the impact of the air cleaning technology on IAQ related practices in daily life. At the same time I collect additional data specifically aimed to add value to TinyWolf's further product development process.

1.5 About this project

1.5.1 Scope and opportunity

The air pollution challenges that the world's population is facing today are hard to tackle by one single thesis project. However, every small step in changing the world for a better tomorrow will be one in the right direction. Therefore I narrowed the scope down and turn the problem into an opportunity to tackle (literally) from inside out. My project aims to help residents in their ability to improve indoor air quality for a healthier living environment.

In order to achieve my goal and deal with the complexity of the project I split the research in three sub researches.
In the first sub research the opportunity is to evaluate household members' perception of air and their current IAQ related behavioral patterns and routines in the context of their home. Because air is invisible it is hard for people to understand, what makes it a key issue in people's perception of air. Perception of air is a process of understanding the sources that contribute to indoor air pollution, the impact of pollution to health, knowledge of IAQ factors and ability to take the required steps to make an informed decision to improve the air quality. In the second sub research the opportunity is to evaluate how household members' perception of air and their IAQ related practices are influenced by introducing them to TinyWolf's air cleaning technology that aims to reduce indoor air pollutants. In the third sub research a research through design approach is taken in order to evaluate the impact of three design iterations of TinyWolf's purifier on people's perception of air and their IAQ related practices. The opportunity is to evaluate in what way design empowers people's ability to use the purifier in an optimal and effective way.

RESEARCH AIM

Understand people's perception of indoor air quality and related behavior in order to empower and design for their ability to act on improvement of indoor air quality

1.5.2 Research setup

This generative and evaluative research is divided in three parts:

Part 1 consists of a quantitative and qualitative research evaluation of the current situation at households' homes. The first phase is a quantitative analysis in which an online survey is set up and send to the mass audience to gather data on people's knowledge of IAQ, their home conditions and their current behavior regarding IAQ control. The second phase evaluates the current situation of three households in their homes. This is a qualitative research that evaluates the household member's knowledge of IAQ, the way they currently operate and their home environment. This is done through observations, interviews and a context mapping tool which I named 'capture your air' (Appendix 2.C).

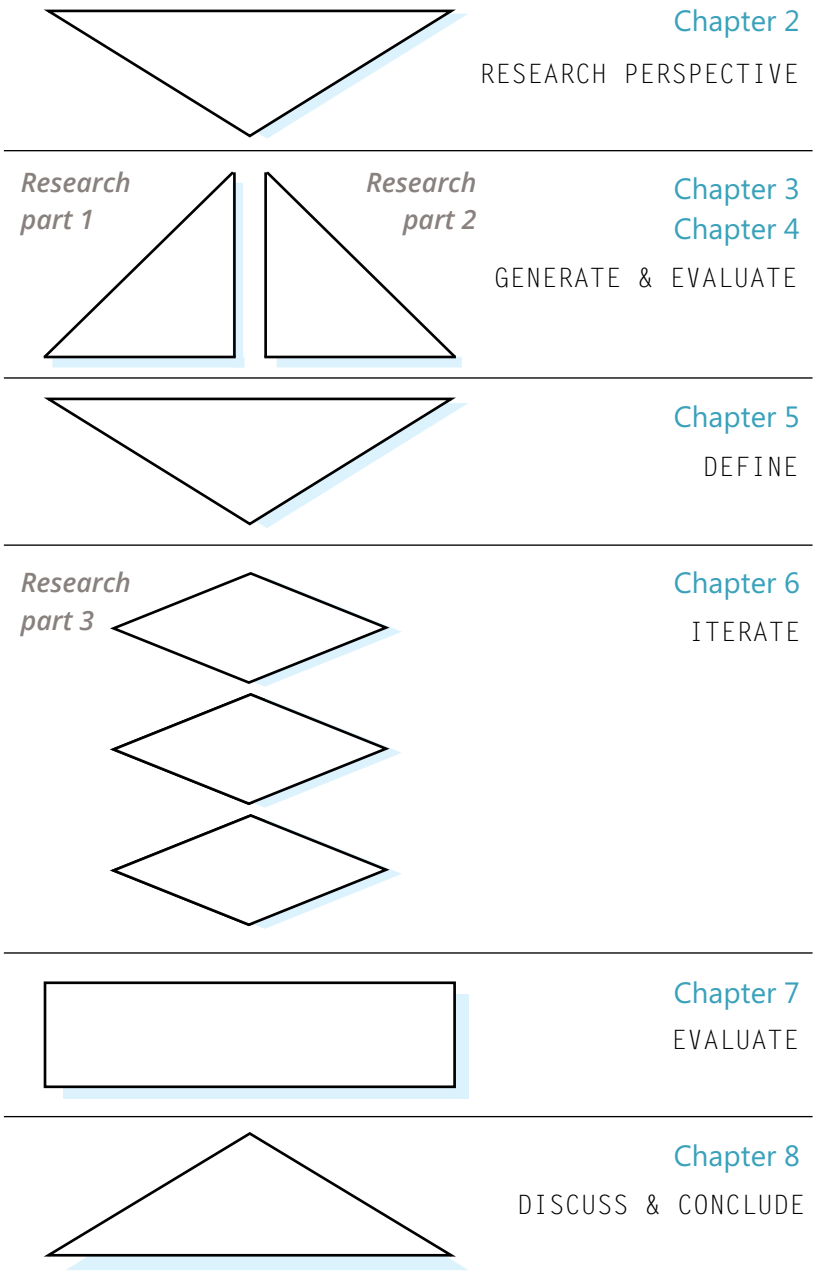
Part 2 evaluates TinyWolf's product at the three households' homes. The purpose of this part is to gather insights on the household members' understanding of the purpose of the device and its influence on their IAQ related perception and practices inside their homes. This is done through observations and interviews. The participants are asked to keep this running log of their activities during the test period of minimum five days (up to 5 weeks).

Part 3 consists of three research through design iterations. This parts arises from the generated data of the previous two research parts. Each iteration continues on characteristics of TinyWolf's product to generate further knowledge about the research area through exploration of design opportunities. These design opportunities refer to adjusted features of Tiny Wolf's device in terms of product embodiment design. Again each iteration is tested over a period of minimum five days.

Eventually all main findings are evaluated and discussed plus conclusions about the whole project research are drawn.

1.5.3 Report structure

The structure of this report is organized in the following way. The next chapter introduces the research perspectives and describes the main method that is used throughout the research. Chapter 3 serves as starting point of the research and presents the evaluative research findings of the current situation (research part 1). Chapter 4 describes the evaluation of Tiny Wolf's purifier (research part 2) . Chapter 5 summarizes the main findings and results from the first two research parts and defines the research and design opportunity for the three iterations. Chapter 6 describes the research through design process in which the three iterations of TinyWolf's purifier are evaluated (research part 3) . Chapter 7 represents the main findings of the research through an evaluation of users' air practices. Chapter 8 presents discussions, conclusions and further research opportunities. Chapter 9 reflects on the whole graduation project.



RESEARCH PERSPECTIVE

CHAPTER 2

2.1 Introduction

In preparation of my research I developed the way how to conduct the research as well as how to present the research findings. This means that I needed to think about the type of data best addresses the research goal and question. The choice of a suitable theory begins with the identified research aim and opportunity.

Because the aim of the research is to understand people's perception of and behavior towards indoor air quality in order to support their ability to improve it. It is important to understand the complexity of human behavior.

Theories can help explain human behavior as well as suggest how to develop more effective ways to influence to change behavior. The research design of my research is built on a research theory perspective to guide the search of understanding behaviors and/ or situations.

For the analysis of behavioral patterns and routines of household members in their daily life I am choosing a research perspective of social science. The reason for choosing this is because social science studies how individuals and/or groups behave, think or feel in particular situations.

The theory perspectives provide a framework to study family and personal life to create an insightful overview for understanding everyday habitual practices within a wider social or cultural structure. This is particularly interesting for my research.

2.2 Research perspectives in social science

2.2.1 Different research perspectives

Over the years several types of research perspectives have been applied in social science. In this section three research perspectives are discussed and one of them is chosen to being used in my research.

SDT

The first theory is the self-determination theory (SDT), which is about what is important for people and links personality to human motivations and optimal functioning. According to the SDT there are two main types of motivations that drive people for taking certain actions, intrinsic and extrinsic motivation. Both are powerful sources in shaping who we are and how we behave *(Deci & Ryan, 2008)*. However, the distinction of the two motivations has not been seen as an either-or distinction. What means that the same individual can be intrinsically and extrinsically motivated at the same time. This would limit my research in a way that although the SDT predict a persons' experience of making a clear choice of whether to control the indoor air quality, it has a considerable controversy about the meaning of that choice.

DM

Decision making is based on two systems according to Daniel Kahneman, intuitive thinking and rational thinking *(Kahneman and Tversky, 2007)*. The basic idea behind his decision making perspective (DM) is that the first phase (intuitive thinking) is an analysis of the problem and outcomes based on facts, automatism and emotion *(David, E. Bell, 1988)*. In the next phase (rational thinking) the framed prospects are being evaluated and the prospect of the highest value is selected. Criticists of the DM state that his theory is not wrong, however it does not comply with what can be observed in everyday life either. Studies reasoned that the DM could be applied in organizations where people make decisions, but it rarely applies to decision making choice on an individual in everyday life, what than would be a challenge for me in my research as well.

PT

The third perspective is the practice theory (PT). The practice theory is a more pragmatic approach and mainly analyzes data regarding people's skills and abilities. In fact, this theory may offer a way to address the limitations of SDT and DM. What makes the PT most appropriate for me to use as basis for the research design is that this theory provides a framework that can help me to gain better understanding of the impact of designed products and how these are influenced by the context of use.

2.2.2 About the practice theory

The social practice theory pays attention to how people's actions are collectively guided. The theory is based on the notion that daily routines are created by residents performing a series of habitual social practices *(Shove et al., 2012)*.

According to *Reckwitz (2002a)* a practice is a routinized type of behavior. He describes that a practice consists of elements that are interlinked to one another. This can be in forms of physical or mental activities, obtaining knowledge or understanding, forms of emotional status and psychological motivation. From his definition it becomes clear that practices can be viewed as sets of interconnected elements.

What this indicates is that a product alone does not immediately lead to behavior change. An idea of what the product does and a measure of competences are also necessary, and thereby the question remains about how the material and other elements are combined. *Shove et al. (2012)* explains that when new elements are introduced or when existing elements are reorganized in new ways a change of practice can be made. A change of practice conceptualizes behavioral change.

PRACTICE

''A routinized type of behavior which consists of several elements, interconnected to one other.''

- Reckwitz (2002a) -

A practice is comprised of the following elements:

Material
This element includes things, technologies, tangible physical entities and stuff of which objects are made. This includes not just our designs but everything, including wind from outside and abstract things such as a numbering system.

Skill
This element encompasses skill, know-how and technique. There are physical and cognitive aspects that can also be learned, not just capabilities such as how well someone can see for example. In most design cycles we underestimate the importance of skill, but they are valuable to capture.

Meaning
This element includes symbolic meaning, ideas and aspirations, not just individual meaning, but also social meaning and conventions.

A configuration of these elements may provide an analytical tool to understand relationships between human and products, but it does not necessarily lead to understanding of how the relations are changed by design. Therefore, it is important to note that human behavior can be seen as a performance of a practice. The performance of one ore more practices is considered to be guided by a organizational dimension of practices, which *Shove et al. (2012)* refers to as practice-as-entity. The reason why it is an entity is because the practice can exist but does not necessarily need to be performed at that specific moment, instead it can travel in space and time.

2.2.3 About emotional design

In order to understand the impact of design on human activities and to develop an approach that facilitates desirable behavior change is a major challenge in the discipline of design.

Although the practice theory has made their way into design research, I will use another theory framework described by Chapman and Norman to analyze the more product related data of my research. The reason for choosing to use this approach is because according to their theory emotional design can create empathy and thereby influence the way people feel, think and act. The framework is divided in three levels of emotional design:

Reflective level
This level of processing is about interpretations, understanding and reasoning, in other words about personal satisfaction.

Visceral level
This level has everything to do with the physical appearance.

Behavioral level
This level is about the usability and pleasure of effectiveness of use.

Where the practice theory is taking practices instead of interactions or product as unit of the analysis to help gaining deeper understanding of the relationships between objects and users *(Shove et al., 2007)*, Chapman's and Norman's theory offers a systemic approach to analyze data related to emotional design what can help refining the opportunity to support effective use of Tinywolf's purifier for indoor air quality improvement.

SKILL

Understanding know-how
taste and competences

Behavioral

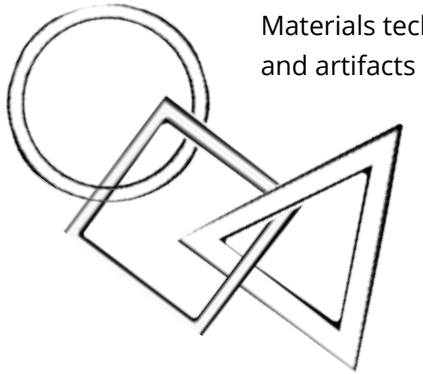
Usability and how a
product works

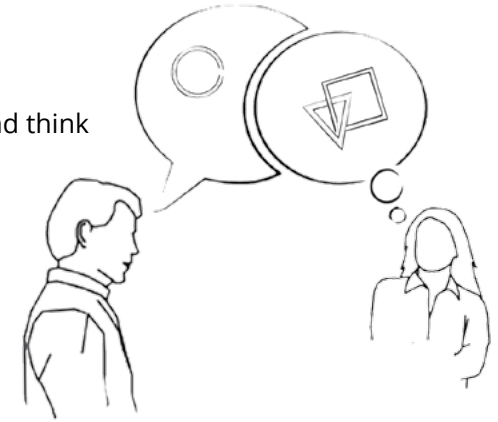
MATERIAL

Materials technologies
and artifacts

MEANING

Emotions and meaning
What people say feel and think





Visceral

Physical
appearance

Reflective

Interpretations
and reasoning

Figure 1: Practice theory and Norman's theory

2.3 Research design

2.3.1 Research boundaries

The boundaries of my research about people's current and future behavioral patterns and routines regarding indoor air quality management determines factors for characterization of the three elements of a practice (skill, material and meaning).

