CHALMERS

The Vision of Effortless Cleaning

A Product Development Journey Integrating Human and Technology with User Experience

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

Department of Product- and Production Development
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PREFACE AND ACKNOWLEDGEMENTS

This master thesis is the result of a product development project carried out during the spring in 2016 at Chalmers University of Technology. The project covered 30 credits and was carried out by two students from the Industrial Design Engineering program at the division of Design and Human Factors, at the department of Product and Production Development.

We want to thank our partner Electrolux and Vice President of Design Pernilla Johansson for giving us the opportunity to take on this project. Thanks also to Global Design Manager Esbjörn Svantesson for helping us through the project by providing us with necessary information and support.

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Pedram Nayeri and Sebastian Olsson

ABSTRACT

The technology around us have been evolving at a rapid pace for the last decades. It has changed our lives and allowed us to do so much more than before. Our lifestyles are full of short activities and interactions. We do whatever we want – whenever and wherever we want it. Yet we spend hours every week doing something that most of us dislike – cleaning. And cleaning hasn't evolved at all.

This master thesis aims to change that – to change the experience of cleaning and to create pleasure throughout people's lives. On behalf of the home appliances manufacturer Electrolux, a visionary concept for the future of cleaning was developed.

There have been several attempts to make cleaning easier. A number of different vacuum cleaners have for example been introduced over the years. However, user studies showed that none of the alternatives have been able to replace the traditional vacuum cleaner yet, and all of them bring displeasure to clean keeping. Cordless stick vacuum cleaners are clumsy and too complex – they are aimed to do more than they can handle. Furthermore, they look weak and incapable. Robotic vacuum cleaners are not capable enough and people don't trust them.

The solution is in making what's pleasurable about cleaning even more pleasurable. People were found to like the results of cleaning. Seeing, feeling and smelling the freshness is pleasurable, but unfortunately the results of cleaning don't last because most cleaning tools spread dirt as well.

The visionary concept Halo creates a lasting clean impression. It rethinks the clean keeping human-machine system from the ground up by introducing a mesh of devices – all specialized and seamlessly working together. Halo shows a new path of purposeful cleaning products that are visible in people's homes. It opens up for endless possibilities in a new era of smart products.

***Keywords**: clean, cleaning, clean keeping, dust, dirt, user experience, pleasure, lasting impression, vacuum cleaner, ionizer, air cleaner, future, product development, industrial design*

CONTENTS

01.

INTRODUCTION

Why is clean keeping in need of revolution? And what can we do about it? The background, purpose, goal and scope of this master thesis project are presented in this chapter. A description of the thesis's structure is also presented in the last section of the chapter.

A. BACKGROUND

Let's be honest. Almost no one likes cleaning! Despite that, 78 % of people vacuum clean more than once a week. 33 % even vacuum 2 to 5 times per week, and 57 % vacuum for more than half an hour every time (Electrolux, 2013). The vacuum cleaner is and has been an essential part our lives for decades. Even though our lives have changed, the vacuum cleaner is pretty much the same. We work more, spend less time at home and value our spare time more. Still, we spend a lot of time doing something we would prefer not to. But why? Maybe because 30 % feel satisfaction afterwards (Electrolux, 2013). Or just because we have to? Or because there are no other options?

We spend a lot of time doing something we would prefer not to. But why?

Improvements have been made to make vacuuming simpler. Electrolux's cordless products are great examples that make the cleaning more effortless, but they still require time and effort, and the suction power can be questioned. Robotic vacuum cleaners are thought to eliminate the need of user time and effort, but we don't trust them because they don't work. They can't clean in corners, beneath furniture or in stairs. Sometimes they even get stuck! Furthermore, they lack functionality that allow the user to clean floor skirting or other surfaces.

In the end, vacuum cleaning is only one of the tasks in a cleaning session. Every session includes several completely separate activities and tools, which results in a lengthy, disruptive and effortful experience. The users have to switch between the vacuum cleaner, the cloth and the mop several times. The vacuum cleaner requires several nozzles and the cloth needs to be rinsed over and over again – so does the mop.

A new way to keep homes clean is needed! A way that creates a vastly better experience for the user, either by eliminating the need of user-involved cleaning or by making cleaning pleasurable. There is room for one or several products that consider and reimagine the entire cleaning situation and there is a need of bringing user experience expertise into the world of clean keeping!

B. PURPOSE

The ultimate purpose is to create a great clean keeping experience that is considerably better than the one today. One part of the purpose is therefore to investigate the current clean keeping system, from dirt to devices and activities. Another part of the purpose is to develop one or several clean keeping product concepts that create a better experience of clean keeping than today, by increasing pleasure and decreasing displeasure.

C. GOAL

The goal is to present a vision of the future of clean keeping, represented in a product concept. A concept that considers and improves the experience of the entire clean keeping situation. The concept is a visualization and a scenario of the vision and should be realizable within five to ten years.

D. SCOPE

This master thesis project considers clean keeping and the clean keeping situation. Focus is on non-professional clean keepers in home environments. It is furthermore limited to the Swedish market, since differences in culture, interior, architecture and climate heavily affect the cleaning situation and are considered out of the scope of this project. This project covers all parts of clean keeping from the spread of dirt to storage and maintenance. Recycling and disposal of dirt are however not parts of this project.

Focus is on the use and the experience of products. Machine architecture is therefore only briefly covered in this project.

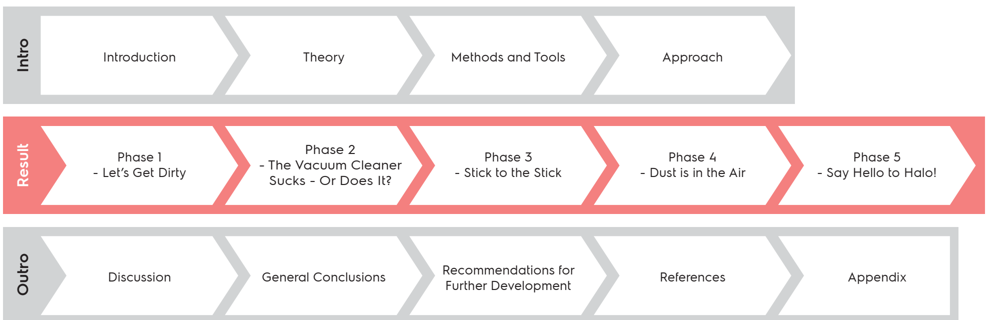
E. PARTNERS

This project is carried out in cooperation with the home appliances company Electrolux. Electrolux is a global leader in home appliances (Electrolux, 2016a) and therefore, they have every opportunity to redefine clean keeping. They create innovative products based on consumer insights, which is the foundation of user-centered design and user experience.

F. THE STRUCTURE OF THIS THESIS

The theories, methods and tools used in the project are presented right after this introduction followed by a description of the approach used throughout the project. The main part of the thesis that eventually leads to the end result is presented in five chapters that each represent a phase of the project. The purpose, goal, result & analysis and conclusions from each phase are presented in each of those chapters. The result from the five phases are followed by a discussion of the project, general conclusions and recommendations for further development. The structure of the thesis is illustrated in Figure 1.

Figure 1
The structure of this thesis.



The chapters are briefly described below. The following chapters represent the foundation of the project:

2. **Theory** – description of the product development and user experience theory used in the project.
3. **Methods and tools** – description of the methods and tools used for data collection, analysis, ideation and concept development.
4. **Approach** – description of the approach that was used throughout the project.

The following main chapters represent the result of the project:

5. **Phase 1 – Let's get dirty** – results from initial studies, user studies, analyses of the current cleaning system, experience analyses and trend analyses.
6. **Phase 2 – The vacuum cleaner sucks – or does it?** – results from ideations and workshops regarding technical principles and new clean keeping devices.
7. **Phase 3 – Stick to the stick** – results from ideations and analysis of the stick vacuum cleaner.
8. **Phase 4 – Dust is in the air** – results from an explorative phase with ideations, evaluations and concept development.
9. **Phase 5 – Say hello to Halo!** – results from concept development, evolution and evaluations of the final concept.

The result is followed by discussion, general conclusions and recommendations for further development:

10. **Discussion** – discussion of the project. Covers the project's approach, all of the five phases, reliability and validity.
11. **General conclusions** – presentation of the most important learnings results and conclusions from the project.
12. **Recommendations for further development** – recommendations and explanations from the designers regarding how the product development should proceed to make the most of the results from the project.

02.

THEORY

The theory relevant to the product development process is presented in this chapter.

A. DATA

According to Oxford Dictionaries (2016), data is “facts and statistics collected together for reference or analysis”. Data can be classified into two categories: quantitative data and qualitative data.

Quantitative Data

Data in numeric variables (e.g. “how often?”) is considered as quantitative data (Australian Bureau of Statistics, 2013). Studies that generate quantitative data, such as surveys, are often conducted as verification of the qualitative data. However, such studies do not withhold deep understanding of the user and the human-machine system. (Karlsson, 2007)

Qualitative Data

Data represented by name, symbol or a code (e.g. “what type?”) is considered as qualitative data (Australian Bureau of Statistics, 2013). Studies of which the outcome is qualitative is fundamental in the early phases of the development process, since such data often represent attitudes, values and underlying motives that are essential to know about. (Karlsson, 2007)

B. USERS

When conducting a *user-centered product development* (Norman, 2013), *users* are very important participants in the development process. A *user* is a person, that at any phase of the product life cycle, interacts with the product of interest (Warell, 2001).

User Classifications

There are several types of users. The *primary users* are the persons that use the product for its main purpose (e.g. passengers of an aircraft). The *secondary users* do interact actively with the product, but not for its main purpose (e.g. the repair man of the aircraft). There are persons that do not actively use the product and doesn’t have the purpose of, but still are affected by it (e.g. by the noise). Those are called *side users*. However, there are people that do not use the product but are still affected by it (e.g. pilots of other aircrafts – they must notice the aircraft in order to prevent any accident). Those people are called *co-users*. (Janhager, 2005)

C. ERGONOMICS – DESIGN FOR ALL

With the rise of the digital age, accessibility and equal opportunities for all has become increasingly important (Persson et al, 2014). The EIDD[1] Stockholm Declaration (2004) defines the term *Design for All* (DfA) as *"design for human diversity, social inclusion and equality"*. The declaration further implies that everyday objects in the society and in the built environment that are designed by people, must also enable equal opportunities to all people by being accessible and convenient to use.

The everyday objects in the society (including jobs, machines, tools, workplaces and habitants) are designed for the "normal" adult and thus, make the life of many people that do not fit into this norm difficult. These people are the *elderly*, the *small* and *big people*, the *disabled*, the *expectant mothers* and lastly *children* (Kroemer, 2006). Design for All is about including those people in the society by practicing design processes that, at every step, involve those end user(s) (EIDD Stockholm Declaration, 2004).

D. USER EXPERIENCE

According to Hassenzahl (2013), *User Experience* (UX) is about creating experience *through* a product. Thus, products are *mediators* of experiences. When a product creates experience that fulfills the needs for relatedness to relevant others, the experience becomes positive (Hassenzahl, 2013), and thus, a *pleasure*. The pleasure is, among other things, affected by the level of *congruity* between a person's expectation and product attributes (Ludden, Schifferstein & Hekkert, 2012).

The Four Pleasures

There are many definitions of pleasure. One is *"the enjoyment or satisfaction derived from what is to one's liking; gratification; delight."* (Dictionary.com Unabridged, 2016). Patrick W. Jordan defined pleasure, in relation to products, as *"the emotional, hedonic and practical benefits associated with products"* (Jordan, 2000). He stresses the fact that pleasure is not an inherent property of a product (as e.g. placements of buttons or colors) – it is the outcome of an interaction between a person and a product in a context.

Connected to products are both pleasures and displeasures. Jordan (2000) presents a framework for considering pleasure with products by *The Four Pleasures*:

- **Physio-pleasure** – pleasure directly connected to the raw visual, tactile, olfactory, auditory and gustatory sensation from products that are directly derived from the sensory organs. For example, the smell of the inside of a car can be pleasurable since it "smells new".

[1] The European Institute for Design and Disability (EIDD) changed its name in 2006 to EIDD Design for All Europe.

- **Psycho-pleasure** – pleasure connected to the cognitive and emotional reactions of people. A user friendly product (that is, a product that is easy to understand and to use) result in a higher level of psycho-pleasure than a product that is bothersome to use. “It just works” is an excellent quote that represents psycho-pleasure when using a product.

- **Socio-pleasure** – pleasure connected to social contexts. Products connect people. The phone is a great example of a product that generate pleasure connected to social interactions. A coffee machine becomes a gathering spot during coffee breaks and facilitates social interaction.

- **Ideo-pleasure** – pleasure that is a result of partly the aesthetics and embodied values of products, partly people’s preferences (tastes), goals (aspirations) and moral beliefs (values). A product made of biodegradable materials embodies values of environmental responsibility, and thus, creates ideo-pleasures for people that are environmentally conscious. Products as pieces of art also create ideo-pleasure, e.g. the Arne Jacobsen “Egg Chair”.

The four theories of pleasure shouldn’t be seen as a theory of pleasure as such, but rather as a structured approach to the issue of pleasure for people involved in the design process. The model also serves as a guidance to the vast spectrum of product derived pleasures. (Jordan, 2000)

Congruity

Based on the visuals of a product, a person automatically forms expectations about it. Such expectations concern e.g. what the product feels like when touched and what the product can do. When the perceiver’s expectation is congruent with the actual attributes of the product, *congruity* between expectation and reality is met. On the other hand, product attributes that generate false expectations are defined as *incongruent*. Congruency creates harmony but little surprise, while incongruity creates a surprise that could be either positive (the product is better than expected) or negative (the product creates confusion). (Ludden, Schifferstein & Hekkert, 2012)

E. SEMIOTICS

Semiotics is seen as an approach to which the human’s view and understanding of the world can be interpreted with (Nöth, 1995). *Semantics* is a subcategory within semiotics and tells about *sign* – the foundation of how humans communicate with each other (e.g. numbers, gestures). *Charles S. Peirce* describes the sign as a triadic relation between the *representamen*, *object* and *interpretant* (Peirce, 1897). In relation to products (or *artifacts*), the representamen refers to its shape, the object to the embodied meaning in the shape and the interpretant to the person processing the totality of the representamen and the object. This means that, to *design* something, is to create a sign for someone about something.