The main purpose of using the practice theory for the evaluation of household members' practices regarding indoor air quality is to construct an overall picture of practices by looking whether the elements change or not over time.

As shown in section 1.5.2 the research of my project is split in parts, with each part its own focus and corresponding research aim and questions. The questions need to be answered in order to provide a basis for the exploration of potential practice based means.

Overall, the practices are studied rather than people's behavior in order to reveal the connection between what residents do in their daily life concerning indoor air quality control and the outcomes for healthier living conditions.

2.3.2 Data collection and analysis

The qualitative data is gathered through interviews, observations and additional research documentation which are specifically mentioned per research part in the following chapters.

During the interview sessions with the participants data is obtained through audio records, which are fully transcribed after each session. This allowed me to pay all my attention to the participants while interviewing them, what increased the quality of the data. The analysis is done by using statement cards with the transcripts written on them in order to categorize them. In this way I could structure the data to gather insights of the evaluations and identified themes of practices.

A more detailed explanation of the additional research documentation is given in the researches where they apply to. For example, a sensitizing tool is being used in the evaluation of the home situations.

2.4 Discussion and conclusion

2.4.1 Practice theory and design

According to *Reckwitz (2002a)* the social practice theory is not a grand theory, what means that it does not claim to be 'true'. Rather the potential of the theory provides room for design speculations and interventions. This is of importance for the development of new design solutions, in my case, in the field of indoor air quality related practices.

Design research inflected by the social practice theory brings a unique material thinking and knowledge, a tendency to notice small material details but also styles and standards of practicing that might be overlooked in more conventional sociological analyses.

Shove et all. (2012) emphasized an opportunity for design to consider its role in configuring socio-technical interactions of use practices, via products and information. Inquiries into understanding of design users are far from new and are central to human-centered approaches in product design and interaction design. But the design outcomes are largely artefactual responses to meeting perceived end-user needs. Design has understood its power and knowledge production technically, as inscribed in its instruments and outcomes.

HOME EVALUATION

CHAPTER 3

3.1 Introduction

This generative research evaluates how household members currently perceive IAQ as well as how they behave to control IAQ in the context of their home. In this introduction of this chapter the relevance of my research in relation to existing literature is discussed.

3.1.1 The indoor generation

Given that people are a valuable asset in buildings and their amount of hours spend indoors, it seems practical to make them able to manage their own indoor air quality. The question remains in what way they could be best supported in their ability to establish safe air to breathe.

Research shows a strong relationship between IAQ related human behavior and IAQ components, such as opening a window *(Fabi, 2012)*. In this research human behavior of residents is examined based on data analysis from smart home sensors and measurements to monitor IAQ levels. However, this research does not provide insight in people's understanding of IAQ and the influence of their perception of air on their actions to improve the air quality.

Other research does report the effect of using IAQ sensors to provide people with information of IAQ and shows that these monitors can help people to better express perceptions about the reduced risk of exposure to indoor air pollution *(Wong-Parodi et al., 2018)*. This study might show that technology became the messenger of IAQ, however it does not show the impact this has on IAQ related human behavior.

Attitudes of families with young children on their air quality awareness has been studied by *Philips (2012)*. This research shows that people lack understanding of informative tools on IAQ that are available in the market. It is true that this research has been done in 2012 and that in the recent years technological development has run fast what could mean that the IAQ monitors of today have improved in communication of information that people would need to understand the IAQ. Therefore the relevance of Philips' findings on IAQ monitors is doubted.

Nevertheless, in contrast to *Fabi's (2012)* and *Wong-Parodi's (2018)* researches I will not use any IAQ measurements in this evaluative research. Although information on IAQ levels could be provided, it does not mean that people will understand where pollutants are coming from or how to take the required actions to reduce indoor air pollution. In order to evaluate the challenges they face to effectively reduce indoor air pollution in the current situation I want to gain understanding of their perception of air quality factors without them being influenced by provided information of IAQ sensors or monitors. This would help me gain deeper understanding of how to best help them improve the air quality with a solution that is designed with them and not for them.

3.1.2 Vulnerable people to indoor air pollution

Several studies have researched the effect of IAQ on human health and they represent the following three groups of people who tend to be most vulnerable to indoor air pollution:

1. Young children
2. People who suffer from respiratory diseases or asthma
3. Elderly

The reason why these groups of people are more vulnerable to indoor air pollution than others, is because some people of the world's population relatively spend more hours indoors, or they already have more difficulties breathing in comparison to other persons.

3.2 Research design

3.2.1 Target group and participant screening

In my research I target families with young children, aged under five years old. The reason for this specific group of participants is because children are still in an important development phase of their growth what makes it very important for them to breathe safe air.

The target group meets the screening criteria of having at least one child aged under five years old, located in the city center and being health conscious.

3.2.2 Research aim and question

The objective of this home evaluation research is to understand household members' perception of and behavior towards indoor air quality in the current situation. In order to evaluate this objective a combination of both quantitative and qualitative research methods is used. The research is split into two phases:
1. An evaluation of people's relation to indoor air quality in terms of knowledge, awareness and behavior (quantitative research)
2. An evaluation of household members' perception of IAQ and their IAQ related behavior at three different household homes (qualitative research)

Based on this two research questions are formulated:
1. What are household members' perception of IAQ?
2. What are household members' current behavioral patterns and routines regarding IAQ?

The outcomes of these research questions are combined into an overview of perceptions and IAQ related practices that help to refine the opportunity to help them improve the air in their homes.

RESEARCH QUESTION 1

''What are people's current behavioral patterns or routines regarding indoor air quality in their homes?''

3.2.3 Method

In the first phase of the home evaluation an online survey is sent to the mass audience in order to gain general insight into how people think, feel and behave to IAQ. The findings of this survey help to generate a basic understanding of the relationship between IAQ and human behavior. Based on these findings I could develop the setup of the interview questions that are asked during the interview sessions with the three households in the second phase of the evaluation.

The setup of the evaluation at the three household homes consists of an introduction and post interview, observation and additional documentation through a sensitizing tool (Appendix 2.B).
In the first interview session questions are asked in the following themes:
1. What household members know about IAQ
2. How they perceive IAQ, both in terms of awareness and impact to their health (risk perception)
3. Their current behavioral patterns and routines regarding IAQ.

'Capture your air'
The sensitizing tool is used to gain deeper understanding of people's perception of air. Participants are asked to take photo's of elements or objects in their home that they find good or poor IAQ factors. They are given two to three weeks' time to freely wonder and reflect about the subject, until the next interview session in which the results of the task are discussed.

3.2.4 Data collection and analysis

During this evaluative and generative research quantitative and qualitative data was gathered. The online survey delivers mostly quantitative data through the open-ended and closed questions that are asked. Whereas the second phase delivers rich qualitative data about the relationship between IAQ and household members.

The combination of participant's response, observations and the results of the sensitizing tool gave me a quite elaborate understanding of how they perceive, feel, think and behave to IAQ in the current situation.

3.4 Main findings

3.4.1 General opinion on indoor air quality

The online survey is filled out by 52 respondents. The main findings of the survey refer to how people feel, think and behave to indoor air quality.

Quantitative data

N = 52

46% of the respondents lives in the city next to a busy road

31% perceives IAQ problems at home

Seeing dust / mold
Feeling humidity / dryness of air
Smelling traffic / food inside

84% thinks poor IAQ impact health

Irritable feeling of airways and eyes / coughing

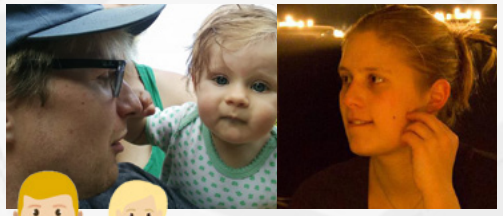
98% opens the windows

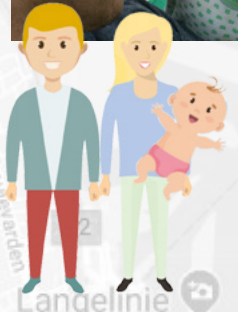
98% does not make use of any products to improve IAQ

Qualitative data

3.4.2 Participating households

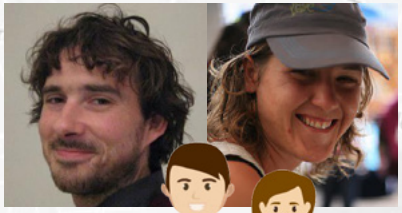
The participating households all meet the screening criteria (3.2.1). All families have children who are not having any particular respiratory related health symptoms and are aged under five years old. House A and House C are situated next to a busy road.

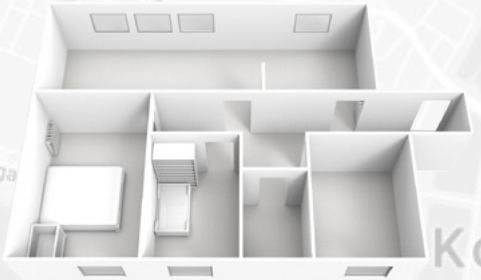




HOUSE C

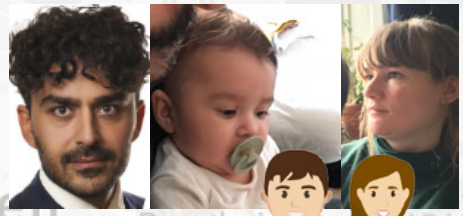
Oliver and Tanja
Frida (1 year)

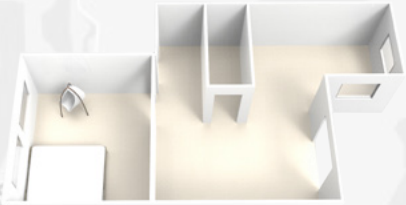




HOUSE A

Hugo and Imke
Nova (3.5 year) and Otto (1 year)





HOUSE B

Alireza and Fanni
Helia (3 months)

3.4.3 Perception of and behavior towards indoor air quality

The main findings of the home evaluation are divided into findings regarding household members' perception of air, IAQ related behavioral routines and practices.

Perception of air

In general, participants seem to be aware of indoor air quality factors through sense of smell, touch and/or sight. Mainly the awareness of presence of poor IAQ factors lead to change of IAQ related behavior. For example, according to Alireza, seeing moisture on the windows motivated him to open the windows. At the same time he is aware of the poor air quality levels because he reasoned: 'Normally I open the windows when I see that even the windows start to sweat, but I know that then the air must be really bad, if I can even see it.'. This is a good example of how the awareness of poor IAQ motivates household members to improve the air.

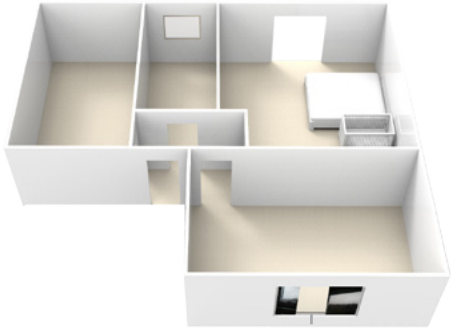
''Normally I open the windows when I see moisture on them.''

Perception of air

Vision	seeing dust / moisture / mold
Touch	feeling a breeze / temperature / humidity
Smell	smell of nature / neutral / food / traffic / artificial fragrances

Reduced perception of health risk

Risk	concern about the impact of IAQ on health
Knowledge	connecting IAQ factors to health, however, they wish to know more about it



‘CAPTURE YOUR AIR’

Good IAQ factors

Poor IAQ factors

Reduced perception of health risk

Besides awareness through senses, perception also relies on the risk of exposure to air pollution that is perceived. Findings show that parents of all households have some understanding of the risk of exposure to poor IAQ. Tanja reasoned: 'We are not opening the windows during rush hours anymore, because there was too much smell of traffic'. Although she is aware of the risk of exposure to air pollution, the link between poor IAQ factors to health symptoms is lacking. Nevertheless, her knowledge of air pollution in general leads to changes in IAQ related behavior such as opening the windows only at certain times of the day.

Practices

Both situations (Alireza and Tanja) refer to cleaning practices in which sense of IAQ factors motivates to be actively involved in improving the air in their home.

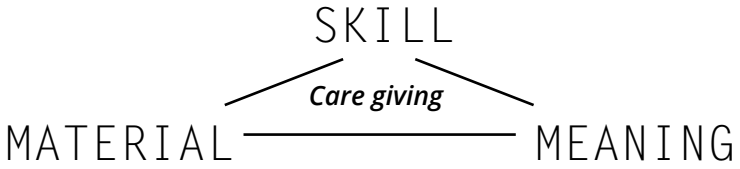
Two other themes of IAQ related practices that emerged at the households' homes are child care giving and obtaining peace of mind. Findings show that actions to improve IAQ are reinforced by parent's feeling of being responsible to care for their children. Imke said: 'I want to create a calm and clean place for my children at home because I have the feeling they are already exposed to a lot during their time in the daycare'. And her husband Hugo reasoned: 'To prevent air pollution harming our children we have tried to circulate the air by using a hair dryer in the bedroom before they go to sleep'. These findings refers both to stimulating a healthy indoor environment for the child as regulating the IAQ at home for obtaining peace of mind.

According to Fanni it is hard to control the air in the bedroom in winter, because it either gets too cold when opening the windows what concerns her for the health of her baby, or if she keeps the windows closed she has a feeling of a 'heavy head' after a night of sleep with three persons in one room. Also Hugo mentioned the same: 'During the winter I would like to have the windows opened in the bedroom, but I always have to go out of bed in the night to close it because it gets too cold'. He mainly does this because he is also concerned about the impact of cold air on his son's health.