Awareness of the semantics of the artifact in development is beneficial in order to correctly signal the developer’s thoughts and intentions to the user.

F. BIOMIMICRY

Biomimicry is a rather new discipline that studies the nature and how it works in order to solve design or process oriented problems in the development process. Animals and plants existing today are results of billions of years of iteration. Thus, biomimicry comes from the belief that nature already has solved many of the problems that product developers face. As an example, the study of the leaf has taught engineers how to harness solar energy, and thus, invented solar panels. To study how animals, plants and the nature work is an inspirational source in the product development process. (Nationalencyklopedin, 2016, Benyus, 1997)

G. FLUID MECHANICS

The field of science called *mechanics* involves force, energy, motion, deformation, and material properties of material bodies. *Fluid mechanics* is a discipline that focuses on the mechanics of material bodies in gas or liquid phase. The flow of such fluids can be *laminar* or *turbulent*. (Crowe et al, 2009)

Laminar flow is a state of flow that is well-ordered, while the state of a turbulent flow is described as unsteady. The flow of a thick syrup from a pitcher is an example of a laminar flow – the layers of the fluid run smoothly with respect to each other. In contrast, the smoke from a smoke stack that is affected by wind is turbulent – intense cross-stream mixing affects the flow of the smoke in an unpredictable way, which is observed when the plume widens and disperses. (Crowe et al, 2009)

H. SUSTAINABLE DEVELOPMENT

The Brundtland Commission (1987) defined sustainable development in as "Sustainable development is development that meets the need of the present without compromising the ability of future generations to meet their own needs". World-famous Vitsœ industrial designer Dieter Rams defined ten principles for good design (Vitsœ, 2016) for sustainable and responsible product development:

1. *Good design is innovative*
   Technological development opens up new opportunities for innovative design.

2. *Good design makes a product useful*
   Anything that does not empathize a product's usefulness should be disregarded.

3. *Good design is aesthetic*
   Aesthetics are integrated into a product's usefulness.

4. *Good design makes a product understandable*
   The product is, at best, self-explanatory.

5. *Good design is unobtrusive*
   In order to leave room for user's self-expression, product's should be neutral and restrained.

6. *Good design is honest*
   It is as powerful, innovative and valuable as it looks like.

7. *Good design is long-lasting*
   Going against the throwaway-society of today, good design never appears antiquated.

8. *Good design is thorough down to the last detail*
   Good design does not leave anything to the chance. Every detail is well thought through.

9. *Good design is environmentally friendly*
   Throughout the lifecycle of the product, its design preserves the environment.

10. *Good design is as little design as possible*
    Focus is on the essentials. Less is more.

I. EUROPEAN COMMISSION'S CONSUMER GUIDELINES

The European Commission (2016ab) have listed regulations and ratings from A to G around the different vacuum cleaner properties, where A is great performance and G is just above the legal limit. Battery operated vacuum cleaners such as sticks were excluded from the regulations. Some of the factors are described below:

- **Dust pick-up on hard floor** – Refers to the ratio of how much of the dust is collected from hard floors.

- **Dust pick-up on carpet** - Refers to the ratio of how much of the dust is collected from hard floors.

- **Dust re-emission** – Refers to how much of the collected dust is being re-emitted into the air.

03.

METHODS AND TOOLS

In this chapter, methods and tools relevant to the product development process are presented in this chapter. However, these categories should not be considered as project phases. For example, data collection methods were used throughout the project.

A. DATA COLLECTION

Data collection is a central part of product development. Here, methods and tools used in the project in order to gain data from users and other stakeholders are listed.

Interviews

To conduct *interviews* is to verbally gain information from one or several parties (Egidius, 2008). It's a data collection method that allows for both *open-ended* and *close-ended* questions. While open-ended questions allow (but do not force) the interviewees to answer thoroughly in their own words, the answers to close-ended questions are pre-defined (as in 'yes' or 'no') (Brace, 2013).

The nature of interviews varies. *Structured interviews* are conducted by strictly following templates. In contrast, *unstructured interviews* are improvised – open-ended questions are formulated during the interviews as follow-ups to the given answers. Lastly, *semi-structured interviews* are to some extent conducted by following a template, but also allow for improvisation and to tweak the questions depending on the interviewees, their answers or the context of the interview. (Egidius, 2008)

If the aim is to gather quantitative data, structured interviews are to prefer. Unstructured interviews could result in quantitative data as well, but such data would be difficult to compare between the interview persons. Unstructured interviews fit much better when collecting qualitative data. (Bligård, 2015)

Observations

Visual studies of processes are called *observations*. Often the purpose of observations within product development is to record and study the actual acts and reactions of participants towards products or stimuli. Interviewing as a data collection method give subjective data that could deviate from reality, which is why observation is a useful complementary data collection method.

There are several types of observations. *Direct observations* are the most common and refer to the fact that the event of interest is studied directly, either by human or by apparatus (e.g. video recorder, oximeter). In *participatory observations,* the observers are part of the event of interest by being involved in the interactions between the participants and products in some way. *Self-observations* are about making the participants into observers of themselves by e.g. writing a diary. (Karlsson, 2007)

Direct and participatory observations can be *open* and *hidden*. Open observations denote that the participants are aware that they are being observed, while during hidden observations participants are not aware of the observers and their presence. Open observations allow the observers to ask questions and to make the participants "speak their thoughts", which facilitates the elicitation of valuable information about the user problems, needs and wishes that are harder to convey by interviews. (Jorgensen, 1989)

The observers should be aware of the *validity* of the study. During open observations, the participant's awareness of the observation most likely influence their behaviors in a way that deviate from the real use case. Being more diligent in both thought and act is a typical example of such deviation that could distort further analysis of the observation results. The validity of the study is also dependent on the context in which the observations are conducted. A *real use environment* is optimum for the validity, but observations can be difficult to conduct in such context without the observer influencing it (which would decrease the study's validity). Another problem is that data from several observations in a real environment can be hard to statistically and quantitatively compare since the circumstances may vary during or in-between the observations. Constructed environments are on the other hand less valid than real ones since they do not reflect the real use situation, but data elicited from observations made in a certain constructed environment are comparable and thus easier to analyze. (Jorgensen, 1989)

Online Questionnaire Surveys

Online questionnaire surveys are internet based questionnaires that usually aim to gather quantitative data. In contrast to interviews, web surveys as a method of data collection opens up the possibilities of gathering a great amount of data if distributed correctly. However, the validity of the surveys is hugely dependent on the design of the surveys. The participant should be able to understand the questions and be able to answer in a correct way. (Trost, 2007) Online questionnaire surveys are referred to as "surveys" in this thesis.

Workshops

Workshops are gatherings of people that are in some way related to the subject of interest. The purpose of such events is to evoke discussions around posed problems and encourage a solution centered ideation session. A moderate variation in the participant profiles is preferred since different mindsets and perspectives on the subject benefit the quality of the outcome. Depending on the character of the workshop (setup, participants, tasks), different types of data can be collected. (Wikberg Nilsson, Ericson & Törlind, 2015)

Participants

To conduct interviews, observations, surveys and workshops, *participants* are needed. The participants are people that are in some way related to the subject of interest – users, engineers, sales persons, etc. There are two dimensions from which participants are chosen from: the *qualitative dimension* and the *quantitative dimension*. The qualitative dimension implicate that the chosen participants are statistically representative while the quantitative dimension concern the amount of participants in the study (Karlsson, 2007). The validity of a conducted study relies partly on these dimensions. According to Griffin & Hauser (1993), several studies implicate that around 80% of the user needs are identified after 8-12 interviews.

B. ANALYSIS

In order to make sense of the data gained from e.g. user studies, various methods and tools for data analysis are needed.

Hierarchical Task Analysis

By scrutinizing the task of interest into sequences of actions, *Hierarchical Task Analysis* (HTA) helps product developers to gain understanding of the task and its overall goal. Firstly, the overall goal has to be defined. Consequently, the overall goal is divided into subordinate tasks, usually illustrated as a tree structure. The subordinate tasks can be further scrutinized into sequences of actions until a favorable level of detail has been reached. The level of detail depends greatly on the motive of the HTA. (Kirwan & Ainsworth, 1992)

System Model

A *system model* is a graphical illustration that describes the human-machine system of interest in terms of its components and relations in-between them. The method starts by identifying the system's components and describing their relevant properties. Thereafter, the connections between the components are identified and categorized as either *energy/force*, *information* or *matter*. Knowledge of the human-machine system in the development process is crucial in order to gain a high level understanding of the use situation. Some components, so-called *actors*, play central and active roles in the human-machine system. The influence of actors in the human-machine system is important to identify and study. (Bligård, 2015)

Link Analysis

A *link analysis* (LA) is a method used to map out links between the user's activities. For instance, a link can be to press button B after pressing button A. The links can be weighted and categorized for further analysis. The outcome of a link analysis is a graphical chart with activities connected by lines (that represent the links), clearly illustrating how often certain links are used and in which order. Link analyses are very helpful in development projects where placements of activities (such as buttons, informative messages etc.) can improve the user's performance in terms of e.g. errs. (Kirwan & Ainsworth, 1992)

Use Case

A method to identify and analyze user needs is to formulate *use cases*, which are generalized descriptions of situations that the user and the machine of interest somehow are involved in. Firstly, a use case describes the actor(s) of the situation, the goal, pre-conditions and context of use. The normal course of the use case is described as a step-by-step numbered list of interactions between the machine and other actor(s). The use case ends with short descriptions of the post-conditions, alternative courses and exceptions from the normal course. (Bligård, 2015)

Affinity Diagram

An *affinity diagram* is a method to get the overall picture of a huge amount of data. First, the data is written on pieces of papers, where one piece of paper contains one unit of data. As affiliation between data units are found, data is clustered into categories. Subsequently, affiliation between categories can be found and thus organized in relation to each other. The outcome is an affinity diagram. The strength of this method is that the categories emerge naturally, which facilitates the process of understanding huge amounts of data. The term was introduced by Japanese anthropologist Jiro Kawakita, thus sometimes referred as the *KJ method.* (Kaulio et al, 1999)

Rapid Upper Limb Assessment

The physical strain of an action on the upper body is estimated by a *Rapid Upper Limb Assessment* (RULA). Focus is on hand and arm ergonomics, which makes RULA especially useful on hand and/or arm intensive tasks. Apart from the joint positions of the upper body, RULA takes the weight of the load and static/dynamic aspects into account. The outcome is a calculated number that indicate the level of severity of the task. The higher the number, the higher risk of hurting oneself. (McAtamney & Corlett, 1993)

Rapid Entire Body Assessment

A *Rapid Entire Body Assessment* (REBA) is an assessment of the physical strain on the entire body (whilst RULA focuses of the upper body). By analyzing the posture, REBA takes the quality of the connection between human and the load into account. As with RULA, the outcome of REBA is a number that indicate the severity of the task. (Hignett & McAtamney, 2000)

SWOT Analysis

A *SWOT analysis* (Strengths-Weaknesses-Opportunities-Threats analysis) is a structural method that evaluates *internal* and *external* factors of a business venture. The internal factors are the *strengths* and *weaknesses* while the external factors are the *opportunities* and *threats*:

- **Strengths** – a list of company characteristics that gives the company advantage over other business competitors.

- **Weaknesses** – a list of company characteristics that gives the company disadvantages compared to other business competitors.

- **Opportunities** – a list of elements that the company could use to its advantage.

- **Threats** – a list of elements that the company could experience trouble from.

The SWOT analysis function as a part of the decision basis in present product development projects. It supports a holistic view of the company and its position relative others. Furthermore, SWOT can also be used to explore the possibilities of solutions to found problems. (SVID, 2016)

C. CONCEPT DEVELOPMENT

Methods and tools listed in this section are used to process and visualize the needs of the users gained from the data collection and analysis. They are also used as support for the creative thinking and concept development.

Brainstorming

To elicit as many ideas as possible, the method of *brainstorming* is commonly used. A problem or a theme is given to the participants (a group of several people), who subsequently start to present their solutions and ideas concerning the problem or theme to each other through sketches or discussions. The strength of brainstorming is that the participants can spur each other, building on each other's ideas. Important to keep in mind is that no critique, positive or negative, should be presented in order to maintain a creative process. The ideas and solutions are evaluated at a later stage. (Österlin, 2010)

Brainwriting

Brainwriting (or *6-3-5 brainwriting)* is an ideation method. First, every participant sits down and write/sketch their ideas on their own paper sheet. After a set time, participants switch paper sheets, get inspired by the already documented ideas and continue building on the idea(s). It's also allowed to come up with totally new ideas unrelated to those the previous participant documented. The purpose of brainwriting is to make the participant able to ideate together with other participants without risking their own ideas to be overshadowed by the ideas of other participants. (Österlin, 2010)

Six Thinking Hats

Depending on mood or personality, product developers can easily get stuck and focus on one or few perspectives of the problem. *Six Thinking Hats* is a method, developed by Edward de Bono (2000), that helps developers to maintain a broad mind by imagining the thinking into "roles". Each role is assigned a colored hat that represent one mindset and perspective:

- **White hat** – focuses on facts and information. Poses the question "what do we know?" but also "what do we need to find out?".

- **Black hat** – focuses on the difficulties. Poses the question "what are the problems?".

- **Red hat** – focuses on feelings and intuition. Poses the question "what do we want?" and "what do we believe in?".

- **Green hat** – focuses on the possibilities and alternatives. Poses the questions "how do we improve this solution?" and "can we think the other way around?".

- **Yellow hat** – focuses on the benefits. Poses the questions "what's good?".

- **Blue hat** – focuses on the development process. Poses the questions "what's the purpose of doing this?" and "how do we move on?".

Six thinking hats presents a systematic way of thinking that inspires innovation. The method increases the amount of ideas and cooperation by keeping an open mind and attacking counterproductive behaviorism (Wikberg Nilsson, Ericson & Törlind, 2015).

Prototyping

Prototyping is in many cases a central part of the product development as it is a method of visualization, evaluation and validation of concepts. A prototype is a physical externalization of a concept or an idea. There are many kinds of prototypes. Relevant examples are listed below:

- **Principle prototype –** are made to evaluate and/or validate a specific aspect or function.

- **Visual prototype** – are made to explore and evaluate the physical aspects e.g. form. Also called *mock-up*.

- **Functional prototypes** – are made to evaluate and/or validate technical functions. These kind of prototypes are usually more advanced than principle and visual prototypes.

Apart from evaluation and validation, prototypes are excellent as communication mediums between developers and with other stakeholders. (Bligård, 2015)

Persona

A *persona* is a detailed description of a fictive user that represent the target group of the product or service of interest. The persona aims to help product developers keep focus on a user-centered development process. The persona should be created after a good amount of user studies in order to avoid non-substantial stereotypes. (Aldin & Pruitt, 2010)

Persona Artifact Board

A *persona artifact board* is a collage of three pictures: one representing the persona characteristics, one about their style, values and attitudes, and lastly one describing their desired experience with the product of interest (Wikström, 2012). The board acts as a support for developers to get an idea of who the target group(s) of interest are, and thus, keep a user-centered mindset.

Expression Board/Moodboard

An *expression board* is a collage of pictures that altogether visualize and mediate the desired product expression. The pictures symbolize *material*, *color*, *form*, *metaphor* and *artifact* that the product in development is supposed to relate to. The expression board also suits as a source of inspiration in the development process. A *moodboard* is similar to an expression board, but does not necessarily refer to those specific five themes. (Wikström, 2012)

Expression Association Web

An *expression association web* is a constellation of six adjectives that the product in development should express. There's a main adjective, which expresses the character of the persona. The other five adjectives should describe the desired expression of the product and relate to the categories of *objective/measurable*, *aesthetics, social values, emotions* and *interface/use* – one adjective per category. An adjective could also act as a support/explanation of an another adjective, opening up the possibilities to have more than five product expression describing words. (Wikström, 2012)

D. EVALUATION

The detailed constructions of ideas on how to solve one or several problems that are found in user studies (concepts) need to be systematically evaluated in order to make decisions and choose which concept(s) to pursue with.

PUGH Matrix

A *Pugh matrix* is used to evaluate how well concepts fulfill a list of requirements. The concepts are judged in relation to a reference (which can be one of the concepts or an already existing product). If a concept is better than the reference at fulfilling one requirement, it gets one plus. If it's equally good it gets zero and minus if it's less good. The scores for each concept is summarized and the total scores are compared to the score of the reference (which is zero). If the score is positive, the concept is better than the reference. (Johannesson, Persson & Pettersson. 2013)

04.

APPROACH

The overall process is described in this chapter, followed by a detailed approach to each phase of the project.

A. THE OVERALL PROCESS

The process used in the project follows Lars-Ola Bligård's (2015) development process from a human-machine perspective, the *ACD³* method. The method is based on the belief that product development is an iterative process between the following design levels: need finding, design of use, overall design, detailed design, structural design, production and commissioning. On every design level, planning, data collection, evaluation and documentation support the process (see Figure 2). Therefore, ideation was made throughout the project and insights about users and cleaning were continuously elicited.

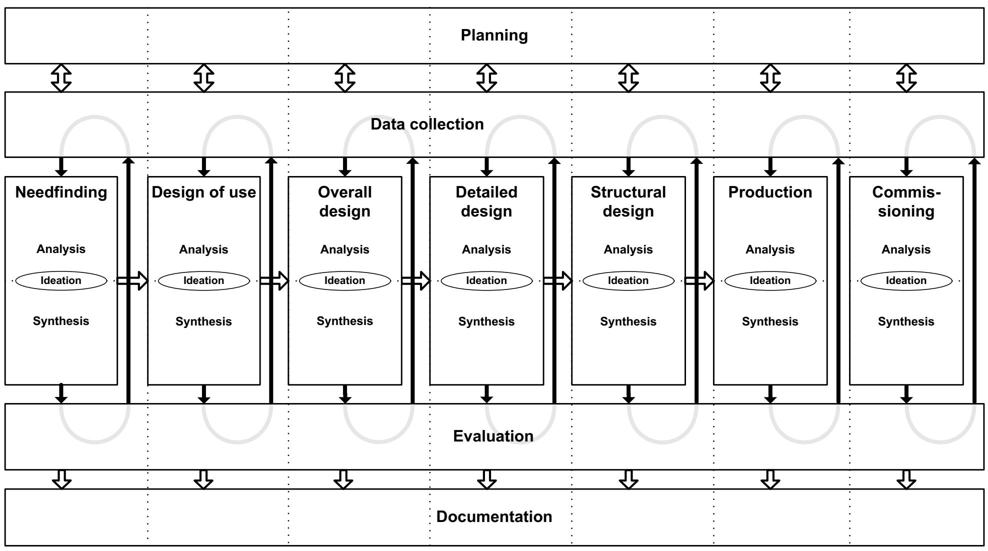


Figure 2
Illustration of the iterative structure of the ACD3-process.
(Source: Bligård, 2015)

The framework of ACD³ is built upon three dimensions: *design activities*, *design levels* and *design perspectives*. The correlation between these are described by the matrix model in Figure 3. Any "box" in the matrix (which are the design activities) can at any time be processed and dealt with in the product development. However, the boxes must be closed in a certain order: from left to right, and from top to bottom.

Design perspectives \ Design levels	Effect	Use	Architecture	Interaction	Elements
Problem	Main problem	Use problem	Architecture problem	Interaction problem	Element problems
Structure	Users, stakeholders and context	Human-machine system	Logical architecture machine	Detailed subdivision machine	Logical architecture elements
Function	Capabilities and values	System functions	Machine functions	Control and information	Element functions
Activity	Intended use	User tasks	Overall interaction	Detailed interaction	Machine process
Realization	Possibilites and limitations	Technical principle och introduction	Overall design	Physical form and interfaces	Implementation elements

Figure 3
Matrix model of the dimensions of ACD3.
(Source: Bligård, 2015)

The amount of design activities that are processed in a project is dependent on the purpose and goal of the project.

An innovation-driven design process requires information processing on a high level of abstraction in order to find ground-breaking insights and radical solutions. Consequently, the project was by large an iterative process between the *effect* and *use* levels, which naturally led the project into several shifts of focus that are referred to as *the five phases*:

- **Phase 1** – Let's Get Dirty.
- **Phase 2** – The Vacuum Cleaner Sucks – or Does it?
- **Phase 3** – Stick to the Stick
- **Phase 4** – Dust in the Air
- **Phase 5** – Say Hello to Halo!

After each phase, the project either diverged into a vast, explorative study or converged into a focused investigation of a certain subject, as visualized in Figure 4.

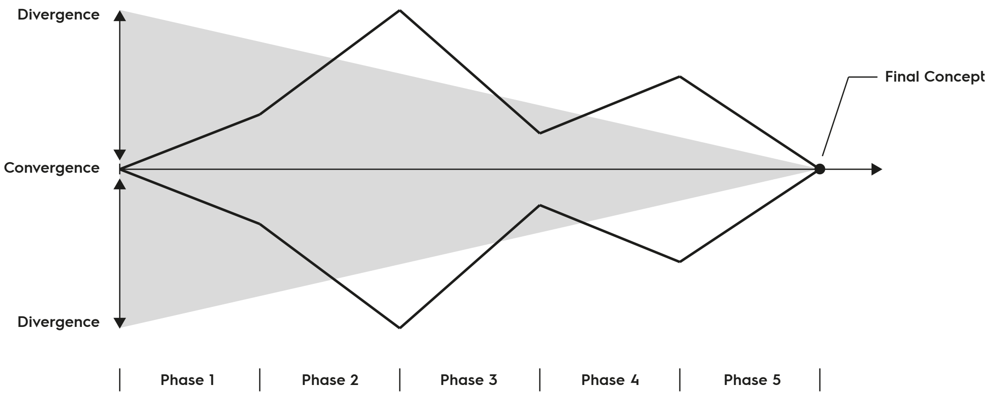


Figure 4
The convergent and divergent phases of the project. The gray area represents the funnel commonly known as the "product development funnel".

The approach of each phase is presented in the following sections.

B. PHASE 1

The first phase was all about understanding the user, the dirt, the cleaning tools and the context. The approach in this phase was mainly conduction of interviews and observations of people that clean. A survey regarding people's opinions on different types of vacuum cleaners was made. The data was analyzed and created a foundation for e.g. the system model, capabilities model and persona.

Purpose and Goal

The purpose of phase 1 was to create a foundation for the project that aids into a user-centered approach in the development process. Furthermore, the purpose was to be able to choose an approach for the next phase of the development process.

The goal was to gather knowledge and create an understanding for the subjects of interest – the dirt, the cleaning tools, the contexts and the users.

Categorization of Dirt

Dirt is the reason for cleaning equipment to exist at all, and the main function of cleaning equipment is, of course, to remove one or many types of dirt. Numerous types of dirt were listed during a brainstorming session. Pictures of homes and dirt in combination with different real life scenarios that produce dirt were used as mediating objects to generate a comprehensive list of dirt types. The different types of dirt were analyzed in terms of the following aspects:

- Size
- State of matter
- Source
- Spread rate
- Weight
- Accumulation time
- Commonality

An affinity diagram of the data was made, which generated categories of dirt. The categories were further analyzed in terms of development and transformation over time but also in terms of the way they travel (e.g. through air).

Mapping of the Current Human-Machine System

The current human-machine system was mapped out to understand the existing components, their functions and the relations between them. The components were divided into *equipment, spaces and activities,* and *users*.

Equipment, Spaces and Activities in the Current System

The following brainstorming sessions were carried out in order to understand every aspect and component of cleaning:

- What types of rooms exist in most homes?
- What types of interior, interior decorations and other surfaces are cleaned in each room?
- What types of surface finishes exist?
- What cleaning activities exist (e.g. vacuuming, dusting)?
- What are the most common pieces of cleaning equipment?

Further barnstorming and market research was carried out to list all categories of existing consumer vacuum cleaners. The most common types of cleaning equipment and vacuum cleaners were chosen for further analysis.

The outcome was analyzed in matrices to map out the following compatibility relations:

- Types of surfaces related to cleaning activities
- Cleaning equipment related to dirt categories

Users in the Current System

The users were listed according to Janhager's (2005) user types; primary users, secondary users, co-users and side users. The users were furthermore defined by specifying properties that could affect cleaning itself or just the image of cleaning:

- Age categories
- Disabilities
- Lifestyles
- Homes

Current System Model

The equipment and the users were visualized in a system model according to traditional systems theory to understand the relations between them and how those could be changed.

Function Analysis of Current Vacuum Cleaners

The most common types of vacuum cleaners were analyzed in terms of functions. An Electrolux UltraOne canister vacuum cleaner, an Electrolux Precision BRC upright vacuum cleaner, an Electrolux UltraPower stick vacuum cleaner and a Miele Scout RX1 were subjects of the analysis (see Figure 5). The elicited functions were categorized into higher level categories of functions by creating an affinity diagram. Those categories were further developed into a cleaning capabilities model. A list of user values affecting the design of clean keeping equipment was furthermore developed using the lower level supporting functions.

Figure 5
Function analysis of Electrolux UltraOne, Electrolux Precision BRC, Electrolux UltraPower and Miele Scout RX1.

Capabilities of Clean Keeping Equipment

The description of the current system, its components and their functions was used to create model of the top-level capabilities required from any piece of clean keeping equipment. The model was created using Bligård's (2015) theory of functions on several design levels; in this case, the effect level.

Current vacuum cleaners and other pieces of cleaning equipment were analyzed according to the capabilities model to compare what functions they fulfill, and to what extent.

Initial Studies

Vacuum cleaner tests and retail store visits were used to create a foundation of data for the forthcoming user studies.

Vacuum Cleaner Tests

A considerable amount of vacuum cleaners from the most common vacuum cleaner categories were tested on different surfaces in different contexts using participatory observations. The main goal was to find general advantages and disadvantages that could be used as input for further studies.

Buying and Selling Experience Study

Six vacuum cleaner retail stores were visited to understand the buying and selling experience. The following aspects were covered:

- Assortment of vacuum cleaners and vacuum cleaner categories
- The way vacuum cleaners are displayed
- Trying vacuum cleaners in-store
- Guidance from a sales person

User Studies

A survey, interviews and observations were conducted to elicit opinions from users but also cleaning behaviors and emotions in relation to cleaning.

Survey

Semantic scales were developed based on the findings from the vacuum cleaner tests and reviews. A small pilot study was conducted to evaluate the validity of the scales. Six participants were asked to name five words they associated with different vacuum cleaner categories and five properties the wanted a vacuum cleaner to have. The survey was then adjusted to include the same open questions as the pilot study since several new aspects emerged. Over 60 people answered the final online survey. All of the questions and responses can be found in Appendix 1.