3.4.4 Overview of existing practices

Encouraging child development by following rituals and creating routines

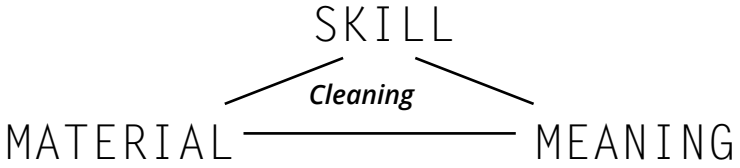
Stimulating health and sleep with use of building elements, products and applications



Parents are feeling themselves responsible for the child's health including the value of good sleep

Active cleaning happens mostly during the day

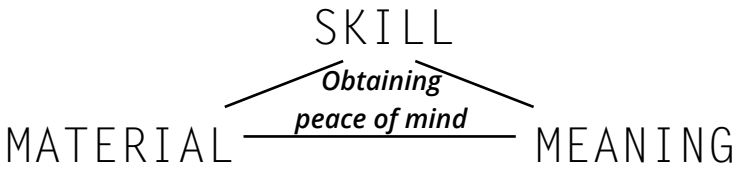
Windows are being opened when noticing poor IAQ factors, and cleaning additional cleaning activities with use of products



Sensing poor IAQ factors (mostly moisture and dust) motivates to take action for improvement

Creating a clean and calm environment at home for all household members

Regulating IAQ by opening the windows and sequential regulating temperature by heating the radiators



Having the feeling of being in nature creates a feeling of freshness, although real freshness is still questioned

3.5 Discussion and conclusion

3.5.1 Discussion of the findings

Findings of this research show that the sense of poor IAQ factors and/or perceived risk of exposure to air pollutants acts as environmental stimulus for household members to take action to improve the air quality inside their home. Findings showed that poor IAQ factors that are perceived include a variety of factors such as humidity, pollutants, temperature or air movement. Without the use of any air measurement tools it may be hard to tell what air quality factors cause particular feelings or actions of residents.

Despite that, findings show that the perception of poor IAQ factors lead to shifts of IAQ related practices. Both findings, of the quantitative and qualitative research, show that opening the windows is a habitual routinized behavior in everyday life. This action for indoor air quality improvement mainly occurs in sequence of other practices of the households. For example, opening the windows after cooking, showering or sleeping. The themes of practices presented in the findings point to several IAQ related behavior as part of daily routines and practices of households with young children.

Overall, parents stick with their existing routines and do not really know how to act on further improvement of indoor air quality levels at home due to lack of understanding of the impact of poor IAQ to health. These findings extend to earlier mentioned findings of *Philips research (2012)* that stated that families lack understanding of health conditions due to poor IAQ. However, in relation to Philips research, the participants in my research show to have some understanding of pollutant sources. Nevertheless, it still remains hard for them to understand what the air quality around them really is and how they could improve it more effectively.

Although household members lack understanding of the link between poor IAQ factors and health symptoms, they still manage the IAQ regularly due to their knowledge of air pollution in general. By becoming more knowledgeable about IAQ, residents would be in a good position to maintain a healthy and comfortable indoor environment. However, household members may not be in immediate control of some factors such as the quality of outdoor air. Therefore it is important to provide household members with the right information or tools that can help them to improve the indoor air quality.

3.5.2 Conclusion

After finishing this evaluative and generative research I could draw a series of conclusions that should be considered in further support of household members' ability to improve IAQ at home.

The research succeeded in its aim to clarify how household members think, feel and behave to IAQ in the current situation at home. The practice theory perspective allowed me to critically examine the elements that are involved in IAQ related practices of household members rather than their behavior.

The themes of practices presented in the findings point towards a need of parents to be able to maintain a healthy and comfortable indoor air quality at home. Not only for themselves, but in particular for their children. Parents feel responsible for the health of their children and feel the need to create a calm and clean environment for them to be at home.

To support parents in preventing air pollution harming themselves and their children, parents would need to shift practices or be more aware of the air to reduce poor IAQ. Awareness of IAQ through senses plays an important role in stimulating household members to take action and ensure improvement of IAQ.

Right now parents stick with habitual routines because of the lack of know-how, knowing how to improve indoor air quality more effectively. In order to support them in their ability to change IAQ related behavior for further improvement of IAQ levels one should focus on providing household members with the right tools to mitigate air pollutants indoors.

Both the online survey and the home evaluation were useful for gathering knowledge about people's understanding of IAQ as well as their perception of and behavior towards IAQ. As air pollution could harm human health and has become worse of the years due to rapid urbanization and climate change, it is of importance to get household members involved and generate ideas with them to deal with it. This will be further investigated in the following research part.

3.5.3 Limitations of the research

A limitation of this research is that without the use of any IAQ measurement tools it is hard to say whether some behavior or feelings related to IAQ are caused by what IAQ factors. For example, when a household member would feel a ‘heavy head’ it remains unclear whether this is caused by high concentrations of CO2 or pollutants.
In general, air pollution mostly triggers the human body to react in forms of allergic reactions, asthma or other respiratory health symptoms, irritation of airways or eyes. However, this has already been studied by other research about the relationship between IAQ and human health.

3.5.4 Further research recommendation

The home evaluation findings present a first step in analyzing how household members could be empowered in their ability to improve indoor air quality levels at home. It is necessary to first understand how they currently think, feel and behave to IAQ in order to find what challenges they face in further improvement of IAQ and how they can be best supported.

PURIFIER EVALUATION

CHAPTER 4

4.1 Introduction

In this chapter the influence of an air purifier on people's perception of air and their existing IAQ related practices is evaluated. An introduction to a new way of thinking air purification is discussed and the relevance of my research in comparison to existing literature is stressed.

4.1.1 Impact of air cleaning technology on behavior to air

Helping residents to improve indoor air quality is not new and can be done through multiple ways. As the research in the previous chapter shows do most people 'clean' the air in their home by opening the windows. This air cleaning practice might lead to a decrease of concentration of air pollutants due to the higher amount of incoming outdoor air, it does not mean that the air is healthier and contains less particles. On the contrary, by opening a window particles can actually enter the house, and in the quantitative research I did find that 28% of the respondents (n=52) actually said to be aware of this.

A more effective approach to reduce indoor air pollutants is filtration. Filtration of air through the use of air cleaners for private use is an upcoming technological trend in the recent years. Research shows that air purification can help to capture some of the irritants that may trigger health symptoms. The effectiveness of an air purifier depends on how well the device collects pollutants, how much air is going through the filtering elements, but also how much the device is being used and 'how' it is used. A question which is as important is 'why' residents are using such a device.

Research about different applications of air filtration in homes shows that residential air filtration can be provided by whole house filtration or portable room cleaners. Concluded from this research it seems that the best and most cost-effective approach for residents to filter the air in their home is a combination of both *(Sublett, 2011)*. This means that using a high efficiency filtration in combination with a breathing zone filtration in the bedroom would be most effectively to reduce indoor air pollutants.

Thus, moving air in and out of a semi closed environment using filtration is essential in keep IAQ at acceptable levels and keeping building occupants healthy and comfortable. Still there is little known about how residents use these type of products in their daily life.

For most people air purification introduces a new way of thinking how to clean air. People might associate the product with existing air cleaning solutions, what could lead to ineffective use of the purifier. Because of the novelty of these products it is of importance to gather insight in what way people understand the purpose of a purifier in order to make sure the use of it is guided to an intended way. Therefore this research will introduce household members to an air purifier utilized by TinyWolf in order to evaluate the impact the product has on people's understanding of the purpose of the device as well as the impact it has on their perception of and behavior towards air quality which is equally important because that is what will partly influence their actions.

4.2 TinyWolf's air purifier

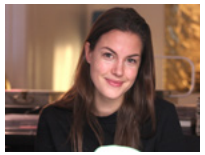
4.2.1 The product's concept

TinyWolf is developing an air purifier for instant relief where it matters the most. The first iteration is specifically aimed at children. The purifier will be evaluated by the three households to gather insight in their understanding of the purpose of the device as well as how the device impact their perception of air and existing IAQ related practices.

4.2.2 The TinyWolf prototype

The prototypes used in this research are built by the TinyWolf team. The prototype process started with sketches which I than transferred to a 3D modeling program in order to model the product components for 3D printing. The main requirement for the prototypes is to make them safe to use with children. Therefore, for example wires are covered or assembled internally.

PROTOTYPE PROCESS
who did what



Form factor, 3D modeling, checking if off-the shelf components are in the house, prototype plan

Prototyping plan for assembly of products, buying additional components (wires, switch, mount, etc.)

TINYWOLF

3D printing, check prototyping plan in terms of time and resources

Check prototyping plan in terms of availability of time for assembly of the products, delivery of 3D printed components

Together: assembly of the product, including internal and external wiring

4.3 Research design

4.3.1 Research aim and question

The objective of this evaluative research is to understand what the impact of the TinyWolf purifier is on people's understanding of the purpose of the product and how the purifier influences the way they perceive the air quality and their ability to improve indoor air. In order to find an answer to this objective a qualitative research is conducted in the context of their home.

Based on this two research questions are formulated:
1 In what way do household members understand the purpose of the TinyWolf air purifier?
2 In what way does the use of the TinyWolf air purifier influence household members' perception of air and existing IAQ related practices?

The outcome of these research questions are combined into an overview of shift in existing IAQ related practices that help to refine the opportunity to design for further support of residents ability to improve the air quality in their home more effectively.

RESEARCH QUESTION 2

''In what way do the households understand the purpose of the purifier and has the use of the product influence on their perception of and behavior towards air?''

4.3.2 Method

The purpose of the evaluation of TinyWolf's air purifier is to verify the users' perspective on the products influence on perception of and behavior towards IAQ. The same three households participate in this research as did in the previous evaluation (3.4.3).

The research is set up in the following way:
Each household receives its own TinyWolf, which they can freely use over a period of minimum five days. Because I am not at their homes during the test period I ask the participants to keep a running log of their activities, thoughts, feelings and behavior. I used this in the post interview as a basis to ask participants to clarify what they did, felt or thought during the test period.

Furthermore, questions in the post interview are related to
1. Participants experience of shifting practices
2. Their motivations for IAQ improvement
3. Their experience of the product's concept in relation to IAQ perception and behavior
(4. and the potential of the product's concept which mainly gains insights for TinyWolf)

4.3.3 Data collection and analysis

As has been explained in chapter 2, the interviews are audio recorded and fully transcribed. The transcripts are analyzed in order to identify reorganization or creation of new practices.

Additionally data has been collected specifically for TinyWolf. However, this data is only shared with TinyWolf because of confidentiality.

4.4 Main findings

4.4.1 Understanding of the product's purpose

The three households were free in how they used the TinyWolf purifier. The participants interpreted the products purpose differently and thereby used the product in different context of use. House B and C used it above their child's crib, whereas house A has used the product for an additional purpose of distributing heat from the radiator.

"The combination of air ditribution and filtration at the same time is great!"

"I had the feeling the product should be close to have an affect."

"The product did what it had to do, cleaning air."

4.4.2 Impact of the purifier on perception and behavior

During the test period the participants gave various feedback on the awareness of air created by the product's presence in the home. Hugo felt as if smell and dust all became a bit less when using the product and Oliver mentioned that the air felt more crisp and fresh in the room when the product had been running for a couple of hours. Also Alireza considered the air to positively change when using the product, he said: 'Normally we open the windows half an hour before Helia goes to bed, now we combined this with having the product on as well for an extra clean effect where she is going to sleep'.

Findings show that the TinyWolf purifier seemed to have impact on health (reduced perception of health risk) as well. Imke's dad came over for the weekend and slept in the area where they had positioned TinyWolf's purifier. She said that he perceived less breathing problems after this visit compared to previous visits. House C also mentioned less health problems with the use of TinyWolf. Tanja said: 'Actually the three of us were having a cold, now that Frida sleeps with the product she has been coughing a lot less than both of us'.

Overall the three families found the TinyWolf easy to adapt in their daily practices. Oliver said: 'Turning on the product became part of the way of bringing Frida to bed'.

Perception of air

Vision	seeing less dust
Touch	air is perceived as colder
Smell	less smell / neutral smell

Reduced perception of health risk

Risk	Having the feeling lung problems are less / child is coughing less than before

''I was having the feeling that the product definitely did something, the air felt more crisp, soft and fresh''

4.4.3 Impact of the purifier on existing air practices

Existing practices

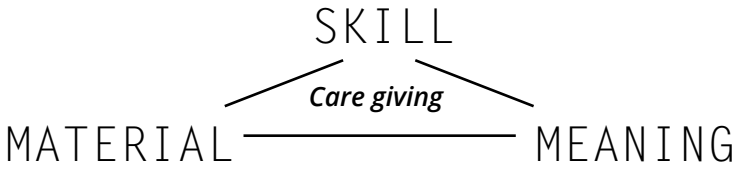
Impact of TinyWolf's purifier

Encouraging child development by following rituals and creating routines

Ease of adaptation of TinyWolf into existing routines

Stimulating health and sleep with use of building elements, products and applications

The clear function of TinyWolf makes the product easy to use, however noise can be disturbance of sleep quality



Parents are feeling themselves responsible for the child's health including the value of good sleep

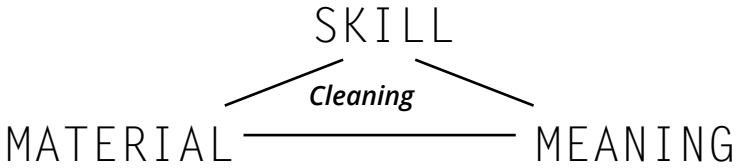
TinyWolf positively empowers the feeling of being a good parents because they now feel they can actively help improving the air and thereby sleep quality of the child

Active cleaning happens mostly during the day

and TinyWolf provides 'passive' cleaning during day and/or night

When poor IAQ factors are noticed multiple cleaning activities are started, such as opening windows, vacuum cleaning, cleaning with cleaning goods

Besides the air cleaning activities, TinyWolf helps to actually reduce the concentration of air pollutants



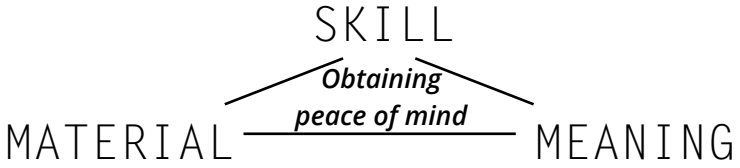
Sensing poor IAQ factors (mostly moisture and dust) motivates to take action for improvement

Gaining more knowledge about IAQ leads to more conscious improvement of the air quality

TinyWolf helps creating a clean and calm environment at home for all household members

Regulating IAQ by opening the windows and sequential regulating temperature by heating the radiators

With TinyWolf IAQ can be regulated without creating a temperature difference. TinyWolf is considered as ventilation and filtration product



Having the feeling of being in nature creates a feeling of freshness, although real freshness is still questioned

Knowing that the air comes from TinyWolf positively influences the feeling of freshness

4.5 Discussion and conclusion

4.5.1 Discussion of the findings

In this section the findings of the purifier evaluation are discussed and the relevance of the findings to existing literature or further research recommendations is stressed.