The data was cross-analyzed using two methods: affinity diagram and word count analysis. The categories found in the affinity diagram were compared between the different vacuum cleaner categories. The results were further compared to the most named words to give a better understanding of the importance of each aspect.

Interviews

Interviews were conducted to further develop an understanding of the results of the survey but also other aspects of cleaning. The main focus was on experience and emotions. Answers on emotions were elicited using Kansei engineering inspired questionnaire including a variety of both pleasant and unpleasant emotions. Nine people in different age categories participated, one of whom was a previous professional cleaner. The interviews were structured and covered the following topics (the full interview guide can be found in Appendix 2):

- Lifestyle
- Dirt
- Cleaning and cleaning behavior
- Vacuum cleaners and other pieces of cleaning equipment

The data from the interviews were compared to the survey by compilation into matrices. The analysis was focused on finding the underlying reasons to arisen issues. Furthermore, the data was analyzed in terms of user experience by categorization into Jordan's pleasure model (Jordan, 2000). Answers on emotions were also numerically analyzed. Lastly, a description of different lifestyles and cleaning behaviors was developed.

Observations

Observations were used to elicit immediate reactions to the use of different vacuum cleaners. Eight people, one with professional cleaning experience, were asked to use a stick and a canister vacuum cleaner in a fully furnished room. The participants were free to use the vacuum cleaners in whatever way they wanted. Reactions and comments were noted and noteworthy events were photographed.

Self-observations

A total of 6 self-observations (two people, three occasions) were used to understand the issues of cleaning in the real cleaning context at home. The entire cleaning sessions were self-observed with special focus on vacuum cleaning, effort, emotions and experience. The thoughts were discussed in detail afterwards and related to the findings from previous studies. The same method was used to evaluate concepts throughout the project.

Electrolux Global Vacuuming Survey 2013 Report

The user studies were complemented with data from Electrolux's global vacuuming survey from 2013. The data was used to evaluate the global validity of the studies and to strengthen conclusions regarding:

- Most common vacuum cleaner categories
- Vacuuming frequency and time
- Activities during cleaning
- Storage of vacuum cleaners
- Annoying factors
- Wanted factors
- Emotions

User Journey

After comprehending all results from the surveys, interviews, observations and research, a user journey diagram was produced. The user journey was used to understand what parts of cleaning and the vacuum cleaner life that affect the user most. Several iterations were required to visualize the cyclic nature of cleaning.

Trend analyses

Trends were analyzed in the areas of vacuum cleaners, product evolution, emerging technologies, and users and homes in order to understand opportunities and requirements for the future and heritage from the past.

Vacuum Cleaner History

To deviate from what has been, an understanding of the history of a product was necessary. The history of the vacuum cleaner was analyzed by picture research. Vacuum cleaners from different time eras were compared and a timeline of evolution was created. The timeline was later compared to the evolution of other products.

Evolution in Other Different Product Categories

Completely other products' evolutions were analyzed to find trends in products but also in peoples' lives and lifestyles. Products that many people find completely necessary in their lives were used:

- TVs
- Computers
- Phones
- Watches
- Picture sharing services

Key paradigm shifts and what brought them to life were identified and related to how they changed peoples' lives. The evolutions of the different products were compared to the evolution of the vacuum cleaner.

Emerging Technologies

Research on technologies that are emerging at the moment was used as inspiration to find new technical principles as solutions to the issues found in the user studies. It was furthermore used to understand what other products will be like in the future and therefore how a clean keeping device might fit into such a future.

Users and Homes

A future device has to fit into future homes and user lifestyles. The answers from the user studies were used to find differences between ages categories and a persona was created. The focus of the persona was to represent the future target group of clean keeping devices. A persona artifact board was used to describe the character of such a target group.

Homes and home interiors were further analyzed by picture and trend search to understand what future homes might look like. Three persona apartment boards were created to describe the contexts of future kitchens, living rooms and bed rooms. The persona apartment boards were further used as a tool of evaluation throughout the project.

Since automation is an increasing part of our lives, a discussion and analysis was carried out to understand how homes and lives could be affected by home automation and robotics if taken to their extreme. The analysis was yet another way to make sure that future devices will be compatible with each other and our lifestyles.

Electrolux Brand Analysis

As part of the overall market analysis, the Electrolux brand and product range was analyzed to find gaps in the market and therefore opportunities for new products. Furthermore, the product range in the clean keeping area was listed. An overall SWOT analysis was performed to find areas that need improvement and opportunities to innovate.

C. PHASE 2

Phase 2 was an explorative phase that diverged from the conclusions from the user studies in phase 1. Brainstorming and ideation were the main approaches for exploring the design space of possible solutions to the found issues. A workshop was conducted in order to collect ideas and standpoints from Electrolux. The ideas were evaluated and analyzed.

Purpose and Goal

The purpose of phase 2 was, with the user studies from phase 1 in mind, to explore the vast landscape of possibilities to create new and better experiences connected to cleaning. Moreover, the purpose was to gain high-level insights concerning vacuum cleaners and clean keeping.

The goal was to meet the desired *effect*, which was formulated as *"creating a better experience by solving the individual problems found in phase 1, and by amplifying pleasurable experiences"*.

Brainstorming Session on Possible Improvements

What are the areas of improvement in the human-machine system when it comes to cleaning? With the user studies as help, various ways of improving cleaning on the *effect* and *use* levels of ACD[3] (see Figure 3) were listed. The goal was to use it as a guide for the coming ideation session(s).

Ideation Sessions

With the help of the list on possible areas of improvement, an ideation session on *technical principles* was conducted. The outcome of the session (raw sketches on what technical principles exist that could help keeping the home clean) would subsequently serve as inspiration to another sketch session: ideation of *clean keeping products*. The second ideation session was conducted to find specific solutions to either a specific problem or to several problems that were found in the user studies.

Exploration of Proactive and Reactive Cleaning

In order to cover the whole design space of cleaning, *proactive* and *reactive* clean keeping were explored and categorized. How can the dirt be taken care of at its *source*? Can the dirt be caught in its *travel*? Or at its final *destination*? Already existing cleaning tools were also analyzed by its *proactivity* and/or *reactivity* in order to be able to compare to the new ideas and solutions.

Inspiration from Other's Ways of Thinking

Different companies have different ways of viewing the world and thus solving problems. An inspirational session was conducted, in which creative thoughts on how companies would have solved the problems of clean keeping. The brainstorming/ideation process was based on the question *"What if [company name] would've made clean keeping products?"*. In addition, an ideation session on what clean keeping would have been like if it resembled a certain activity/product category was conducted. The posed question was *"What if cleaning was like [e.g. watching a movie]?"*. The general purpose of these activities was to explore and get inspired by other's way of thinking.

Exploration of Interfaces

The *product interface* is the way of interaction that occurs between the user and the product during use. The interface of e.g. a vacuum cleaner consists of pulling its head back and forth on the ground.

In order to make sure ideas on high level of innovation were conducted, an alteration in the *effect* and *usage* of today's clean keeping is required. A change of interface would most likely result in such radical change. Thus, new interfaces were explored by ideation sketch sessions and discussions. The new interfaces were focused on floor care, but other surfaces than the floor were also considered. The question *"How would you clean in a dream world?"* was posed in order to support the creative process and to find intuitive solutions to clean keeping.

Workshop

In order to coordinate the project, a workshop with the partner Electrolux was conducted at their headquarters. Findings from the user studies, ideas and various insights were presented for a group of 7 people from their development teams (marketing, design and mechanical engineering). In addition, several "creative sessions" were conducted with the participants. The sessions were ideations based on three questions:

- "In a dream world, how would you keep your home clean from dirt?".
- "In what ways can you make a cleaning tool: easier, simpler, more capable, create a better experience?".
- "What could a new interface look like? Think of new ways of interacting with a cleaning tool!".

The workshop was conducted with de Bono's *Six Thinking Hats* as a basis in order to ensure a variety of opinions in the evaluation process. Throughout the workshop, comments and opinions from the participants were documented, as well as their ideas and thoughts.

Prior to the workshop, a *pilot workshop* was conducted with two participants. The purpose was to evaluate the set-up and process of the Electrolux workshop before conducting it.

Further Vacuum Cleaner Tests

The Electrolux Ergorapido (stick vacuum cleaner), Electrolux One (bagged canister vacuum cleaner) and a regular microfiber cloth were evaluated and compared in an extensive use test with one of the thesis authors with non-professional experience of clean keeping. The tests were of the participatory observation nature, conducted in a workplace environment and included cleaning of following surfaces:

- Hard floor, open area
- Hard floor, beneath tables & chairs
- Hard floor, beneath drawers, ~25 cm gap
- Plastic shelf in kitchen, ~140 cm above floor height
- Interior decorations, ~140 cm above floor height
- Wooden surface, ~90 cm above floor height
- Metallic, angled surface, ~90 cm above floor height
- Windowsill in stone, ~80 cm above floor height
- Window frame, between ~80 cm and ~190 cm above floor height

The observations were video recorded and the participant was encouraged to speak freely regarding emotions and general thoughts during the test. The video recordings were complemented with an unstructured interview afterwards. The purpose of the test was to shine light upon the pros and cons of each cleaning tool and their compatibility with different types of surfaces.

D. PHASE 3

Phase 3 was the mid-point of the project. By further studying the vacuum cleaner, and especially the stick vacuum cleaner, important conclusions could be drawn about the future of the vacuum cleaner and thus, the project could converge into a specific direction. The approach of this phase was to further evaluate the functions of the vacuum cleaner, to conduct literature studies, to analyze the semantics of the stick vacuum cleaner and also to figure out the desired expression of a product that's visible in homes. An expression board and an expression association web were made, followed by translation of the expressions to actual design cues. At this stage, it was discovered that the project could move forward in two different directions.

Purpose and Goal

The purpose of phase 3 was, with the insights gained from phase 2, to investigate what the future of clean keeping holds for vacuum cleaners. Furthermore, the purpose was to be able to choose a future direction for the project.

The goal was to decide whether to proceed with vacuum cleaner development, or to deal with other clean keeping strategies or devices.

Further Investigation of the Vacuum Cleaner's Functions

Further analysis of the vacuum cleaner was made by mapping out and analyzing the add-on functions of the vacuum cleaner. To put the complexity of the problem into perspective, the vacuum cleaner was compared with the television remote control, since both products categories have witnessed a similar evolution of function adding.

Study of the European Commission's Regulations Regarding Vacuum Cleaners

By studying the European regulations regarding effectiveness and efficiency, the user's standards regarding what good dust pick-up really is could be mapped out and understood from an objective view.

Comparison of Sticks and Canisters

Stick vacuum cleaners and canister vacuum cleaners were compared with regard to dust pick-up, re-emissions, people's opinions and also the use on open floor areas and other surfaces. The dust pick-up and re-emission data for the vacuum cleaners was collected from various sources, while the previous user studies supported as basis for the comparison of people's opinions and the use on open floor areas and other surfaces. Products of interest for the comparison were Electrolux UltraPower ZB5022, Bosch Athlet BCH6256N1, AEG AE7810 and Bosch BGL32400 (see Figure 6).

The purpose of the comparison was to investigate the actual difference between the stick and the canister.

Figure 6
Dust pick-up and re-emission comparison between AEG AE7810 and Electrolux UltraPower, and between Bosch BGL32400 and Bosch Athlet.

Further Investigation of the Stick's Issues and Solutions to Those Issues

The result of the stick and canister comparison led to further investigation of the stick's issues. Semantic properties of the Electrolux Ergorapido were analyzed by interviewing users. The posed questions were:

- What is not good with the stick?
- Why do you think the stick is ineffective?
- What about the design makes it look ineffective?

The data from the interviews were compared to the initial online survey in order to get the bigger picture of the problem. The negative factors that people expressed were listed and explained. A brief ideation on how to improve the problems areas was conducted.

Development of a New Expression

The development of a new expressions was motivated by the need to explore how the stick can be improved. Thus, an expression board and expression association web were created in order to visualize the desired expression of a clean keeping product that is visible in a home. The expressions were translated into concrete design cues.

E. PHASE 4

In phase 4, the project proceeded once again into a divergent phase of explorative studies and investigation. Surfaces that the new product(s) should assist the user to clean were found and discussed. To gain more ideas on how these surfaces can be kept clean, a workshop with users was conducted. Biomimicry research on how clean keeping is done in the nature was conducted as an attempt to get inspired by smart solutions. Ideas turned into prototypes and an expert in fluid dynamics was consulted as the feasibility of the ideas were evaluated. The process of prototyping, evaluating tests and validating ideas was iterative and kept going until three substantial concepts were obtained. An evaluation of the concepts was done by conducting interviews and making Pugh matrices in order to select the concept with most potential.

Purpose and Goal

The purpose of phase 4 was to explore the possibilities of creating a mesh of devices that eases and simplifies clean keeping.

The goal was to develop concepts that complement the vacuum cleaner in clean keeping.

Definition and Analysis of Problem Areas

The found problem areas were further analyzed with already conducted interviews as basis. What did people clean? What did people think was difficult to clean? Why? The participatory observations that had been made in beforehand also created a basis for this analysis.

The breakdown of problem surfaces/areas were categorized into two main home areas. Deeper analyses of how these home areas *today* are kept clean were made by below methods:

- **Hierarchical Task Analysis (HTA)** – used to understand the detailed process and subtasks of clean keeping. The HTA:s were made with the interviews and participatory observations as a basis.

- **Use Case** – homes look different and people have different tools, different kinds of dirt and different objects to clean, creating a complexity in the system that is very well framed by this method. Pre-conditions, the normal course, the alternative courses, post-conditions and also exceptions were defined for two cases.

- **Link Analysis (LA)** – by drawing lines on a 2-D sketch of the personas' home, the cleaning routine of today for each home area of interest was mapped out for analysis of the efficiency of the task.

- **REBA/RULA** – the ergonomics of clean keeping of the home areas of interest were analyzed by the REBA and RULA assessment tools in order to gain insights about the severity of the tasks when it comes to physical strain.

The methods served as tools to limit the solution space and to highlight the problems that needed to be solved.

Workshop

Various ideation sessions had been conducted, leading to a saturation in the idea space. But there was a need for more ideas concerning the found problem surfaces/areas. Thus, an ideation workshop was conducted with the target group. Thus, the participants consisted of 6 people between 24 and 30 years old. The structure of the workshop was based on the 6-3-5 brainwriting method and was proceeded as follows:

1. The moderators explained the theme of the workshop. The theme was the two problem areas and how we can clean these areas in e.g. an efficient way, in an ergonomically better way than today, in a fun way etc.

2. The participants started brainwriting their ideas on how to clean in the first problem area. This was the first session. The participants were assigned 5 minutes for each "round". The participants were told to sketch/write 3 concepts during each round. Each session consisted of five rounds i.e. four "rotations" of papers.

3. When swapping papers with each other, the participants were assigned max 1 min to explain their ideas to each other – if they thought it was necessary.

4. The same process was applied for the brainwriting on how to clean in the second problem area.

The duration of the workshop was approximately 1 hour. In total, 144 ideas were gained from the workshop. The found ideas were then evaluated by the workshop moderators and brought into later concept development as an inspirational source.

Inspiration from Biomimicry

Turning to nature in order to find inspiration in the product development is called *biomimicry* and was performed by research on the web. A TED talk by Janine Benyus with the subject *Biomimicry in action* was studied (Benyus, 2009). The search engine asknature.org by The Biomimicry Institute in Montana, U.S. was used in order to search for *cleaning* and find information about how nature cleans, but also information about other products that has been inspired by nature's way of cleaning.

Tests, Prototyping and Evaluations of Technical Principles

Many ideas were collected throughout the project by various ideation sessions and workshops. The interesting ones were of course not full-fledged concepts that the authors of the thesis knew would work. Thus, in order to evaluate and test the ideas, a prototyping process was initiated.

How Does Blowing and Suction Work?

Technical principles were tested a d evaluated. A computer fan (Velleman BLS12/120), a 2300 W blow dryer (Babyliss 6614DE) and a high-pressure air-can (CRC Dust Off) were obtained as sources of blowing for the prototypes, see Figure 7. These devices covered a vast range in blowing effectiveness. As a source for suction, a vacuum cleaner (Electrolux ZSPC2010) was used.

Figure 7
Blowing and suction devices used for prototyping.

Figure 8
Materials used to create different nozzles – add-on nozzle included with the blow dryer, straws and PVC pipes in different sizes.

The blowing and suction devices were built in to the prototypes. The prototypes were made of foam board, PVC pipes, many straws and a lot of gaffer's tape.

So what was tested with the prototypes? First and foremost, the *effectiveness* of the blowing. How effective should it be in order to move dust in a desired way? The jet was also separated into many smaller jets by straws in order to investigate how smaller "rays of blowing" affect the dirt. To investigate spread blowing and concentrated blowing, directed vs non-directed jets were investigated with different nozzles (one nozzle consisting of many straws directed towards one direction, one nozzle consisting of many straws in different directions and one nozzle being a long PVC pipe with holes). The material used for creating the nozzles are shown in Figure 8.

The combination of suction and blowing was interesting to investigate as well. Is it possible to release dust by blowing and pick-up the dirt with suction, all in all from the same nozzle? Two plastic pipes were attached to each other, one producing suction and one blowing.

The tests were conducted in the workshop hall at Chalmers University of Technology. The elements in the tests were the prototypes and sawdust on the floor (which was presumed as an acceptable approximation to dust). During some tests, pieces of lightweight paper were the elements used as dust approximation. The procedure of the tests was very simple: the airflows from the prototypes were directed towards the floor where sawdust was placed in a random manner. The influence of the distance between the floor and the nozzle of the prototype was also investigated.

Evaluation with Users

The evaluation of blowing as a technical principle was also made via interviews. Six persons were given a scenario: "Think that it's Saturday and you've recently been eating breakfast. You see that there's dirt beneath the couch and on your shelves." The scenario was concluded with a question that evaluated blowing as a technical principle: "What do you think about blowing in order to remove the dirt?".

The results from the test and the interviews were documented and analyzed.

Concept Generation

Ideas from the workshops, learnings from the test, insights from the user studies and other ideas documented throughout the project aided as support for the coming concept generation. Four principles for clean keeping devices had been developed earlier and were used as guidance in the selection of ideas that showed good potential. An ideation session was carried out in order to bridge the ideas into constructive concepts.

The concept generation aimed to create concept(s) that showcase improvement in *effects* and *use*, and partly *architecture* rather than detailed *interaction* and *elements* of the product. The generated concepts were brought into further testing and evaluation.

Tests, Prototyping and Evaluations of Concepts

The concepts from the concept generation had to be validated and evaluated. *Do they work? And how effective are they?* In order to answer those questions, functional mock-ups were built in wood, foam board, plastic pipes, straws, gaffer's tape, vacuum cleaners and blowing devices.

In order to increase the validity of the test, the mock-ups were tested on surfaces similar to the ones that they are meant to work on. The dirt used in the tests was actual dirt that was collected from a vacuum cleaner.

The mock-ups were altered several times in-between the tests in order to reach a desired effect. Some of the questions that arose during the tests were:

- Can we control the flow of the air and keep it laminar?
- Is dirt spread in the air when blowing? If yes, how much?
- How much of the dirt is actually removed from the surface/area?
- Is it possible to catch the blown dirt on "the other side" of the blowing device?

The result from the tests were documented by photos, video recordings and notes.

Consultation

Some of the result from the test were difficult to comprehend and to elaborate on. In order to gain understanding of the results and get some inspiration on how to proceed, fluid dynamics expert and senior lecturer Niklas Andersson was consulted.

Investigation of Air Quality

The results of the tests motivated investigation of *air* and *air quality*. Some of the questions posed were:

- What is a good indoor environment?
- How does the dust in the air affect the overall cleanliness in a home?
- What does it look like when dust travels in air?

The two first questions were answered by brainstorming. The last question was investigated by an easy test: a big foam board was used to blow on a window frame. The sunlight through the window makes it possible to witness the dust and how it travels in the air.

Investigation of Perceived Cleanliness

The results from air quality investigation required further investigation with regards to user's experience of cleanliness. What affects the perception of cleanliness? And how is it connected to air quality? A brainstorming session was conducted on that subject. As an inspiration, the Swedish Work Environment Authority's recommendations on indoor air quality were studied. Previously conducted user studies in this project laid a basis for the search for the answers to the above questions.

The functionality of air cleaners was furthermore investigated by literature studies.

Further Concept Generation and Development

The study of air led to questions regarding the usefulness of cleaning products when they're not in the closet. Can it do something while being visible? Can its presence have a value that's not only connected to aesthetics? Further ideation processes, sketching and interviews with colleagues at school were conducted with the above questions as inspiration.

In total, three different concepts were developed – sketched and briefly described. Those concepts were brought into the stage of evaluation.

Evaluation of Concepts

The goal of the evaluation was to end up with one concept, or a combination of concepts, to bring into next phase of the project. The evaluation was performed by mainly two methods: unstructured interviews with users and Pugh matrices.

Interviews

Sketches of the three concepts were shown to six interview persons. These persons were selected with the criteria of being used to home cleaning (but not professional cleaning) and being between 24 and 30 years old (the target group). The interviews were semi-structured and conducted in pairs:

1. The first concept was explained and shown in a sketch.

2. Comments from the interviewees were collected. If their comments were vague, they were asked to further explain their thoughts.

3. Step 1-2 were repeated for the second and third concept.

4. The interviewees got to decide which concept(s) were their favorite(s) and explain why.

Their thoughts were compiled, analyzed and taken into consideration when choosing concept(s) for continued development and concept(s) to scrap.

Pugh Matrices

The three concepts were compared with each other with the help of the Pugh-matrix method. The product of reference was the classical canister vacuum cleaner. The areas of comparison were areas of issues found in the initial user studies:

- Storage
- Size/weight
- Effectiveness/cleaning ability
- Sound
- Versatility/flexibility
- Time/efficiency
- Effort/usability
- Reliability
- Maneuverability/movability/controllability
- Maintenance/service
- Cord/battery/power
- Hygiene
- Ergonomics
- Safety/harm/damage
- Environmental sustainability
- Allergies
- Dirt pick-up

Initially, the above list included *aesthetics/appearance, applications, tube/hose, pets, emotions/expressions, accessories* and *feel/structural design*. However, these areas were removed from the list due to irrelevance at this stage of the product development.

Apart from the above issues listed in bullet points, *user experience* was another aspect of interest. Another Pugh matrix was created with same concepts and same reference, but with user experience issues that were found in the project:

- Actual cleanliness
- Perceived visual cleanliness after cleaning session
- Perceived olfactory cleanliness after cleaning session
- Perceived haptic cleanliness after cleaning session
- Feedback when cleaning
- Minimal interference with primary user's other activities while cleaning
- Minimal disturbance of side users
- Mental obstacle in preparation
- Mental demand while cleaning
- Overall cleanliness over time

The result from the Pugh matrices presented which concept(s) that were the best within each area/issue and also the overall best concept.

Choice of concept

The interviews, the result from the Pugh matrices and insights gained throughout the project served as a basis for the selection of concept to develop further.

F. PHASE 5

Phase 5 was the final phase of the project. The phase was dedicated to the development of the chosen concept. The phase was of the convergent nature as it moved towards concretization of the final concept. A new system model was presented. The concept gained additional value as useful functions were applied. The functionality of the concept was further investigated by exploring blown air and how it behaves on surfaces. When the functions of the concept were determined, a function allocation was made. An investigation of potential components in the concept was conducted, followed by a thorough form evolution. Finally, the concept was visualized in CAD and evaluated towards physical ergonomics, design principles, semiotics, user experience and realizability.

Purpose and Goal

The purpose of phase 5 was to further develop and finalize the chosen concept on the *effect, use* and partly *architecture* levels of the ACD^3 framework.

The goal was to deliver the proposed future of cleaning. CAD renderings and a description of the concept were the main deliverables.

A New System Model

How does the final concept relate to its context? A new system model that includes the concept was needed to be formulated and illustrated in order to define how the system is planned to work. The system model included power (which was either human force or electricity), matter (dirt) and information.

Adding Value

The final concept was further developed by investigating possibilities of adding other values than the main function to the concept.

The approach for tackling this issue was to ideate on possible new uses. Inspiration was gained from various other brands and products. Important to bear in mind during the process was to not force a function into the concept unrelated to its general intended use. The goal was to keep focus on doing one thing great.

Taking Advantage of Blowing?

Due to the nature of the final concept, additional knowledge about blowing was needed. Thus, additional tests were conducted with below question formulation.

Does blown air bounce or reflect on surfaces? To answer this, the blowing of the 2300 W blow dryer was directed at a large foam board in an approximately one-meter distance. With a piece of string held in the air, the travel of the blown air was evaluated.

Does blowing air from lower height affect dust on a higher height (i.e. shelf)? To answer this, the 2300 W blow dryer was held 30 cm above floor, directed in a 60° angle from the floor, towards the edge of a 90 cm table while blowing. Some dust and a thread was placed on the surface in a random manner in order to see if the blowing from the blow dryer affected the surface of the table.

From what distance, both horizontally and vertically, is the dust affected by the blowing? Two similar tests of the iterative nature were conducted:

- To evaluate how horizontally directed blown air affect particles, the 2300 W blow dryer was held, slightly angled down, towards the surface of a table. The table was at first placed 9 m away from the blow dryer and was moved closer and closer (one meter per move) to the blow dryer until all of the dirt on the table was blown away. The amount of dirt removed at each table position was documented using video recorder.

- To evaluate how vertically directed blown air affect particles, the 2300 W blow dryer was held vertically, 2.4 m above a table (which is the general roof height). The purpose of the test was to evaluate how a roof mounted fan can affect dust on a surface (i.e. table), so instead of moving the blow dryer closer to the table, the table was moved away from the blow dryer (0.5 m per move). Since the blow dryer's airflow is very directed, the blow dryer was throughout the test directed towards the table.

The results from the tests were used as a basis for the continued development of the chosen concept8.

Function Allocation

At this stage, after adding value and exploring how blowing should be implemented, the functions that the final concept was set to have were allocated between the components of the system.

Components

Existing products were used as guidance when choosing components for the final concept. A mix of ideation and component research was made. Due to the scope of the project, a detailed component listing was not considered applicable as it would be outdated in 5-10 years.

Form Evolution

To make sure that the concept fits into any home, a thorough form evolution process was conducted.

Supporting Material

The *personas*, the *persona artifact board*, the *persona apartment board*, the *expression board* and the *expression association web* were used in the form evolution process as support for the various decision-makings in the process that were related to product aesthetics.

The Ones Who Inspired

Product aesthetics influence the acceptance of the product into the user's home. To tackle acceptance of the concept, companies that had been taken on similar issues were used as sources of inspiration.
Thus, the home entertainment company *Bang & Olufsen* and the home automation company *Nest* acted as inspirational sources in this phase of the project. Bang & Olufsen have throughout the years made products that fits beautifully into the home interior. Nest aims to make products that people must have visible in their home but normally don't want to (e.g. smoke detector) into beautiful and useful products that make people want to have visible in their homes. Today, clean keeping products are in the same category as the smoke detector.