Results of the research show that the TinyWolf purifier had positive impact on parents' perception of air. Overall participants perceived reduced poor IAQ factors and health risk. Whether this is caused by their increasing knowledge of IAQ due to the progress of the project, their imagination or their understanding of the product remains hard to tell from the conversations with participants. Based on these findings further research into the impact of the purifier on their perception is recommended to gain a deeper understanding of the 'meaning' of their practices.

Household members' interpretation of the meaning of the product and its influence on perception of air could be caused due to the lack of informative communication of the purifier on air quality levels. This finding was expected since there were no IAQ measurement tools used for the purpose of my research. However, the performances of TinyWolf's product have been validated. Besides that, research shows that offering personalized information through IAQ monitors can help people to express their perception of the risk of exposure to indoor air pollution *(Wong-Parodi et al., 2018)*. Findings show that the purpose of TinyWolf's purifier and the thereby corresponding intention of use have been interpreted differently across all three households. This might be caused by to the allowance of freely using the product as they wanted. However, this approach has provided valuable insight and deeper understanding of how the purifier is adopted to the users' existing practices in daily life.

The assumption that users of a purifier would try to associate with products they already know seems to be true. Findings show that participants try to associate the purifier with existing objects or elements in their environment which they relate to as 'materials' of IAQ practices. Participants reported to have the feeling that opening the windows had a similar effect on the air quality as using the device. In fact, both IAQ related activities are required for different IAQ improvements. What is of significant importance here is what Chapman described as: 'The users are delighted by a product as they not fully understand it, especially when the product is still new'. The novelty of a purifier makes it harder for users to understand and accept. Therefore an opportunity arises to investigate the impact of design on household members' acceptance of the product in order to stimulate effective use of the product to establish improved indoor air quality.

4.5.3 Conclusions

Concluded from the findings of the research it is clear that participants' perception of air is positively influenced by the use of the purifier. However, the findings do not provide a significant impact of the purifier on household members' change of IAQ related behavior.

Household members still stick to habitual routines of opening the windows besides the use of the purifier. What is not wrong, because both practices improve indoor air quality in its own way. However, to establish a change of behavior, further research into the impact of the purifier on elements of the IAQ related practices is needed in order to design for people's ability to improve the air quality.

According to Chapman is an engaging design of importance and can it influence the way people behave and act. What is important here is how his perspective is related to the practice theory perspective. In fact, stimulation a person's action relies on reorganization of existing elements of a practice combined in new ways. This change of practice conceptualizes change of behavior. In order to reach the goal of my research and support people's ability to improve indoor air quality change of IAQ related behavior is necessary.

4.5.3 Limitations of the research

A limitation of the research in getting a comparable result in relation to existing literature is that in this evaluation a prototype has been used rather than a real product. Although participants were aware of this, it still might have influenced the findings of this research.

Another limitation is that I was not there during the use of the product. The made it harder to fully understand the impact of the device on people's perception of air and IAQ related practices.

DEFINE

CHAPTER 5

5.1 Introduction

In this chapter the main insights of both the home evaluation and the purifier evaluation are brought together. The convergent process starts with an overview of the main findings of both evaluations. This leads to the formulation of a research and design opportunity and into desired future practices for further support of people's ability to improve indoor air quality.

5.1.1 From data to design

The home evaluation findings show that household members are concerned about the impact of indoor air quality to the health of their children. Parents normally start improving the IAQ when they perceive poor IAQ factors. As a behavioral response they open the windows. At the same time they realize that the air must already be very bad as even they perceive those factors e.g. moisture. However, parents lack the understanding of the impact pollutants have on health and know-how of how to reduce the risk of exposure to air pollutants more effectively.

In the purifier evaluation households were introduced to TinyWolf's purifier in order to help them reduce indoor air pollution. The purifier evaluation showed that TinyWolf positively impacts their perception of air, since air was perceived less dusty and smelly, instead parents mentioned that air felt more crisp and fresh. Results show that thanks to the TinyWolf respiratory health symptoms were perceived to be improved at two of the three households. Overall the purifier was easily adopted by all households and used in different ways.

In my research I have applied the practice theory to analyze the situated performances of practices of household members in their daily life with and without the use of TinyWolf. I identified three IAQ related practices in the current situation and afterwards analyzed the impact of TinyWolf on the elements of a practice. The results show that TinyWolf has been easily adopted into parent's existing routines and rituals of improving indoor air quality. However, the intended way of use was not explained beforehand, what has led to various use scenarios of the purifier. Furthermore, introducing TinyWolf might be compared to existing IAQ components in the home, such as opening a window. Findings showed that existing behavior of opening windows remained almost the same with the use of TinyWolf's purifier.

Based on the findings a target practice is chosen from the three themes of practices. Findings showed that the 'meaning' of the practice felt for people as being supported by TinyWolf in creating a healthy indoor environment for themselves and their children to be. Parents stressed the importance of the health of their children, and especially valued the sleep quality of their kids for better health. Imke reasoned: 'If I could help improve the quality of the children's sleep by improving the air quality during the night that would be very valuable to us'. This feedback indicates the relevance of further investigation in what way parents could be best supported in improving the air quality during the night for a healthier environment for their kids to sleep in. TinyWolf can help parents to improve the air quality and thereby the sleep quality of parents' kids. This proposition fits well with the needs and values of the parents that participate in my research.


''If I could help improve the quality of their sleep by improving the air quality during the night that would be very valuable to us.''

5.1.2 Relevance of designing for sleeping practice

Since people spend one-third of their life sleeping it is of importance to create a clean bedroom environment with air that is safe to breathe. Research done by *Tynjala et al. (1999)* shows a strong relationship between sleep quality and the ability to concentrate the next day among children. Evidence of the negative effects of sleeping in a room where air quality is poor on performances the next day is reported by *Laverge and Jansens (2011)*.

In general children breathe more air pollution per unit body weight than adults. Besides that, their lungs are still developing what makes the impact of polluted air on children even bigger. This means that even a minor exposure to air pollution overload can make a child ill. When children are asleep their bodies go into deep repair mode in which the immune system attempts to get rid of impurities while sleeping. Normally detoxification of their body is difficult when they are exposed to toxic air in their bedroom.

Beko et al. (2010) did research about indoor air pollution in bedrooms of Danish children and reported that 57% of the rooms had a lower than minimum ventilation rate. According to his research participants' ability to fall asleep was greater with the windows opened. However, having the windows opened during the night has negative side effects such as cold draft of air, noise or smell of the outdoor surrounding. Moreover, pollutants from outdoors can enter the room where a person is breathing during the night.

5.2 Research design

5.2.1 Research and design opportunity

Although literature provides insightful information on the relevance of improving indoor air quality, specifically in the bedroom, it lacks to give an understanding of the type of everyday detail of elements and their relationships that is useful in this practice-oriented design process. Therefore the findings of the two evaluations got merged together to offer insightful understanding of the details of how people deal with IAQ with or without the use of TinyWolf's purifier. In both researches practices were evaluated as unit of analysis.

As a result, the target practice, care giving / sleeping, is chosen and the following research and design opportunity are formulated.

The research opportunity is to investigate the influence of emotional design on the users' perception of impact of the use of the purifier on perceived air quality as well as the adaptation of the use of the purifier into existing routines to effectively improve IAQ.

Hereby the design opportunity is to design the purifier in such a way that the user engages with the product and at the same time fits with the existing daily practices and context of use.

5.2.2 Chosen target practice

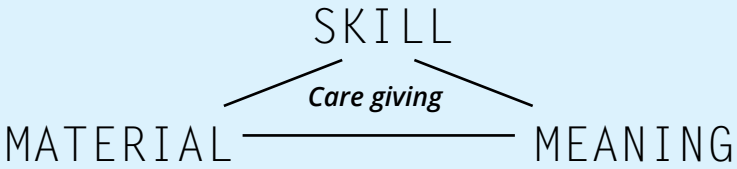
Existing practices
Impact of TinyWolf

Encouraging child development by following rituals and creating routines

Ease of adaptation of TinyWolf into existing routines

Stimulating health and sleep with use of building elements, products and applications

The clear function of TinyWolf makes the product easy to use, however noise can be disturbance of sleep quality



Parents are feeling themselves responsible for the child's health including the value of good sleep

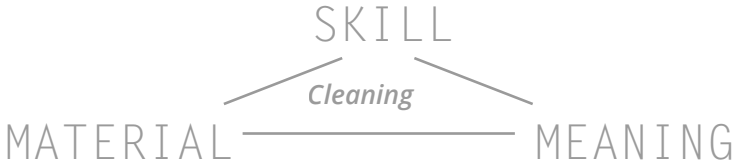
TinyWolf positively empowers the feeling of being a good parents because they now feel they can actively help improving the air and thereby sleep quality of the child

Active cleaning happens mostly during the day

and TinyWolf provides 'passive' cleaning during day and/or night

When poor IAQ factors are noticed multiple cleaning activities are started, such as opening windows, vacuum cleaning, cleaning with cleaning goods

Besides the air cleaning activities, TinyWolf helps to actually reduce the concentration of air pollutants



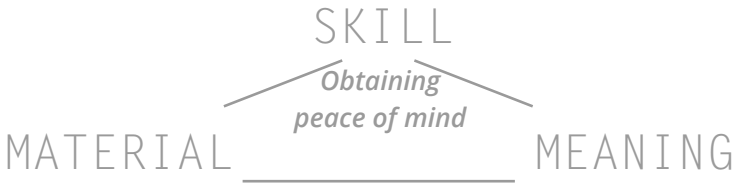
Sensing poor IAQ factors (mostly moisture and dust) motivates to take action for improvement

Gaining more knowledge about IAQ leads to more conscious improvement of the air quality

TinyWolf helps creating a clean and calm environment at home for all household members

Regulating IAQ by opening the windows and sequential regulating temperature by heating the radiators

With TinyWolf IAQ can be regulated without creating a temperature difference. TinyWolf is considered as ventilation and filtration product



Having the feeling of being in nature creates a feeling of freshness, although real freshness is still questioned

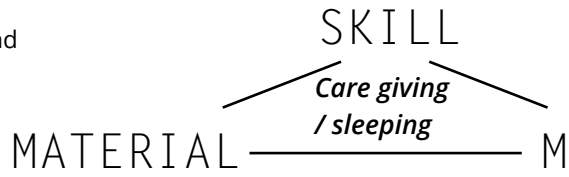
Knowing that the air comes from TinyWolf positively influences the feeling of freshness

5.2.3 Desired future practices

Behavioral

Clear functioning and ease of use

Encourage ease of adaptation of TinyWolf into existing routines and stimulate optimal effect of use



Strengthen emotional attachment to the product

Feeling good as parents by being responsible for creating a healthy and comfortable (sleep) environment for their child to be

Visceral

Emotional design that fits with context of use and child development

Reflective

Empower attachment to the product through design

The purpose of why I am determining the desired examples of practice elements is not to be able to copy them in the end, but it helps to find inspiration from and to form a framework of reference for the chosen target practice.

The desired future practices contain materials (three prototypes), competences (verbal instructions) and meaning (suggestions) to guide towards a certain type of reorganization of practices, and remains open when it comes to the detail of performances.

5.2.4 Design challenges

In this section design challenges are formulated to make sure that the development of the three iterations is guided and fits with the chosen target practice. A balance between the requirements of the practice theory framework and design of the purifier needs to be determined. And corresponding to the framework of Chapman's and Norman's theory where three levels of emotional design highlight what connections products entail.

Because the idea behind the product is that it can be used with children around, the design must be safe to use. Another aspect of the design challenge is to create meaning for the parents on a reflective level. This will be tested through iterations of embodiment design. Yet, the design has to fit within the context of use and child development (reflective level). At the same time the basic functionality needs to be maintained to support an effectiveness of use (behavioral level). And on a visceral level, the design has to stimulate attachment to the purifier in order to create empathy and ultimately long lasting emotion and use.

TO SUM UP:

1. Being safe to use with children around
2. Stimulate the meaning of use
3. Maintain the basic functionality
4. Fit the context of use
5. Fit with child development
6. Stimulate attachment to the product

5.3 In summary

The goal of this chapter was to describe how I went from the processed data to a new research and design opportunity. First the data of the two previous evaluations has been discussed after which the research and design opportunity have been formulated. Based on both evaluations, of the home and TinyWolf's purifier, the needs and values of the participants were uncovered, what made new opportunities emerge.

The 'sleeping' practice is chosen from the three IAQ related practices that were identified in the home evaluation. Because parent's indicated the value of improved indoor air quality for the quality of their children's sleep and health. Moreover, related research shows the relevance of improving indoor air quality in the bedroom for healthy sleep, especially as it relates to children.

The main findings resulted in an opportunity to engage the user more in indoor air pollution by stimulating their attachment to the purifier. Hereby, the intention is to integrate the use of the product into existing practices and challenge the household members to use the product in an efficient way.

In the next chapter the practice-oriented design approach continues and a research is setup to test the impact of three iterations of the TinyWolf's purifier on household members' perception of air and the IAQ related impact on the elements of the 'sleeping' practice.

ITERATION

CHAPTER 6

6.1 Introduction

6.1.1 Practice-oriented design

In this chapter I take practices as unit of design. This means that in this phase of the project the design process involves the three elements of a practice and integrates them into an iterative process of research through design.

The process started with shaping the research and design opportunity into suggested desired future practices. The next step of facilitating three tests is used as basis for acting out ways in which desired practices might work as coherent reorganization of elements. This will be further explained in the research design section (6.3). And the process continues with the production of three redesigns of TinyWolf's purifier (6.2).

6.1.2 Related research

The practice theory has found its way from social science into design research and literature. Related research shows the uptake of a design approach that draws on practice theory is for example the research of *Wessman et al. (2017)*. In this paper a research through design (RtD) approach is taken to evaluate the potential of the developed Peacetime concept on households' planning and shifting activities in finding acceptable energy balance. In the RtD process Wessman et al. used the emotional design framework of *Desmet & Hekkert (2007)* to evaluate which design concept worked best. For the purpose of my iteration research I use a similar approach to investigate what purifier concept enables users to use the product in a pleasurable and effective way. However, instead of the framework of Desmet & Hekkert I use Chapman's & Norman's emotional design framework because this framework divides design into three levels by the information processing according to the situation and response. Where the model of Desmet & Hekkert focuses on the effort of users by the designed product, this framework also includes the relationship between me (as a designer) and the design of the purifier.

The results reported in the research done by *Wessman et al. (2017)* indicates an approach of challenging households to rethink their practices. The results show that design provides the opportunity to align with motivations for enhancing quality of life in a wider perspective than feedback on electricity consumption. This interesting finding is supported by *Strengers (2011)*, who emphasized the importance of designing systems reaching beyond models of users as rational decision makers towards more engaging solutions. For my research this is relevant in the context of enhancing household members' quality of life through stimulation of their motivation to improve indoor air quality.

6.2 Design approach

6.2.1 From ideas to prototypes

In this section the design process from ideas to prototypes is described. TinyWolf continues to deliver a basic design approach while having the needs and values of the participants on top of mind to build in the development of three iterations of prototypes.

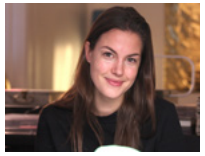
The design approach starts with searching for inspiring elements of existing child care giving and sleeping products that are available in the market. After which ideas are generated that are shared with the TinyWolf team in order to choose concept directions together.

Making the choice of concepts together with the team is important because the development of the products depends partly on feasibility. This means that the availability and time of team members is important for building the products. Besides that the resources that are available influences the concept choice as well. Some components are already in the house, others need to be 3D modeled and printed or bought. Thereby, the design freedom is limited by the availability of resources, such as existing components, time and money.

Another relevant point for the choice of concept is the input of the participants from the previous home and purifier evaluation. Their needs and values give direction to the further development of products as part of desirability. Another desirability aspect is that the concepts should be realized within the scope of developing an engaging embodiment design that fits the context of use and the target practices.

For these reasons three concepts are chosen to be developed into working prototypes. I have set up a prototyping plan in which task are delegated to each team member of TinyWolf in order to communicate clearly what, when and how things need to be done to be able to deliver the prototypes on time to the households. The start of the prototyping started with sketching ideas and building 3D models of the necessary product components. After printing the components the TinyWolf team could assemble the prototypes.

PROTOTYPE PROCESS
who did what



Ideation form factor
design idea clustering into
proposals

Idea selection and
conceptualization, checking
what components are
in the house (feasibility
and viability) creating a
prototyping plan

Product design sketches
and technical drawings,
3D modeling, prototyping
plan for assembly

TINYWOLF

check the proposals with
team, agree on directions

Check the prototyping plan
in terms of availability of
resources such as time of
team members

Assembly of the product, internal
and external wiring

6.3 Research design

6.3.1 Research aim and question

The objective of this research is to evaluate three iterations of TinyWolf's purifier in order to investigate what type of design best supports parents in using the product for the most optimal effect of indoor air quality improvement during child care giving or sleeping practices.

To research this objective a qualitative research method is used, similar to the method used in the purifier evaluation (chapter 4). The impact of the three designed iterations on people's perception of and behavior towards IAQ is evaluated. The same three households participate in this evaluative research.

Each household will be able to test each version of the purifier. Per iteration perception of air and shifting practices due to the designed solution are evaluated. The tests are based on the following research questions:

1. In what way does the design of the purifier influence household members' perception of air and existing IAQ related practices?
2. In what way does the design of the purifier best supports users in their ability to improve IAQ?

The outcomes of these research questions are combined in an overview of how perception of air is influenced per iteration as well as an overview of practices of all iterations. Together the findings help to refine the opportunity for TinyWolf's further product development and the opportunity to support users in their ability to improve indoor air quality more effectively.

RESEARCH QUESTION 3

''In what way does the design of the air purifier empower people's perception of and behavior towards indoor air quality best to support improvement?''

6.3.2 Method

Each household tests each version of the products over a test period of a minimum of 5 days. There are three prototypes that rotate among the three households.

Per iteration the setup consists of three phases:
1. The products are brought to the participant's homes, where the first reactions are recorded and observed.
2. The participants are allowed to freely use the product over five days.
3. A post interview at the participant's homes about their experiences, thoughts, feelings, motivations and practices over the five days of use.

To test the assumptions made to formulate the desired future practices, the interview questions are that asked are about:
1. Shift in perception of air due to the designed product
2. Shift in practices due to the designed product
3. Motivations for indoor air quality improvement
4. Their experiences of the products' design and potential

6.3.3 Data collection and analysis

The interview sessions are again audio recorded and fully transcribed. Comments about the three iterations are color coded to be able to categorize similar transcripts while keeping the distinction between the different designs. This is done per household. In this way, the three designs can be compared among the households and within one household.

Data is categorized similarly as in the previous purifier evaluation (chapter 4) according to the practice theory in combination with Chapman's and Norman's theory framework.

Additionally data has been collected specifically for TinyWolf. However, this data is only shared with TinyWolf because of confidentiality.

6.4 Main findings

6.4.1 Impact of iterations on perception of air

Overall findings show that parents had different opinions about the perceived improved indoor air quality due to the use of the three different iterations. The shape of the product in particular did not have significant impact in participants' opinion. Whereas the size of the product did influence their perception of air. Findings show that parents reasoned to link the size of the purifier to the amount of air that is going through and thereby to the effect the use of the purifier will have on the air quality.

According to Hugo and Oliver all three purifiers had a positive effect on their perception of the air quality. They felt the air as being more fresh and clean in the room where the purifier had been positioned. Whereas Alireza found it difficult to express whether his perception of air had changed due to the use of each iteration. He reasoned that it is hard to sense any changes of air quality and says that he would like to know what IAQ measurements would tell.

Perception of air

Vision	seeing less dust
Touch	air is perceived as colder
Smell	less smell / neutral smell

Reduced perception of health risk

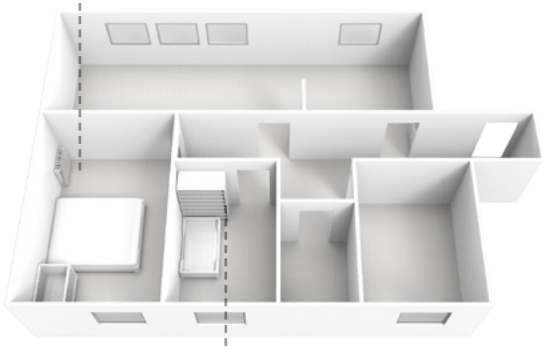
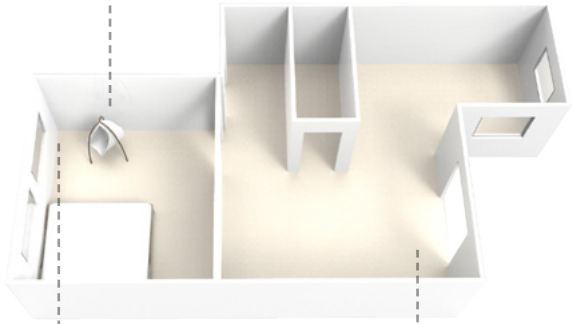
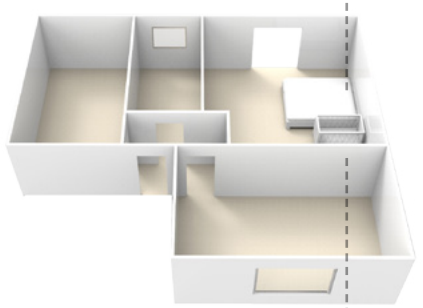
Risk	child is coughing less

"My experience is that it is more fresh in the bedroom when we are having the product. I also have to say that we are opening the windows less now we have the product in our home. That is a bit more calm during the night. And I think that is what makes it fine for me, that you can keep the temperature and refreshing the air."

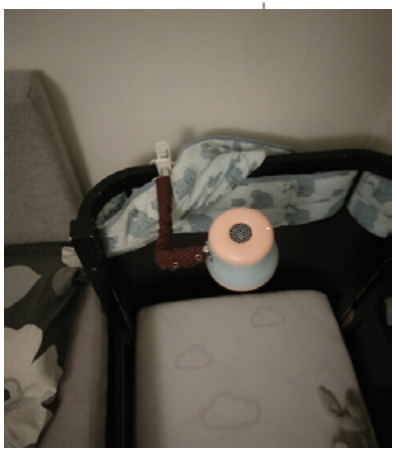
"The awareness of air quality is definitely sparked by having the device around. I feel there is a different feeling in the air when we sit in the living room and go to bed. When we walk into the bedroom and the product has been on for a couple of hours than the feeling of the air is more fresh."

"It is hard to say if the air quality has changed much when using the device, because we still have this habit of opening the window in the morning. So I think it is hard to sense, unless there was some kind of measurement telling you what the air quality is."







6.4.2 Impact of iterations on behavior

The outcomes of the research show that each household had its preference for the redesigned versions of TinyWolf's purifier that best fit their needs. Their preference depends on the influence of the product on their existing target practices.

Findings show that the design has impact on the target practice 'sleeping'. A smaller device was appreciated by parents because of its compact size and mobility. Alireza said that a small device was easy to move around while he was taking care of his baby. On the other hand, the bigger stationary device was appreciated because parents felt the product blended into the context of use and did not need to take required actions to reposition it every time. Oliver reasoned: 'The product became part of the bed and Frida got used to the product being there'.

The purifiers all have been used for sleeping practices in the bedrooms. Findings show that parents easily adopted the use of the purifier into their existing sleeping routines, because of the combination of 'meaning' and 'skill' element of the practice. At the start of the routines the product was turned on, parents said that in this way the child would get used to the product's sound and by the time they would fall asleep they were not disturbed.

Findings showed that each household had preference for a different version of the purifier. This clarifies why the impact of the purifier was perceived differently per household. For instance Hugo reasoned that with the use of TinyWolf they could keep the temperature in the room and refresh the air. Normally he would have opened the windows before they were going to sleep to prepare the room for sleeping. But whenever he would feel the air was getting to cold, he concerned about the health of their baby who was sleeping close to the window. Therefore he normally went out of bed a few times per night to open and close the windows. These activities had shifted due to the use of TinyWolf.

According to the parents, the design of the purifier had impact on their believe in the product's functionality. Fanni reasoned: 'I trust the performance of the product less when I associate the product too much with a toy'. However, the design of the product caused emotional attachment to the product from a child's perspective. Imke reasoned: 'Nova associated the product with a child version of a hair dryer we had, she was accepting the product more easily to be around and wanted to have it placed next to her bed, I was comfortable in placing it there.'.

6.4.3 Impact of iterations on practices

Products are easily adopted into existing practices, turning the device on is at the start of the bedtime routine

Main function of the purifier remains clear and is appreciated

Encourage ease of adaptation of TinyWolf into existing routines and stimulate optimal effect of use

Behavioral

Clear functioning and ease of use

SKILL

Care giving / sleeping

MATERIAL — MEANING

Strengthen emotional attachment to the product

Feeling good as parents by being responsible for creating a healthy and comfortable (sleep) environment for their child to be

Feeling the child sleeps more calm with the device

Visceral

Emotional design that fits with context of use and child development

Reflective

Empower attachment to the product through design

Feeling good as a parent being able to contribute to the child's sleep quality by improving the IAQ

Emotional attachment to the product makes parents feel comfortable in using the product close to their children and makes children accept the product being around

Emotional design engages older children and stimulates the use of the product. However, too childish design could lead to less credibility in the products performance.

6.5 Discussion and conclusion

6.5.1 Discussion of the findings

With the use of Chapman's and Norman's theory framework I aimed to find how emotional design can lead to adaptation of the purifier into something valuable to use for the purpose of improving indoor air quality.

Findings show that when a design is colorful and playful a child can identify with it, what leads to a certain engagement with the product. Moreover, the child will accept the product being close to them more easily because of the created empathy by the design. On the other hand, when parents associate the design too much with a toy it leads to distrust of the product's function. This finding shows an example of the impact of design of the purifier on people's perception towards the product only on a visceral level.

According to Chapman's and Norman's theory emotion is playing a vital role in people's ability to understand and create meaning to a product . Nevertheless, research done by *Aftab & Rusli (2017)* shows that people unconsciously focus on the physical appearance (visceral level) and usability (behavioral level) of a product rather than the meaningful element (reflective level). However, findings of my research show that the design of the purifier also had impact on people's perception towards the product on reflective level. For instance, parents thought that the use of the device enhanced their feeling of being a good parent who is responsible for the health of their child. On a behavioral level, they find that when the device is bigger, it will also be faster to clean the air of the room. Also, they find a portable device useful for child care giving practices because they reasoned that a small device enables better mobility. Yet, findings show that for sleeping practices a stationary purifier of bigger size is preferred by two of the three households.

By introducing TinyWolf's purifier to the households I started to investigate an alternative approach for improvement of indoor air quality. Findings show that some IAQ related activities during the sleeping practices had shifted or were replaced. For example, Hugo's routinized activities of opening and closing the windows at night was changed due to the use of TinyWolf's purifier. He mentioned that he kept windows more closed now that they were using the device. This would imply his perception towards the product on a reflective level. However, his interpretation of the meaning of the purifier relies on his perception of the air quality due to the use of the product and not necessarily on his understanding of the purpose of the product.

6.5.2 Conclusion

The three versions of TinyWolf had been introduced to the three households to gather deeper understanding of how the design impacts the household members' perception of air and the integration into existing IAQ related practices. Findings of the research provide insight in how the design of the purifier could best support them in their ability to use the product for improvement of indoor air quality during the sleeping practice.

Findings showed that the design of the purifier had impact on people's perception towards the product on all three levels of emotional design. On a visceral level a colorful design made parents distrust the function of the product. Therefore it is important to keep the balance between serious and playful design in further iteration. The use of the purifier has been different among the households. Two of the three households had been using the purifier on daily basis (behavioral level), whereas one of the households was not able to do so due to private circumstances. Nevertheless, what is important to conclude from the findings is that the use of the purifier has been sustained due to parents' notion of perceived health benefits and improved IAQ. Research has shown the importance of the meaningful way of perceiving products to maintain long lasting emotions *(Aftab & Rusli, 2017)*. Which is important to create because according to Chapman's and Norman's theory empathy between people and products can influence the way people act.