The Process

The form evolution process of the final concept was mainly restricted to two dimensions. Thus, the process was split into two parts: front view shape design and side view shape design. A similar procedure was applied in both cases:

1. **Ideation session on different shapes:**

   a. Sketching and discussion were the main tools for the form exploration.
   b. Products from companies mentioned in previous section functioned as inspirational material on how to make beautiful products that are visible in people's homes.
   c. Expression board, expression association web and persona apartment board were used as inspiration and aiding tools to design a product that conveys the desired expressions.

2. **Exploration of proportions and size:**

   a. Measurements in a user's apartment were made to get an idea of how big the product can be without feeling obtrusive.
   b. A 2D sketch of humans (man & woman) and different pieces of furniture (shelf, sofa, table, chairs) in correct proportions was made as a template for size exploration. Anthropometrics were applied to get the correct size of a 50^{th} percentile man and 50^{th} percentile woman.
   c. Foam boards were cut into the correct sizes and proportions in order to illustrate the size and form in 2D (this method was only applicable to front view design).
   d. Inspiration from clothes and coat hangers was used. The size of coat hangers was found to be a good starting point. Jackets, shirts and other clothes were tested on the 2D foam boards (this method was only applicable to front view design).

3. **Proposed form design(s) sketched/modeled**

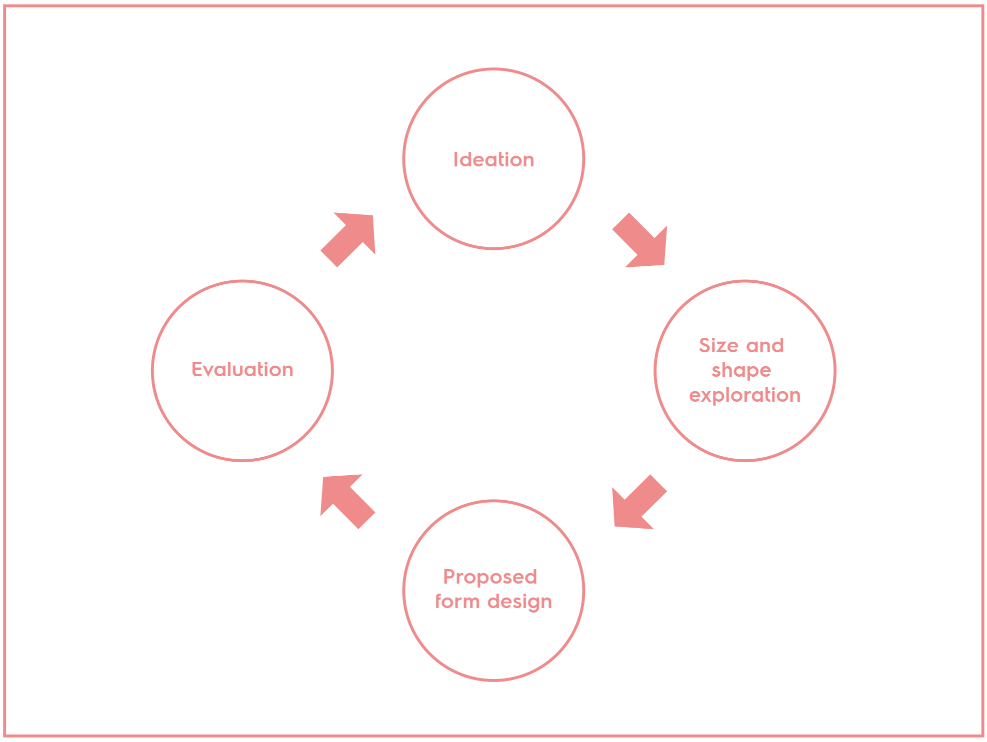


Figure 9
The form evolution process.

4. Evaluation of proposed form design(s) with users:

- **a.** Six users participated in the evaluation sessions of the semantics. The participants were interviewed, often in groups of two in order to create a discussion between them, about what they thought about the size and the shape.
- **b.** When evaluating the size and front view design, the foam board mock-ups were used as mediating objects.
- **c.** When evaluating the side view design, 2D sketches on paper were used.
- **d.** The asked question was simply *"How would you like something like this to be your clean keeping device?"* In most cases, the participants had several options to choose from. Questions were based on the wanted expression and consisted of semantic words. Their motivation for their choices were documented and used in the next iteration of the form design.
- **e.** In the later iteration stages of the form evolution, a semantic scale was used as an evaluation of the expression. The form design that leaned towards the intended expression was chosen in the iteration.

The process was iterative as each evaluation resulted in yet another ideation session, as illustrated in Figure 9. The steps were re-executed until a satisfactory result was reached.

What Should a Robot Look Like?

One of the posed question was whether an autonomous product should look like a robot or not. The problem was tackled by various ideations on good-looking things that move and on technical principles on movement in order to find a shape that is compatible with both stationary characteristics and robotic characteristic. These ideation processes were conducted in tandem with the form evolution process.

Visualization of the Final Concept

The final concept was visualized using the CAD programs Autodesk *Alias Autostudio* and Dassault Systèmes *CATIA V5*. Materials, surface finishes, surface continuities, curvature continuities, etc. were designed at this stage.

Interaction

An ideation session was conducted on the interaction and maintenance of the final concept. The focus was on the motto “the best interface is no interface”.

Evaluation

What are the pros and cons of the final concept? The evaluation included:

- **Physical ergonomics** assessment with the help of REBA.
- Check-off with **design principles** formulated throughout the project.
- **Semiotic** analysis. The expression board and the expression association web were used as comparative material.
- **User Experience** analysis. Jordan’s The Four Pleasures model was the foundation for the evaluation.
- **Realizability** analysis.

Comments from the opponents and other attendees of the presentation of this thesis were considered in the evaluation.

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09.

RESULT AND ANALYSIS »

The results from the five phases of the project are presented in chapters five to nine.

05.

PHASE 1: **LET'S GET DIRTY**

Everyone has, at some point in their lives, been cleaning something. It may have been one's work space, car or bedroom. Cleaning is not rocket science...or is it? *Let's Get Dirty* is about the work behind unfolding the truth behind cleaning and what thoughts that rush through the head of people when they clean. Are there any problems? And if so, what are they? Phase 1 resulted in several insights and models that were later used as a foundation for the rest of the project. This section includes the definition of dirt, a description of the current human-machine system and user insights among other things.

A. WHAT IS DIRT?

Different kinds of dirt are brought to our homes, and thus on the surfaces within it, all the time. For example, we bring sand from outdoors and drop corn flakes on the floor while preparing breakfast. Some of the situations and scenarios that produce dirt are presented below:

- Walking into the home from outdoors
- Making the bed
- Doing laundry
- Cooking
- Eating
- Visiting the bathroom
- Cleaning
- Having an open window
- Pets and humans moving

The brainstorming session regarding dirt resulted in a list of dirt types including everything from foods to particles such as pollen. The entire list can be found in Appendix 3. It was concluded that all types of dirt can be described by the eight clearly distinguishable categories presented in Table 1 below. A complete definition of the dirt categories can be found in Appendix 4.

Table 1
Dirt categories.

	EXAMPLES	SIZE	STATE	SPREAD RATE	COMMONALITY	OTHER
Particles	Dust Pollen Smoke	Small	Dry	High	Common	Airborne Allergenic
Fibers	Hair Fur Spider web	Medium to large	Dry or wet	Medium High	Common	Airborne Allergenic
Bits	Gravel Sand Corn flakes	Small to large	Dry	Low to medium	Common	
Goo	Jam Mud	N/A	Wet	Low	Fairly common	
Liquid	Water Juice	N/A	Wet	Low	Uncommon to common	
Stains	Lime	N/A	Dry	Low	Fairly common to common	
Grease	Oil Body lotion	N/A	Wet	Low to high	Common	Airborne
Bacteria	Bacteria Mold	Very small	Dry or wet	High	Common	Airborne

It was also found that some types of dirt transform between the different categories over time. Some examples are:

- Juice transforms from liquid to goo or even stain when drying
- Particles or bits mixed with liquid transforms into goo

The results of the transformations are however still within the eight categories which is why such transformations were not further investigated in this project.

Another factor that differentiates the dirt categories is to what degree of quickness they are usually removed by the user. Liquids might for example be a result of an accident and are therefore removed immediately. Particles on the other hand accumulate over time and get removed on an intermittent or regular basis. It was found from the interviews that dirt types that affect the user (by for example developing smell over time) are more likely to be removed immediately. Goo, liquid and grease are examples of such types of dirt. They are also far more uncommon than the other categories, which is why the project was primarily focused on particles, fibers and bits.

Furthermore, it was found from the brainstorming session that different types of dirt travel in different ways. Particles, fibers, grease and bacteria can for example all be airborne in some way and therefore easily travel into and within a home, which is why their spread rate is fairly high. Other types of dirt such as bits and liquids require another solid or liquid media to travel and therefore don’t spread as easily.

B. THE COMPONENTS OF CLEANING TODAY

People use slightly different techniques to keep their homes clean from the types of dirt found above. They do however rely on a system that includes the following components:

- Cleaning context
- Cleaning activities
- Cleaning equipment
- Human

The Cleaning Context

All homes, even small ones, include several different rooms. Some examples are vestibule, bathroom, living room, bedroom and kitchen. When listing the interiors of those rooms it was found that most rooms can be grouped into *one* category with similar properties. Only bathrooms and kitchens have additional and completely different properties. The surfaces that need cleaning in each of the three categories are presented in Table 2 below.

Table 2
Surfaces that require cleaning in each category of room.

GENERAL ROOM	BATHROOM	KITCHEN
Floor	Shower (shower cabinet)	Sink
Walls	Basin	Oven
Ceiling	Toilet	Stove
Windows	Mirror	Stovetop
Furniture	Bathtub	Kitchen fan
Skirting	Bathroom floor	Fridge
Cornice		Freezer
Corners		Dishwasher
Surfaces		
Inside cabinets		
Door steps		
Carpets		
Curtains		
Light fixture		
Decorations		
Plants		
Doorframes		
Stairs		
Electronics		

It was found that all of the surfaces presented above can be described with a set of properties to make the description of cleaning more general. The properties are presented below:

- Fixed or non-fixed
- Hardness
- Finish
- Form
- Rotation
- Height
- Size of surrounding space

A skirting can for example be described as a fixed, hard, smooth, flat, horizontal/vertical surface above floor height in open space. That might sound like a much more complicated description, but the same description is applicable for several surfaces in a home, for example cabinets, floors, walls, etc.

The surfaces described above are static, just as the number of rooms and the size of the home. It was found that there are several aspects of the context that are dynamic, during and in-between cleaning sessions. The following factors were found to change dynamically:

- Amount of dirt
- Types of dirt present
- Distribution of dirt
- Number of people and their position
- Objects and clothes, and their position
- Time of day
- Lighting
- Temperature
- Season

All of the factors above were found, based from the interviews, to affect if people can and want to clean. They even affect how people clean. One of the interview participants for example meant that vacuum cleaning has to be excluded in a late evening cleaning session because it would disturb cohabitants and neighbors. Another example is the effect the outside temperature has on whether people keep the windows open during cleaning or not in order to clear the air from dirt.

The Cleaning Activities

Cleaning an entire home requires a whole set of activities. Different activities are for example used when removing water from the kitchen countertop than when removing gravel from the floor. It was found from the interviews that the most common cleaning sessions might include the following activities:

- Vacuuming
- Dusting
- Mopping
- Sweeping
- Window cleaning
- Wiping
- Scrubbing

Vacuuming, dusting and wiping were found to be the most versatile activities.

According to the interviews conducted, vacuuming and dusting/wiping activities are more common than the other ones. They were found to be part of almost every cleaning session among all interviewees, both regular (e.g. weekly) and intermediate sessions (e.g. after an accident). Vacuuming, dusting and wiping were furthermore found to be the most versatile activities. Table 3 shows the cleaning activities compatibility with the different surfaces found in each room.

Table 3
Versatility of different cleaning activities.

	VACUUMING	DUSTING	MOPPING	SWEEPING	WINDOW CLEANING	WIPING	SCRUBBING
				Most rooms			
Floor	•	•	•	•		•	•
Walls		•				•	•
Ceiling	•	•					•
Windows					•		•
Furniture	•	•		•		•	•
Skirting	•	•				•	
Cornice	•	•				•	
Corners	•	•	•	•			
Surface	•	•		•		•	•
Inside cabinets	•	•		•		•	•
Shelves	•	•		•		•	
Door steps	•		•	•			
Carpets	•			•			•
Curtains	•	•		•			
Light fixture		•				•	
Decorations	•	•				•	
Plants		•				•	
Doorframes		•				•	
Electronics	•	•				•	
Stairs	•	•	•			•	•
				Kitchen			
Sink		•				•	•
Oven						•	•
Stove	•	•		•		•	•
Hob	•	•		•		•	•
Kitchen fan		•				•	•
Fridge						•	•
Freezer						•	•
Dishwasher						•	
				Bathroom			
Shower					•	•	•
Basin		•				•	•
Toilet		•				•	•
Mirror		•			•	•	
Bathtub						•	•
Bathroom floor	•		•			•	•

As seen from the table above, vacuuming is usable for most of the surfaces in a home. It is however also clear that vacuum cleaning is not enough on its own. Dusting and wiping were found to be essential parts designated to similar tasks. The user studies showed that mopping, sweeping, window cleaning and scrubbing are parts of more infrequent cleaning sessions, and in those cases as a second layer of cleaning to reach a higher level of cleanliness. The project was therefore focused on vacuuming and dusting/wiping and improvements of those tasks.