Concluded from the findings of the iteration evaluation each household had its own preference for the type of purifier. Their preference depended on how the redesigned version best matched their needs and values. Findings show that on one hand parents value a stationary device that has a bigger size because they have the idea that the use of the product enables them to clean the air of the room faster (and for more people in the room). On the other hand parents value a small portable device as much because it allows them to have clean air where ever they go. Moreover, the use of a small device is easier to integrate in child care giving practices. Based on these findings the choice of size remains undecided, This decision would require further market research into potential of the product, what is out of the scope of my thesis research.

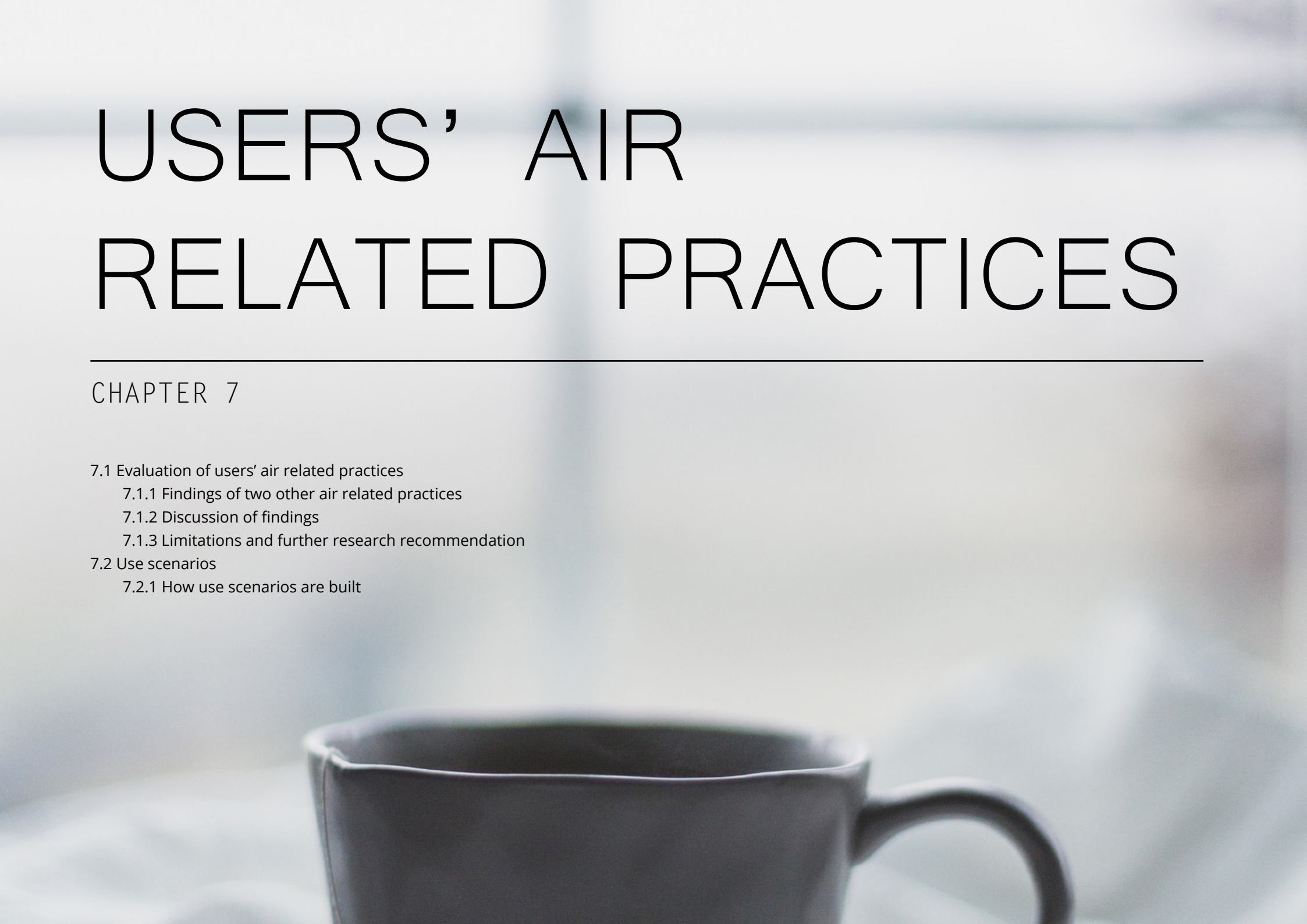
6.5.3 Limitations and further research recommendation

A factor that has had impact on the findings is that the same three households have participated in the whole research. This means that the participating parents have become more knowledgeable of IAQ throughout the progress of my project. Their knowledge of air in combination with their perception of air leads to the action they take to improve indoor air quality. However, their level of knowledge of IAQ has only been measured in the beginning of the research. In future research I suggest to either measure the level of knowledge of IAQ throughout the project or recruit other participants per evaluation.

Another limitation of the research was that one of the households had to deal with some private circumstances. However, they still wanted to continue. Therefore they were not able to use to purifiers as much as they wanted, what has had impact on the findings of the research.

USERS' AIR RELATED PRACTICES

CHAPTER 7



7.1 Evaluation of users' air related practices

As a result of the home evaluation three major themes of practices were identified. One of these practices, care giving / sleeping, was chosen as target practice. This particular practice was point of focus during the research through design process and therefore the data analysis and findings of the previous chapter focus on this practice. However, in reality the iterations of TinyWolf's purifier had impact on all three IAQ related practices that were identified in the home evaluation (chapter 3). In this chapter the two other practices are evaluated based on the data that was found during the iteration evaluation.

Furthermore, this chapter provides an overview of use scenarios that are inspired by the users' input during the research project.

7.1.1 Findings of two other air related practices

Findings show that the perceived impact of the purifier in general is slowly evolved into a new way of experiencing air quality. Where parents first mentioned the similarity of the perceived effect of using the purifier and opening a window, now they see it more as two different ways of improving indoor air quality. Imke reasoned: 'I think that the use of product and opening the windows are becoming two different things to me. Opening the windows is something I do to get a lot of fresh air in, and the product I use to ensure a maintained effect of the air quality'.
A similar finding has been seen by Alireza mentioning: 'You can open the windows and you know the air is fresh, it may be in my mind, that the device might make a difference, but with opening the windows I am for sure'.

The whole use of the purifier has been an experience for the participants to learn more about reducing indoor air pollution in another way. Hugo said: 'It has been a process, but there is a form of gaining understanding of indoor air quality. So I find that we are able to make more links now to what we could do to take action to improve the air quality'. Oliver mentioned he definitely thinks more about the air quality since they have been involved in my project. He reasoned: 'I think it is good to focus on air quality and it has made it easy to make a difference with the device around, just in everyday life. And the more I become aware of the air the more I pay attention to it and how to improve it'. Also Imke became more aware of the air quality and she said that the awareness of IAQ ensures to keep it fresh during the day and night when they were at home. And Tanja mentioned: 'I think about it that I want to clean the air in the room where we are sleeping. So I definitely started thinking more about the air quality and ways to improve it'.

Active cleaning happens mostly during the day

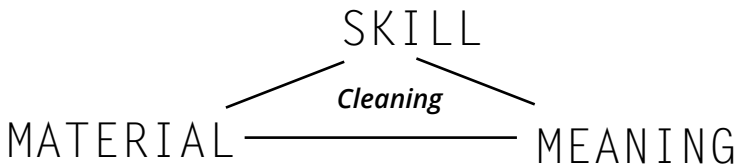
and TinyWolf provides ‘passive’ cleaning during day and/or night

Preparing the room before using them and being there, combining opening the windows with the air purifier for an extra clean feeling

When poor IAQ factors are noticed multiple cleaning activities are started, such as opening windows, vacuum cleaning and cleaning with cleaning goods

Besides the air cleaning activities, TinyWolf helps to actually reduce the concentration of air pollutants

Still opening the windows for fast fresh feeling, while improving IAQ through air filtration with the use of the air purifier



Sensing poor IAQ factors (mostly moisture and dust) motivates to take action for improvement

Gaining more knowledge about IAQ leads to more conscious improvement of the air quality

Linking and connecting IAQ factors more, what leads to more conscious improvement of the air quality

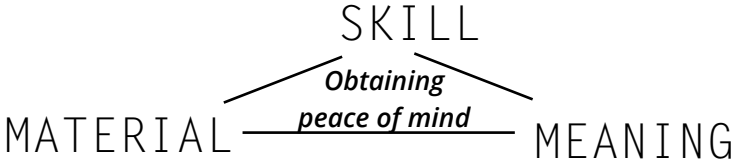
TinyWolf helps creating a clean and calm environment at home for all household members

Maintaining a clean and calm environment while being in the indoor environment

Regulating IAQ by opening the windows and sequential regulating temperature by heating the radiators

With TinyWolf IAQ can be regulated without creating a temperature difference. TinyWolf is considered as ventilation and filtration product

Inclined to use the purifier in periods where windows cannot be opened



Having the feeling of being in nature creates a feeling of freshness, although real freshness is still questioned

Knowing that the air comes from TinyWolf positively influences the feeling of freshness

More fresh and crisp feeling of air in the room where the air purifier is compared to the other rooms of the house

7.1.2 Discussion of findings

Interestingly, findings show that some parents had the feeling they could let a lot of fresh air in through the windows and afterwards maintain the air quality by using the TinyWolf purifier. This shows that these parents misunderstood the purpose of the device. The use of TinyWolf does not ensure a maintenance of the air quality levels, instead, it reduces the concentration of pollutants and thereby improves the air quality. However, the perceived impact of the device is not something that is sensible in seconds. Another possible reason could have been the novelty of the product. Meaning that parents first have to learn the beneficial impact of the use of the device on their health over time in order to be able to use the device more effectively.

A key factor that is missing here is the information participants perceived when using the device. *Skov et al. (1991)* described three types of behavior that is relevant in relation to air quality. One of these types of behavior is taken to be aware and engaged in air pollution. Since information about the IAQ levels is not provided to the participants throughout my research, users might not immediately understand the difference between opening a window and using the device. The device still does not generate oxygen, whereas opening the windows does not reduce the concentration of pollutants in the room.

Other findings show that parents became more aware of the indoor air quality factors and thereby they controlled the air more consciously. What could be seen was that the (air) cleaning practices as part of general household routines were performed more regularly or with more attention. Parents said to open the windows more often or vacuum clean more. This shows that household members were able to rethink their cleaning practices and shift their practices accordingly.

7.1.3 Limitations and further research recommendation

Findings show that parents were more inclined to use the TinyWolf during for example winter. This result might have been biased because this research has been conducted only in the winter months. Whether this element of the practice remains the same in summer months needs to be further investigated.

7.2 Use scenarios

7.2.1 How use scenarios are built

The use of TinyWolf's purifier has been evaluated by introducing it to the three households in my research. The household members have been using the product during the tests which each took a minimum of 5 days. Two of the households asked permission to keep the purifier for a longer period of time to notice the effect on their health.

The participants' actual practices are taken as inspiration to describe persona's and user stories (Appendix 5.A). The conversations with the participants in my research help to get into the users' shoes and get to think of the challenges they face, without getting biased by my own ideas. The experiences of participants are converted into user stories and finally into use scenarios. The idea behind a use scenario is to extract the environment, the goals of the participants and the unexpected elements from their situations.

Use scenario 1 – While walking with the stroller
Persona 1
Jakob wants to go for a walk with his baby in the stroller. He gets the product out of the charging station and clips it onto the stroller. He knows that he can for a long walk because the battery is charged for a use of 4 hours.

Use scenario 2 – Clean air while working
Persona 2
Since the children are getting older, the purifier is not necessary anymore above the baby's crib. They have not been using the purifier there for a while anymore. Daan thinks it is more important to have clean air while he is working and therefore he took the purifier and set it up at his desk. He was wondering if it would change his performance and concentration while working.

Use scenario 3 – Relaxation smell and cleanliness
Persona 3
Sara wants to use the purifier in the living room because she is stressed and needs to relax. To calm down she has heard that the smell of lavender does magic. While she is taking the product she switched the top for an additional top which she got in the products' package. This is a top that has a small container for fragrance. She puts some drops of lavender into it and positions the product on the bookshelf next to the couch. She turns it on and continues reading her book on the couch.

DISCUSSION & CONCLUSION

CHAPTER 8

8.1 Discussion
8.2 Conclusion
8.3 Limitations and further research recommendation

8.1 Discussion

The living environments of many people are threatened due to severe air pollution. Technological developments in the air cleaning industry continue to increase in the coming years. In order to make sure that residents are able to manage their own indoor air quality. One way in which they are responsible for their own environment is by becoming knowledgeable and aware of the air around them. Therefore they need to be provided with the right tools and information. In the recent years, air cleaning technology has gained popularity as air pollution is a topic of discussion. Not only in Asia, but also in European countries and other places around the world were cities are growing rapidly.

The aim of my thesis was to understand household members' perception of air and how they behave towards air in order to find ways to help them improve the indoor air quality in their home environment. By evaluating the current situations of their daily IAQ related practices I gained an understanding of what challenges they are currently facing when trying to improve the air quality. I studied how the air purifier utilized by TinyWolf fit within their existing practices and context of use in order to understand in what ways household members could be supported best to reduce indoor air pollution. In addition I have designed three iterations based on their needs and values to help them.

These findings are valuable to TinyWolf as a startup, because in this way the end-users are involved in the design process what stimulates defining new opportunities to work towards to in further product development. As well as to the end goal, which is providing more households with healthier air to breathe. This goal was approached from different angles in my thesis, challenging household members to improve indoor air quality by guiding them in new ways of thinking and acting. The use of TinyWolf challenged them to improve the indoor air quality more effectively. All in order to support their ability to not only use the product in an optimal way, but also to empower them in further improvement of the indoor air for themselves and their children.