The Cleaning Equipment

Each of the found cleaning activities require different pieces of equipment. A full cleaning session might include up to 19 pieces of cleaning equipment:

- Broom
- Dustpan
- Bucket
- Hand feather duster
- Microfiber floor duster
- Mop
- Towel
- Window scraper
- Cloth
- Detergents
- Sponge
- Scrubber
- Water
- Dish-brush
- Vacuum cleaner
- Toilet brush
- Paper
- Fragrance spray
- Canned Air

Vacuum cleaners and cloths were found to be the most common parts of vacuuming and dusting. The user studies furthermore showed that those two pieces of equipment are the most used and liked due to their versatility and effectiveness. The cloth was also found to be compatible with all categories of dirt despite its simplicity. In fact, most tools were found to be compatible with particles and fibers but only a few were found to tackle bacteria. A full analysis of different pieces of equipment's compatibility with different dirt categories can be found in Appendix 5.

Cloths are simplistic but vacuum cleaners exist in many shapes and colors. The research conducted showed that there are at least 12 vacuum cleaner categories in the consumer segment of the market. A description of each category is found below and are illustrated in Figure 10.

Canister

Canisters are in Sweden and other parts of the world the most common types of vacuum cleaners. They consist of a nozzle that is, by a joint, connected to a metallic pipe with a handle. In turn, the handle is by a tube connected to a separate unit that rolls on the floor as the user is cleaning. A motor in the separate unit creates suction that is utilized to transport dirt from the nozzle of the vacuum cleaner into the separate unit via the pipe, handle and tube. The suction goes through a dust bag, in which the dirt is collected. The dust bag is in most cases located inside the separate unit. Apart from the standard bagged canister, there are six other variations:

- **Bagless** - These types of vacuum cleaners are from a use perspective very similar to canisters. The big difference lies in the architecture of these products as a result of the bagless feature. Air is transported in a more complex system ("cyclonic") which gathers the dirt in a container (usually transparent and visible).

- **Water Filter** – These types of vacuum cleaners utilize water instead of cyclonic transportation in order to collect and hold the dust. They do not use bags. Otherwise, they are very similar to canisters in terms of use.

- **Steamer** - By heating water to above 100 degrees Celsius, steamers remove the most difficult grease and stains. Often used in kitchen or bathroom environments.

- **Semi-professional** - Semi-professional vacuum cleaners are very similar to canisters. They are more powerful and also capable of collecting and storing a huge variety of dirt.

- **Backpack** - Comparing backpack vacuum cleaners to canisters, the separate unit is mounted on the back of the user instead of rolling on the floor.

- **Stationary** - Stationary vacuum cleaners are mostly used in professional use contexts, such as in hair salons. The user sweeps the dirt with e.g. a broom to the opening of the stationary vacuum cleaner from which the dirt is collected by suction.

Upright

Popular on the U.S. market, upright vacuum cleaners are similar to stick vacuum cleaners but bulkier and more powerful. Uprights also include a flexible tube, enabling the user to clean other surfaces than only the floor (e.g. skirtings, frames, etc.).

Figure 10
Different types of vacuum cleaners.

Stick

This category of vacuum cleaners differs from the rest. The name hints about the fact that everything is on a stick – the nozzle, the dust holder, the motor, etc. These vacuum cleaners are also in most cases cordless, running on batteries that are charged when positioned in their charging station. Furthermore, many stick vacuum cleaners are in fact handheld vacuum cleaners mounted on a stick with a traditional nozzle, enabling the user to clean surfaces above floor height as well.

Robotic

Being the most advanced among all vacuum cleaner categories, robotic vacuum cleaners clean the floor autonomously, only requiring scheduling or a one button action from the user. These vacuum cleaners normally use brushes to collect dirt.

Central

Central vacuum cleaners utilize pipes installed in the walls of the household to transport dirt. A central unit, usually installed in the basement of the household, collects the dirt by creating suction in all pipes when the user mounts the central vacuum cleaner tube into one of the pipe exits.

Handheld

Being one of the smallest vacuum cleaners on the market, handhelds are specialized to clean smaller surfaces that are above floor height, such as tables and couches. Handhelds are usually divided in two parts – the front part being a bagless dust holder and the back part being a handle. They run on batteries and are sometimes mounted on a stick vacuum cleaner.

As noted above, bagless vacuum cleaners are similar to their bagged counterparts in terms of use and was therefore considered as one category. Based on that assumption, Electrolux's survey showed that canisters are the most common vacuum cleaners worldwide, followed by uprights. Robotics were found in 9% of the households. Canisters, uprights, robotics and sticks were therefore considered in the forthcoming analysis of this project. Sticks seemed far less common but were added to the study because of their similarities to uprights, their simplicity and the fact that they occupy an increasing part of the shelves in supermarkets and stores.

Further analysis showed that canisters, uprights and sticks offer similar capabilities. They can all be used to clean most of the surfaces in different rooms. The robotics were however found to be limited to floor areas and unable to clean stairs for example. A complete analysis of vacuum cleaners' compatibility with different surfaces can be found in Appendix 6.

The Human

Everyone wants a clean home and everyone should be able to clean or get the help to clean. Clean keeping products are therefore excellent examples of products that need to be designed for all. They are not only used by most people; most people are also affected by the them directly or indirectly. The people in Table 4 are the users of clean keeping equipment:

PRIMARY USERS/USES	SECONDARY USERS	CO-USERS	SIDE USERS
People cleaning People emptying vacuum cleaner	Sales people Service people Maintenance people	People cleaning together Kids	Family members Guests Neighbors

Table 4
Users and uses of clean keeping equipment.

As seen in the table above, clean keeping equipment have many users. Secondary users are however not part of the experience while cleaning and were therefore not included in further analysis, neither were other stakeholders such as manufacturers. The user studies showed that cleaning is a teamwork in most 2+ households, which has to be considered when designing new pieces of clean keeping equipment. Side-users were also found to be heavily affected by cleaning, partly during cleaning but also by the results of cleaning.

Based on Kroemer's (2006) aspects of design for all, it was found that several factors might affect the use of clean keeping equipment. Each of the factors are described below.

Age

Adults vary massively in anthropometric measures which affects all sorts of cleaning since surfaces are located on several heights from floor to ceiling. Varying strength and stamina is something that might affect the results but also the time and frequency of cleaning. Kids are at the extreme end in terms of anthropometrics, strength and stamina – they are the smallest, many times weakest but have a lot of stamina. This is an important aspect to consider in the use of clean keeping equipment since the user studies showed that it is desirable to introduce kids to cleaning early. Apart from reduced strength and stamina, elderly might have reduced motor skills, and deteriorated vision and hearing. All of which are factors that make cleaning and the evaluation of cleaning harder. They do however likely have more experience of cleaning. Another factor that results in similar limitations is pregnancy, which also reduces mobility.

Disabilities

Physical and sensory impairments affect both cleaning, evaluation of cleaning and the results of cleaning. Some examples are: reduced gross and fine motor skills, but also vision, hearing, olfactory or somatosensory impairments. Furthermore, diagnoses like asthma and allergies are affected by the cleanliness in a home, which in turn puts high demands on cleaning. It might even make cleaning painful and irritating.

Lifestyles

All people live different lives. Different work hours, hobbies and values. Cleaning has to fit into all of those lifestyles. The user studies for example showed that people clean for different reasons, at different times, with different conditions, etc. Some of the found aspects related to lifestyles are presented in the list below. Lifestyles do however change over time, as the society and technology around us evolve, such changes will be discussed later in this chapter.

- Like cleaning vs like the results of cleaning
- Frequency of cleaning (how often?)
- Regularity of cleaning (routine?)
- Time of day when cleaning
- Planned vs spontaneous cleaning
- Cleaning because it is dirty vs cleaning because it should be done
- Cleaning on spare time vs cleaning during work/studies
- Cleaning on a certain day vs cleaning on any day
- Quick cleaning vs deep cleaning
- Cleaning alone vs cleaning together

Homes

Furthermore, every person lives in a different home in terms of size, type, interior, etc. Trends in homes will also be discussed later in this chapter. Some have pets which might require more cleaning and produce another composition of dirt. Pets also have to be able to coexist with all clean keeping products.

As can be seen above, clean keeping products have to fit into a very complex system of factors. This project was aimed towards enhancing the future experience on clean keeping, which is why special focus was put on factors that affect the effort of clean keeping, such as age, allergies, and lifestyle and home trends.

C. THE CLEANING SYSTEM

The components presented in the previous section and the interactions between them form the system that is keeping our homes clean. The system is described below.

The Cleaning System Model

The cleaning system consists of dirt and feedback being transferred between interior surfaces, human and cleaning equipment. The home constitutes the boundaries of the system through which dirt, power and people travel. The cleaning equipment is represented by the most common pieces; a cloth and a vacuum cleaner. A visualization of the system model is presented in Figure 11.

Diri is spreading to and from every part of the system, even from the cleaning equipment itself.

As can be seen from the system model above, dirt is spreading to and from every part of the system, even from the cleaning equipment itself. It is clear that most of the dirt spreading is actually within the system and not into or out of it. It can also be seen that there is almost no communication between different pieces of equipment.

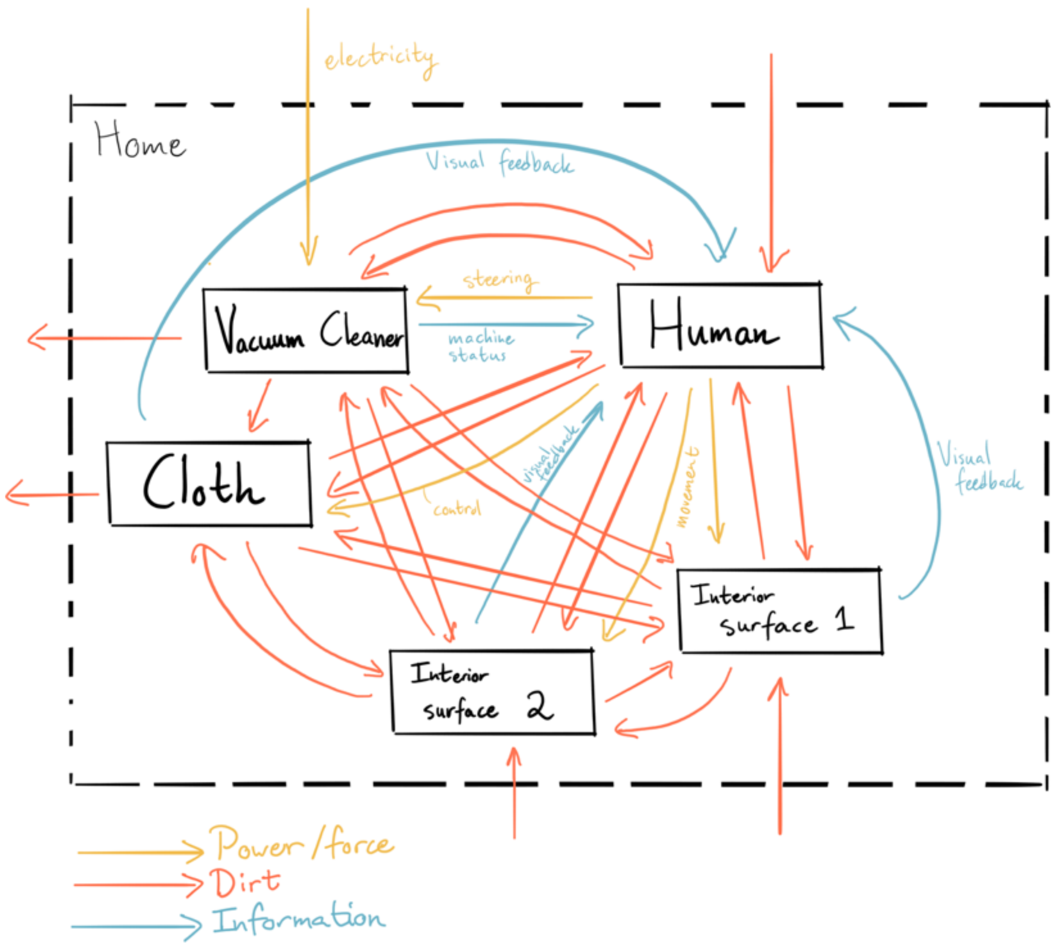


Figure 11
The cleaning system model.