The findings have been based on in depth interviews and observation of the current home, how the household members perceive indoor air quality and are able to improve it with the use of an air purifier. Because this has only been tested by three families generalizing the findings of my research is limited. By linking the findings to existing literature an attempt is made to improve upon the limited generalizability. The following findings will hold most relevance in context of perception of air and behavior towards indoor air quality and household members ability to improve it.

The findings represent participants' feelings, behavior and thoughts throughout my research. Their perception of air, IAQ related practice and perception of the impact of TinyWolf's purifier has been evaluated. Because the same families have been involved the

whole project, the participants have become more knowledgeable of IAQ what might have influenced their actions. Findings show that parents think they can better link IAQ to the required action to improve the air quality. This finding is an example of what has been reported by related research. *Egondi et al. (2012)* reported the importance of a combination of increasing perception and knowledge of air to support behavior change.

Stern (2000) had built a heuristic model of behavior consisting of people's attitudes and perception of air. When individuals deal with the risk of being exposed to indoor air pollution, people may have various beliefs about the impact the air has on their health or the way to manage the air. *Skov et al. (1991)* reports that becoming engaged in air pollution leads to the action of information seeking and participation in controlling the air. This is what has been found in my research as well as findings show that parents became more aware of the indoor air quality what has led to more conscious control of IAQ levels. Moreover, they had become interested in knowing more about IAQ in general, what was the intention of my project.

8.2 Conclusion

The aim of this thesis was to understand household members' perception of air and their IAQ related behavior in order to empower their ability to improve it.

For this research the use of TinyWolf's purifiers has been very valuable to gain insight in how household members perceive the impact of such a device on their perception of air and related practices. However, this also means that the findings of the purifier evaluation and research through design iterations are limited with regard to generalizing the results. For this reason a comparison of data from related research helped in improving generalizability. Yet, the findings of my research best fit in the context of household homes.

The findings of the home evaluation show that household members' ability to improve indoor air quality was mainly caused by their perception of poor IAQ factors. In their ability to manage the air they faced challenges to improve the air because of external factors as for example the quality of the outdoor air which they are not in direct control of. This shows that to improve indoor air quality, a much broader aspect of tackling air pollution in general should be taken into account.

In my research the use of the social practice theory perspective has provided interesting insights to tackle the problem of indoor air pollution in various household homes. First by creating an understanding of IAQ related practices of household members in the current situation at their homes. The activities to reduce indoor air pollution became clear. Parents found it very valuable to be able to contribute to improve indoor air quality, especially in relation to the sleep quality of their children. Second, the evaluation of the purifier and iterations provided a basis for alternative ways of thinking how to reduce the risk of being exposed to indoor air pollution. Thereby, the practice-oriented design approach I used aimed to integrate the use of the purifier into existing sleeping practices. This is needed in order to support the reorganization or creation of new elements of a practice, to combine them in new ways and ultimately change behavior.

Although the evaluation of the purifier and research through design iterations show that design has positive impact on people's perception of air and the way they are able to use the purifier in everyday practices. Still their ability to change behavior for further improvement of air quality relies on more than that. Meaning of the practice as well as meaning on a reflective level is important to stimulate the use of the purifier. Moreover, their ability to change behavior for further improvement of air quality relies also on becoming knowledgeable. Throughout my project parents gained knowledge of indoor air quality. All these factors certainly played an important role in parent's ability to be proactive in improving the indoor air quality.

8.3 Limitations and further research recommendation

Further research in this field is of importance not only for one household, but because of future scenarios that show how climate change and urbanization cause more polluted living environments in the future.

Because of technology driven market trends, also in the air cleaning industry, it is of importance to research how residents respond to such technological innovations in order to shift activities and building an initial behavior that potentially turns into a habitual behavior. Therefore further research will investigate how household members' perception of and behavior towards air is influenced by products that support them in improvement of the indoor air quality.

REFLECTION

CHAPTER 9

9.1 Reflection on the project process and quality
9.2 Personal reflection on ambition
9.3 Reflection on project context and supervision

9.1 Reflection of the project process and quality

Before I had the kick-off of my thesis I felt insecure about determining the scope and main goal of my project. I found it hard to communicate this clearly. Nevertheless, I was able to be in control of the project once it started and things fell into place along the way. Normally when I find it hard to make decisions (what is very often) I follow my gut feeling to turn the uncertainties into new opportunities. This is what drives me in finding new possibilities.

Throughout my project I learned to deal with some setbacks. For example, I expected the team members of TinyWolf to be able to help me with building prototypes. However, last minute they did not all have the time to help what caused a tight schedule to deliver them on time. I learned from this situation and adjusted my plans efficiently. The next time we had to built prototypes I came up with a new plan in order to achieve the goal. I think that this kind of uncertainties improved my ability to react to situations and think clearly of how things can also be done differently. Another example is that during my project I gathered rich qualitative data. But I was not completely sure how to gain valuable insights from them. It had cost me time, because I was going through the data over and over again, while I could also ask for help. I found myself struggling with it and looking for existing research that has used the same method in order to gain understanding of how they used it. This helped me a lot, and in the end enabled me to see my research in a broader perspective, because I could compare it with existing literature.

Because my mind works sometimes (actually most of the time) faster than I can act, I felt the need to set up a detailed planning to structure my thoughts. The way I planned my 20 weeks was by breaking the whole project in smaller pieces and set small milestones for myself. From every milestone I than worked my way backwards to determine what task I would need to start with. The practice of how to set goals and determine what is needed to reach them is something I developed during my thesis. I also believe this is a very important soft skill to learn, for later on in 'work' life. Because I know that making the decisions in my project would cost me time, I left room for reflection days (or weeks) in my research. Moreover, I wrote a weekly update every week in which I reflected on what I had done, how it went and what was coming next. In this way I knew that every week I made progress and I could anticipate on what was upcoming. At the same time this was written in a shared drive document, in order to allow my supervisors to stay connected in my project.

I found the connection between all stakeholders very important in my project. Therefore I always made sure that the adjustments I made in my planning were communicated clearly to the households, supervisors and TinyWolf team to ensure that they would follow what was going to happen. Moreover, by communicating closely with the household members I was getting to know them better (and vice versa!) what allowed them to feel comfortable and open in sharing their thoughts, feelings and experiences. A key factor in communication is not only providing information but learning to listen to what others have to say. That is what has provided me valuable insights and learning points throughout my thesis. Not only for the purpose of myself or the purpose of my project, but also additionally for TinyWolf.

9.2 Personal reflection on ambition

One of the ambitions was to challenge my research skills. I think that after my project I should rephrase this, I could better say ‘develop new research skills’. The reason for this change is because during my thesis I have used research methods that I never worked with before. I found myself struggling with trying to apply the methods I learned during my time at TU Delft. However, I realized that this time my research was different and did not allow to use these methods. I needed some guidance in how to start looking for other ways of analyzing the data I gathered. My supervisors gave me advice in what research perspective I could look into. This helped me to look around and see how many research methods there actually are. Nevertheless, I also found out that the way I was already dealing with the complexity of the data was similar to the method I finally choose, the practice theory. I learned how the method was used by looking how it had been applied in previous research studies. This gave me understanding of the purpose of the theory what ultimately gave meaning to my results.

A second ambition was to develop project management skills. In my opinion these soft skills are valuable because it allows to involve stakeholders into the project. I also found out that I really enjoy being in this position and started to feel comfortable in guiding the project and choosing the direction (yes, making choices!). During my thesis I developed these skills and learned how to use them to deal with the complexity of my research project. The continuity of contact with stakeholders allowed me to connect and receive open and honest feedback. I would say that a key factor in project management skills is learning to listen to what others have to say and use this feedback to learn and improve the work you are doing.

The third ambition was to deepen my knowledge of human behavior in relation to indoor air quality. In the last years I have developed an interest in why people do what they do by reading books about it and listening to podcasts. However, defining the underlying meaning of human behavior from a scientific perspective was still a challenge. The practice theory has helped me in understanding how human behavior is built and can be changed. I would not say that with my research I changed human behavior, however, participants mentioned that my research extended their way of thinking about indoor air quality. Moreover, participants feedback shows that my research motivated them to learn more about indoor air quality. I am grateful for receiving this response, because motivating other people to improve indoor air quality is what this thesis has been all about.

9.3 Reflection on project context and supervision

In the beginning of my project I was searching for ways to allow my supervisors to be connected. During my project I developed understanding of how to approach them. I learned that I could ask them feedback on very small tasks rather than big tasks. What in the end is beneficial for both. Besides writing the weekly updates, I sent them an extra mail to remind them about the progress of my project. And before every meeting I sent an agenda to clearly state what we were going to talk about with the relevant documents enclosed.

Overall, communication went very well among all stakeholders being involved in my project. As I mentioned in the previous section, this has also been one of my ambitions. During the project I learned how to guide the direction of the project to achieve my goal. The engagement with the participants in particular has been important. Feedback from the participants shows that they found that their expectations of my research were set appropriately and that I communicated effectively and understandable. I think in the field of user research it is useful to create openness with the participants in order to connect with them and allow them to be themselves. This resulted in honest conversations which provided me very insightful results in my evaluations.

The partnership with TinyWolf being involved in my project has added value in both ways. For the startup, because I gathered additional information beyond the purpose of my research for further product development. And for me, not only because of the use of the air cleaning technology, but also because the TinyWolf team has been openly sharing their thoughts and opinion about my project as well.

When reflecting on the project as a whole I have definitely seen myself growing. I learned to take a step back once in a while to critically reflect on what I had been doing. By seeing the bigger picture, I was able to make the links between my research, reality and related work. These connections have improved the quality of my work. I feel that I have been challenging myself throughout this project every time to do better, but at the same time set appropriate goals that are feasible to achieve.

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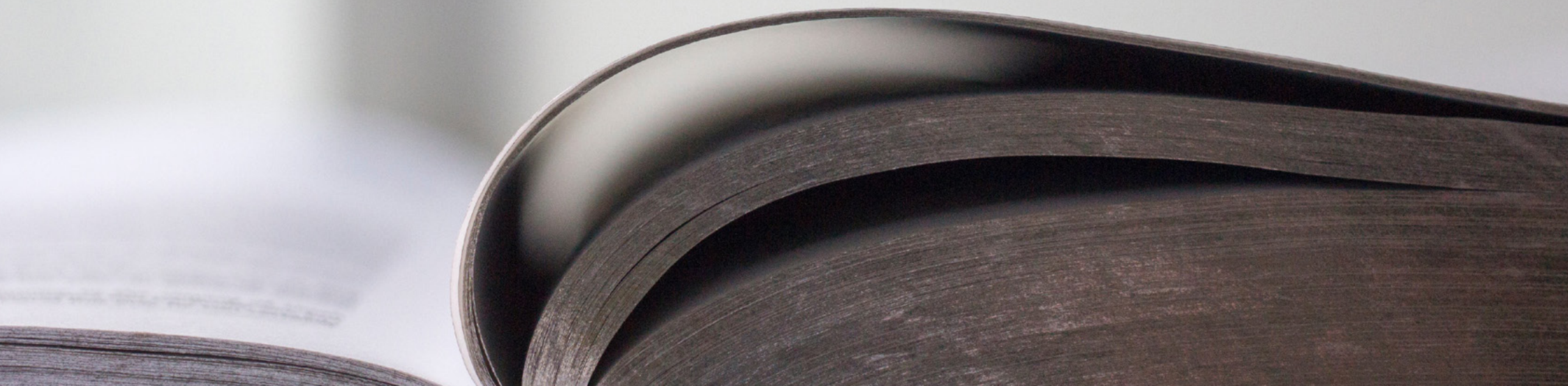
APPENDICES



1.A Explanation of different pollutant sources

Biological pollutant sources
These pollutants can grow as mold in dark and humid places of the house, are carried by pets or come from outdoor sources. For example, people can easily walk dust and soils from outside into their homes or workspace with their shoes and clothes. The most common biological pollutants are mold, dust mites, bacteria, viruses and pollen which trigger sensory irritation of eyes or airways.

Chemical pollutant sources
The so called silent killers, chemical pollutants, are mostly gases that are odorless and dangerous. They make the human body stop from using oxygen as it would do normally, what makes you feel tired, causes headaches or a high heart rate.

Volatile organic compounds (VOCs) are chemicals that evaporate from paint or building materials. VOCs are emitted by furniture or furnishing materials over a longer period of time.

Another common source of chemical pollutants are consumer cleaning goods. These products relies many different chemicals, including VOCs, directly into the indoor air. This reaction happens as well when occupants are using water, e.g. when they are cooking or taking a shower.

Physical pollutant sources
Particulate matter (PM) might be the most serious problem nowadays because these very tiny airborne particles can enter our bodies through our lungs with every breath we take. The biggest size of PM is dust, which is generated from outdoor and indoor sources such as tobacco smoke. This type of pollutant aggravates asthma symptoms and other respiratory condition symptoms.

1.B The perceptual process

The way our brain gains information about objects and other properties or elements of our environment is through a perceptual process. This process describes the steps of how we gain information through recognizing environmental stimuli and the translation into actionable response to the stimuli we see.

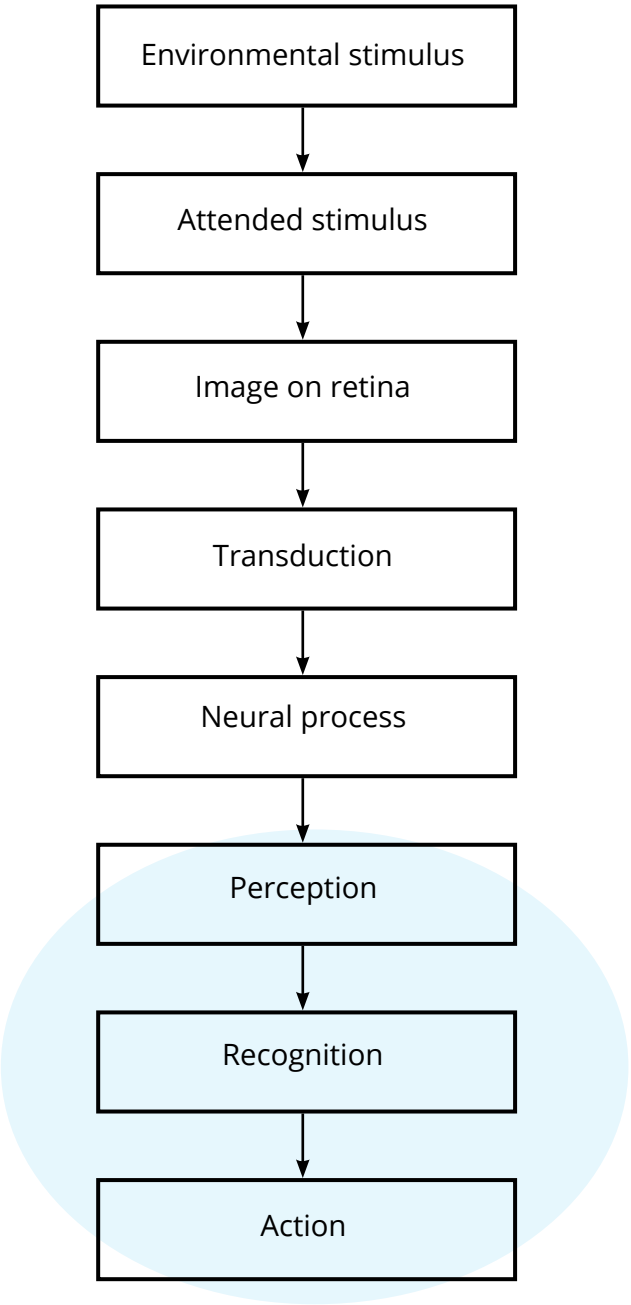
The first step is environmental stimuli, which is everywhere in our surroundings and has a potential to be perceived by human beings. This includes anything that we can sense, for example feeling a breeze or hearing a sound.

People might focus either on stimuli that are familiar to them or that have some degree of novelty. A person focuses attention to specific objects in his or her environment, which is called the attended stimulus.

The visual information that this person captures will be transformed into electrical signals through transduction. This process transmits visual information to the brain to be interpreted. Each type of signal will follow its own path, depending on whether it is visual, auditory or air waves.

The perception step means that the stimuli is perceived and the person is consciously aware of the presence of the stimulus. An essential part of perception is to sort the perceived information into meaningful categories. By doing this we are recognizing our surrounding and are able to understand it and react to our environment.

The response to the recognized stimulus might involve a variety of actions in body movements or behavioral reactions.



1.C Research setup (whole project)

Who am I and who is Tiny Wolf?

I am an industrial design student and for my master thesis I focus on improving indoor air quality through design. At the same time I am a team member of startup Tiny Wolf, and together with our team we have a vision to give families cleaner air inside their homes.

Why is this important?

Because we spend approximately 90% of our life time indoors, where air pollution is often much higher than outside on a busy road. As the indoor air is an extension of the outdoor air, particles can easily move around in your house. Since these particles are invisible the opportunity to reduce them can often be overlooked.

Why I choose you?

In order to help you as a family to create a healthy environment for yourself and your kids. Moreover, Tiny Wolf creates a product that fits well into your life and by sharing your perspective on the product we can find a solution together.

What should you do?

1 The first time is mainly as introduction to the study. I will ask some questions about your perception of air and would like you to share some of your daily routines.

When?
23rd November
1 hour

2 You will be able to use the designed product for two days to try it out and you will be asked to share your experience of the use of the product afterwards.

14th December
1.5 hour
(and the 2 days of use)

3 Three smaller tests that go deeper into some of the characteristics of the product in which you will be able to test additional features with respect to the improvement of the indoor air quality.

8th February
1 hour

21st February
1 hour

7th March
1 hour

2.A Explanation of vulnerable groups of people to air pollution

Children

Children are specifically sensitive to air pollution because they relatively spent more time indoors (at home, in transport or at school) compared to adults. When children are under the age of three it is very important to breathe safe air because their body is in an important growth phase and lungs are not fully developed yet. If exposure to indoor air pollution begins from early on in their life, the possibility to develop asthma or other respiratory diseases becomes higher. Evidence represents a declined rate of asthmatic or chronic cough symptoms of children with asthma or bronchitis who are situated in places with low particle concentration in the air.

Elderly

A study that has specifically investigated the effect of indoor air pollution on elderly shows that elderly are even more at health risks for a poor indoor air quality due to the underlying chronic diseases they might have. Besides, this group of people spent significantly more time indoors than younger generations of populations.
The research even shows that there is hardly any difference of occurrence of respiratory symptoms in winter and summer.

Asthma or respiratory diseases

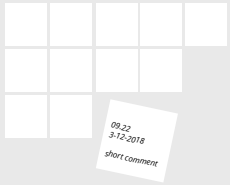
People who already have difficulties with breathing are at high risk when it comes to a poor indoor air quality. The pollutants in the air aggravate the symptoms they already have. Asthma triggers the muscles surrounding the airways to tighten what disables the air to more freely. This causes extremely sensitive irritation or overreacting of the airways when pollutants as pollen, dust or fumes try to enter the body.

2.B Research setup (part 1)

1 Introduction to the research *(1 hour)*

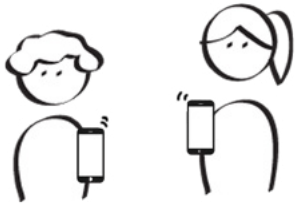
Firstly we will do a short introduction session (interview), getting to know each other and an explanation of the research.

Afterwards the ‘Capture your air’ sensitizing tool will be explained.



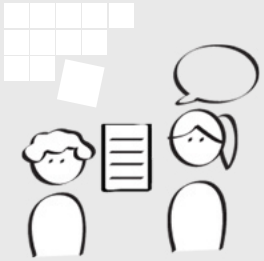
2 ‘Capture your air’

You are asked to take pictures of elements or objects in your indoor environment that you find are related to poor or good indoor air quality factors.



3 Post interview *(1 hour)*

This interview will be hold at the start of our next session. The pictures that have been taken will be discussed.



2.C ‘Capture your air’ sensitizing tool

What is this about?

This is meant to map your current situation and behavior or activities with respect to the indoor air quality of your home and in particular your kids bedroom.

How?

You are asked to take pictures (just with your phone) of the items, objects, activities or anything else that appeals to you for a certain reason, that are concerned with how you manage the indoor air quality of your home/bedroom.

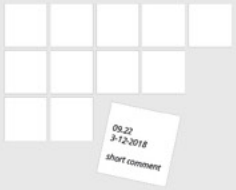
What should you do?

1. Take a minimum amount of 6 pictures over the next 2-3 weeks (until the next time we meet)
2. Make sure the pictures are taken at least at 3 different days
3. Make sure the pictures at least represent 1 activity and 1 object or product
4. Make sure at least one of the pictures represent a relation to poor indoor air quality and one the pictures represent good IAQ.
5. Write a short comment (one liner) for each of the pictures just right after you took it + the date and time

3.A Research setup (part 2)

1 Introduction to the test *(1 hour)*

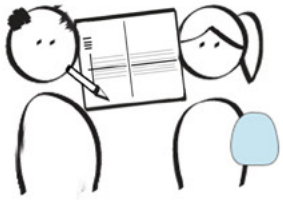
Firstly we will do a short recap of the previous 'capture your context' task.



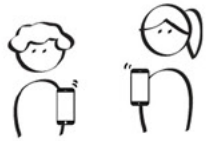
Afterwards you will be asked some questions regarding your expectations of the product.

2 4 days use of the product

You are allowed to use the product freely and you are asked to fill out your personal customer journey booklet.

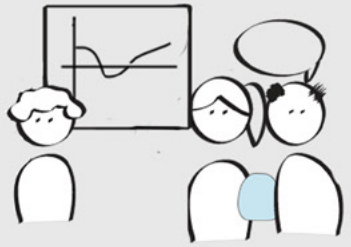


In between the days you will receive a reminder to sent a picutre of the situation regarding the use of the product



3 Post interview *(1 hour)*

In the post interview you will be asked questions about the usage and experience of the product with regard to your perception of indoor air quality.



4.A Research setup (part 3)

What is it about?

Three smaller tests will go deeper into some of the characteristics of the product in which you will be able to test additional features with respect to the improvement of the indoor air quality.

What should you do?

Introduction

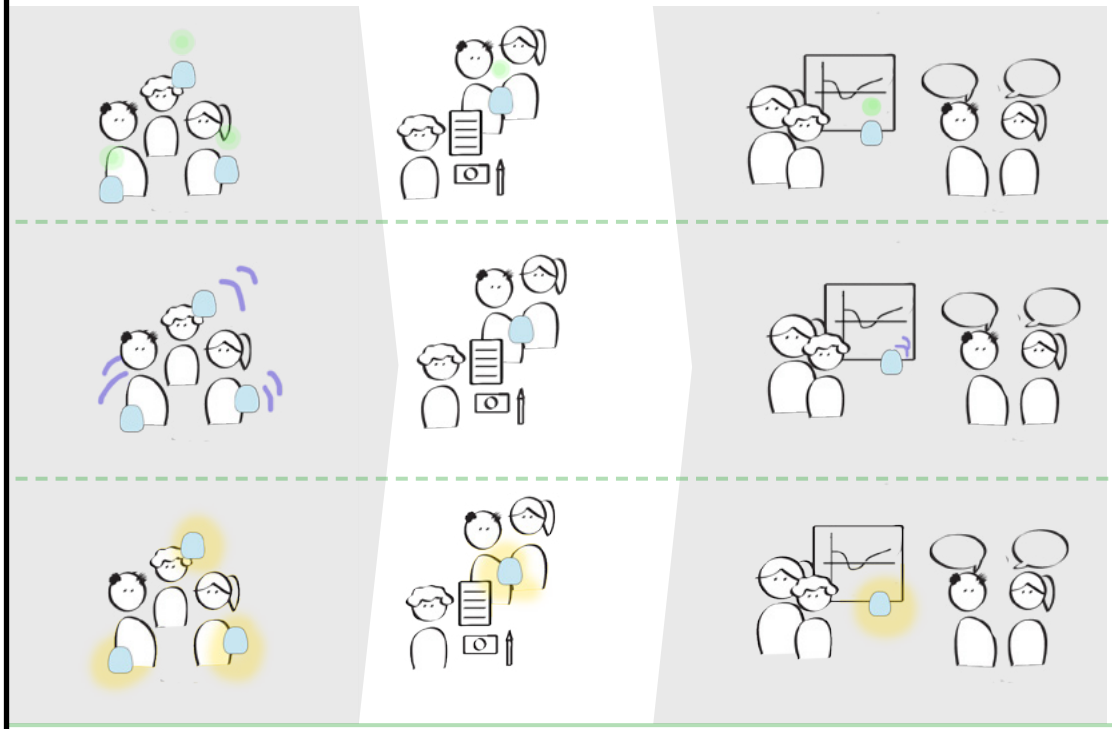
Bringing the product and short recap and questioning.

4 days test

You are allowed to freely use the product.

Post interview

You will be asked questions about the use and experience of the product.



When?

February
7th - 12th or 8th - 13th*
1 hour per meeting

February
21st - 26th or 22nd - 27th*
1 hour per meeting

March
7th -12th or 8th - 13th*
1 hour per meeting

**dates for test periods can be discussed*

5.A Persona's and user stories

Isabel (27)
Danish
Journalist
Lived her whole life in the city
Loves cooking healthy food

Jakob (28)
Danish
Consultant (advisory)
Lived his whole life in the city
Interest in buying new tech products

Persona 1

A young couple living in the middle of urban life. They adopted the healthy lifestyle and combine their busy work with social activities. Their apartment in situated in Vesterbro. Since their first born child has some respiratory related health issues they want to create a healthy and clean environment for her to grow up. Their apartment is really small, what makes sleeping in the bedroom next to the busy road not optimal. They are gaining more knowledge about the baby's health and how to deal with it. Isabel gets inspiration from her family and friends. Jakob has an interest for buying new technological products. They look for products to enhance the quality of their child's life, but it should fit within their small apartment and interior.

User stories 1

At the moment Isabel can work part time from home, whereas Jakob has to go to the office or visit clients in the city. Since Jakob likes 'techie' products, he normally is into buying those products without asking Isabel, because Isabel is more the type of person who first searches for reviews on products before buying them. Now that they are learning more about the health of their child they are willing to spend more money on baby products.

Daan (31)
Dutch
Entrepreneur (sustainability)
Grew up on the countryside
Lives in Copenhagen for 6 years
Buys functional products

Sofie (28)
Danish
Recruiter
Lived in suburb of Copenhagen
Goes to social events
Doesn't care about brands

Persona 2

Young urban professionals caring about the environment and love to be in nature. They are eco-consciousness and think about what they buy and throw away. They both meet a lot of like-minded people when going to entrepreneurial events. They enjoy the lively atmosphere of their neighborhood, but in the weekends they like to escape the city and visit their family and be in nature. Since they concern about sustainability, the increasing traffic in the city is causing their concern. They already look into possible solutions to keep the indoor environment clean, such as opening the windows not during rush hours. They want to create a healthy environment for their youngest child.

User stories 2

Before their baby was getting born they already wanted to try out product that might be useful when the baby comes. They believed in being well prepared since afterwards they would probably not have the time anymore to figure out what products would be good for taking care of the baby. They already have gained knowledge about the impact of air pollution to the environment, also the effect it can have indoors. Therefore they think about what materials products have and how they can best use them while they are doing their practices at home.

Sara (38)	John (42)
Mexican	Danish
Moved from Mexico to Copenhagen	Lived all his life around Copenhagen
Teacher on primary school	Engaged with his children activities
Not really into tech	Not a big spender
Feels socially responsible	Likes to go to the summerhouse
Has respect for people and planet	Goes to work by bike
Is part of the social community	

Persona 3

A married couple with a bit more life experience, having two kids (2 and 5) and living in Osterbro. They are not limited by money, however not big spenders either. Although Sara enjoys shipping products of high quality, especially when it benefits her or other household members' health and wellbeing. None of the children has any air related health problems, so they have never thought of cleaning the air that much. Their house is not organized or tidy but hygienic. They are cultural interconnected and think quality of life is important. John rather takes his bike to go to work than driving his car.

User stories

John likes to be engaged with the family and spent time at home and values a pleasant feeling when he is there. Sara can also enjoy her moments alone when her husband and kids are away. They are an active family and normally organize to do something together with the kids in the weekend, whether this is inside or outside of the house does not really matter to them.