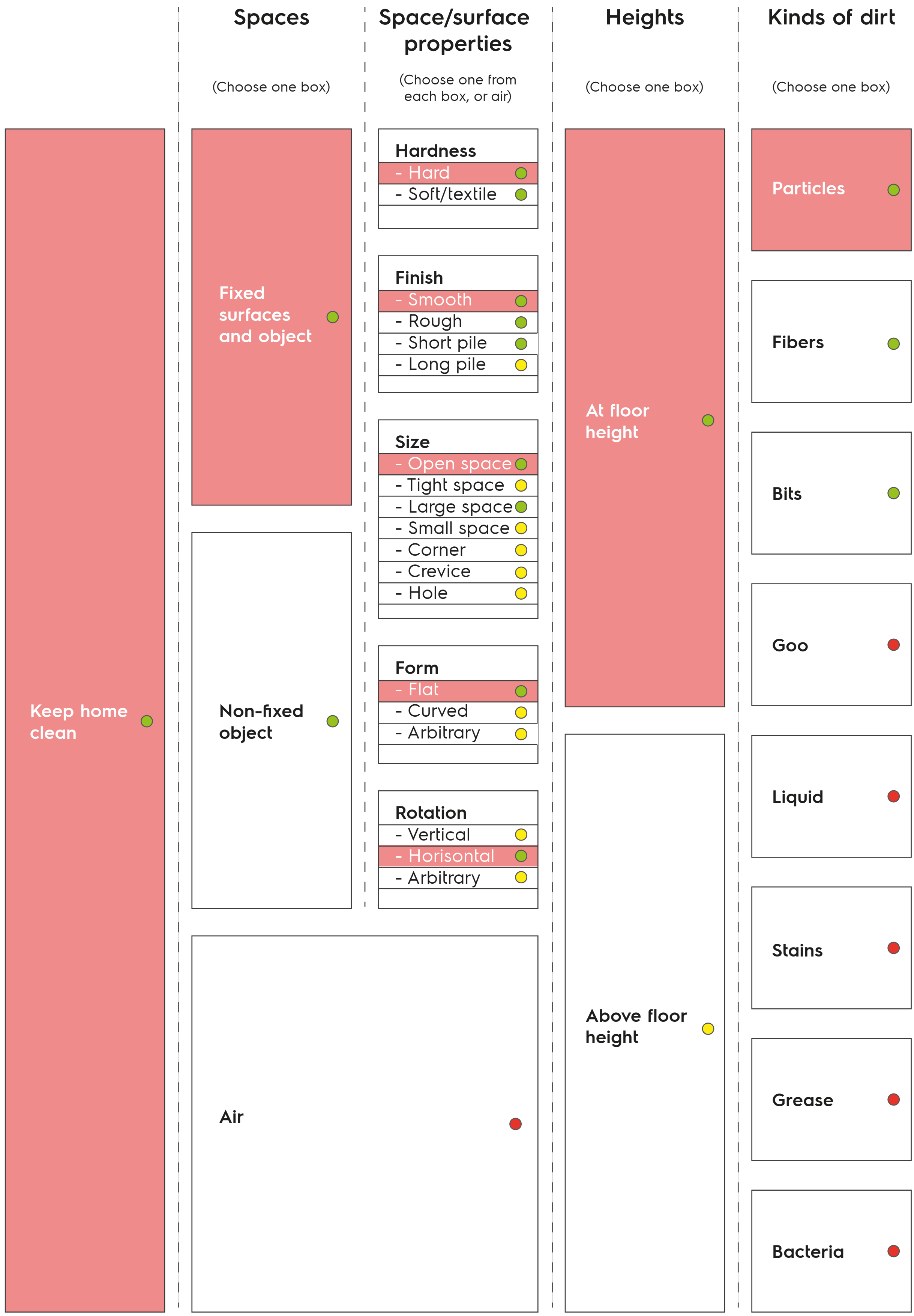
The Capabilities and User Values Within the Cleaning System

The functional analysis of canisters, uprights, sticks and robotics resulted in a large matrix of functions desired from a cleaning product. It was however found that many of them were dependent on a reactive cleaning solution. For example, “facilitate removal of dirt from surfaces” which suggests that dirt is on a surface in the first place. The entire function analysis can be found in Appendix 7. The affinity diagram of the functions led to a list of more solution independent functions presented in Appendix 8. It was found that *keeping the home clean*, with focus on *keeping clean* and not *cleaning*, is the main function of any clean keeping product.

Further analysis of the functions and the description of the system led to the *clean keeping capabilities model*. The model includes five categories and is presented in Figure 12. Any type of clean keeping can be defined by making choices in each column. Keeping a regular hard floor clean from dust is for example exemplified in peach in Figure 12. Marked out in green, yellow and red is also how well a regular canister vacuum cleaner meets the different capabilities. In total, canisters handle dust cleaning from hard floors great. It is also clear that vacuum cleaners are limited to particles, fibers and bits in terms of dirt, additionally they don’t handle dirt in the air. Similar analyses clearly showed that robotic vacuum cleaners are very limited in terms of spaces, surfaces, heights and dirt types they can handle. Such limited capabilities might not be bad in the ones met are met in a great way. One interviewee for example said “A product should do *one* thing really good”. Looking at robotic vacuum cleaners, people from the user studies expressed that robotics are not doing anything very good – not even floor cleaning. In contrast, people think that the canisters are *fairly* good at the many things it’s able to do.

“A product should do one thing very good.”

Figure 12
The clean keeping capabilities model. Hard Floor cleaning exemplified in peach.


Spaces
(Choose one box)
Space/surface properties
(Choose one from each box, or air)
Heights
(Choose one box)
Kinds of dirt
(Choose one box)
Keep home clean
Fixed surfaces and object
Non-fixed object
Air
Hardness
- Hard
- Soft/textile
Finish
- Smooth
- Rough
- Short pile
- Long pile
Size
- Open space
- Tight space
- Large space
- Small space
- Corner
- Crevice
- Hole
Form
- Flat
- Curved
- Arbitrary
Rotation
- Vertical
- Horisontal
- Arbitrary
At floor height
Above floor height
Particles
Fibers
Bits
Goo
Liquid
Stains
Grease
Bacteria

Many of the functions found in the function analysis (Appendix 7) were not immediately related to the main function of clean keeping products, but no less important. Since clean keeping products are closely related to our health and well-being, but also in close contact with both the users and their valuables, they are required to respect many of the users' values. Analysis of the functions found and the comments from the survey resulted the list of user values presented below. A clean keeping product should:

- Require minimal effort from the user (in use and maintenance)
  - Be easy to access/prepare
  - Require minimal time from the user
  - Require minimal maintenance
- Facilitate and encourage ergonomic use
  - Fit different user anthropometrics
- Be sustainable
  - Be environmentally sustainable
  - Encourage social interaction
  - Not damage interior/decorations/house/valuables/etc. (non-dirt objects)
  - Sustain hygiene
  - Be safe for humans and pets
  - Improve the daily lives of allergists and asthmatics
  - Non-disturbing for cleaners and other residents
- Sustain a comfortable climate/environment
- Allow user to be in control (enable manual control)
- Provide pleasurable results
- Be pleasurable to use
- Require minimal storage footprint (the amount of space the clean keeping product claims when not used)
- Provide effective and reliable dirt control

D. THE PROS AND CONS OF CANISTERS, UPRIGHTS, STICKS AND ROBOTICS

The surveys, interviews, observations and tests resulted in huge amounts of data around the problems of cleaning and vacuum cleaners today. The general results are well represented by the analysis of the online survey presented in Appendix 9. The most commented categories of concern are presented below:

- Storage
- Size/weight
- Effectiveness/suction power
- Sound
- Versatility/flexibility
- Efficiency
- Effort
- Reliability
- Maneuverability
- Maintenance
- Power supply
- Hygiene
- Aesthetics
- Ergonomics
- Safety
- Robustness

The categories above are similar to the annoyance factors found in the Electrolux Global Vacuuming Survey Report (2013). The most annoying factors presented in the report are noise level, low suction and emptying the dust container which corresponds well to the sound, effectiveness and maintenance categories. The report from Electrolux also showed that 42% of people store their vacuum cleaner in a cabinet or closet which explains the importance of storage footprint. Conclusions for each vacuum cleaner category are presented in the coming sections.

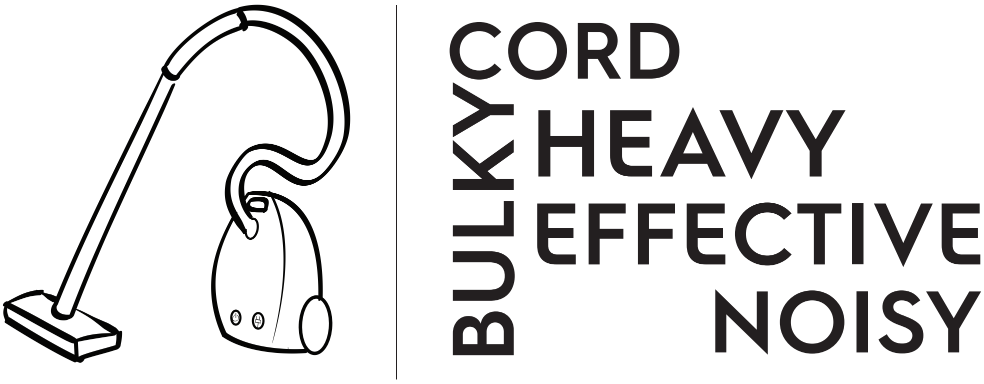


Figure 13
Canisters - most named words.

Canisters

The most united answers came from questions around canisters, probably due to their commonality. As much as ten people named the canister as “standard” or “traditional”, which was well represented by the stock and displays in stores. The most named words from the survey are presented in Figure 13. Comments about cord, weight, effectiveness, maneuverability and sound were equally common. The main subject during all of the user studies was effectiveness or suction power. The canister is considered effective and powerful. The perception of effectiveness was however related to the sound and size of the product which contradicts negative comments about heaviness and noise. Besides their size, canisters were also found to be bulky. People meant that the main unit is unstable and does not follow maneuvers. Participants from the interview also meant that the cord was good because of its power supply reliability but most people from the survey and the interviews were annoyed by the obstacles that are introduced when the cord is tangling. Switching power outlets was another of the main power issues. Canisters were furthermore applauded for their versatility in terms of reaching beneath furniture for example.

Figure 14
Uprights - most named words.

Uprights

It was notable that most people in the user study had never tried an upright vacuum cleaner. All people did however have opinions, mostly about visual aspects and design. The most named words are presented in Figure 14. In general, the opinions of uprights were very similar to opinions of canisters. Uprights and canisters are the only types of vacuum cleaners that are considered as main devices. They are both perceived as effective but heavy, bulky and noisy. People named similar problems with the cord and meant that the big bulky machine is cumbersome to maneuver, which in turn was related to poor ergonomics and back pain. In contrast to the canister, uprights were found to be less capable of cleaning beneath furniture but possibly better for rugs. It was furthermore found that uprights are considered old-fashioned, possibly due the similarities with sticks that are far sleeker.

Figure 15
Sticks - most named words.

Sticks

Sticks are smaller and lighter than both canisters and uprights. Stick vacuum cleaners should therefore be a very appealing category of products, but are they? It was found that they in many ways are, but they have same shortcomings. The most named words from the survey are presented in Figure 15. The analysis showed that the stick is in almost any way the opposite of the canister. Sticks are perceived as easy to store, access and use, which also makes them time efficient. On the other hand, it was found that many people think they are unreliable and not powerful enough. It should be noted however that several participants in the user study, while being observed, were surprised by the stick's dirt pick-up capabilities when they got to test it. It could therefore be concluded that sticks are not congruent in terms of expressed effectiveness and actual effectiveness. Another area of concern regarding sticks is battery. The loss of a cord was found to give rise to concerns about charging, battery life and the available use time. Such worries could possibly be fueled by stick vacuum cleaners in stores not being charged at all (which was often experienced during the store visit study). Furthermore, people expressed that the stick is easy to maneuver when looking at them and in early stages of the tests. They did however experience that they get tiring to use, which makes them hard to maneuver after a while. One participant for example said "Oh my god, this is so bulky!" shortly after starting to use the Ergorapido. On the other hand, people meant that the stick is not a main vacuuming device but rather a device for intermediate cleaning.

Figure 16
Robotics - most named words.

Robotics

As many as 13 people from the survey meant that the robotic vacuum cleaner is modern and a product of the future. It was however also found to be unready. The most named words can be found in Figure 16. One of the most positive talking points was time and effort. Interview and survey participants emphasized the desire to use less time cleaning and a robotic solution was perceived as a good way to make cleaning easier and faster. A main reason was that cleaning is done when you are not at home. Having a robot moving around at home was on the other hand perceived as creepy. The small size was also found to lead to a perception of low suction power and effectiveness, just as with the stick. It was also found that most people think that robotics are expensive and that the value is not enough compared to the cost. All of the interview participants meant that a price of 1000 to 1500 (SEK) is reasonable for a vacuum cleaner and the value they provide today. A perception that many of the participants were found to have is that robotic vacuum cleaners are inflexible and untrustworthy. It could be concluded that people don't think that robotics fulfill the main functions of a vacuum cleaner. They are for example having trouble cleaning carpets, doorsteps, corners, furniture, stairs and skirting, and therefore leave many areas uncleaned. A general concern was also found to be that robotics might get stuck – a situation that defeats its purpose completely. Such a situation means that the user has to get involved anyway, and the surface does not get cleaned on time – especially if the user is not at home and able to free the robot from where it's stuck. Danger and harm for pets, kids and valuables were also big concerns.

E. WHAT SHOULD A CLEAN KEEPING DEVICE BE LIKE?

The word easy was named a whopping 42 times in the online survey as the most important property of a clean keeping device. The five most named words can be found in Figure 17. Additionally, every interview participant wished for a silent product. Many people were also found to have limited storage capabilities which is why a small product that is easy to store is preferable. Many of the wanted properties were however found to be completely dependent on the product solution. Some of the properties were therefore interpreted to be more universal:

- Easy – Easy to prepare, use, understand and handle were named as wanted properties. Behind the message is a wish for **reduced or eliminated effort.** *Easy to prepare* could also be *no preparation*, and the same goes for the other properties as well.

- Good – Good refers to dirt pick-up and versatility. People want the clean keeping product to be good at what it does. Which is really about **providing satisfactory results and reliable operation.**

- Silent – Silent suggests that the product is operating where you are, when you are there. It is really about **reducing or eliminating distractions and disturbing characteristics.**

- Store – Storage is about space and time for preparation. It was interpreted as **reducing footprint and increasing accessibility.** That means no need for storage and that little or no preparation is needed.

- Effective – Effectiveness refers to suction power in the case of the vacuum cleaner. As described earlier, perceived effectiveness was found to be heavily connected to sound. So it is really about **providing satisfactory results or good dirt pick-up**, but also **expressing that capability congruently.**

The cloth was named as the favorite cleaning tool among almost all interviewees, which is very understandable when looking at the wanted properties above. It is small, light, simple and versatile, and requires very little effort to prepare and use. The cloth removes dust better than most tools due of its immediate contact with the surface and since it is compatible with almost every category of dirt. Furthermore, it never lets the user down because there is no downtime – it cannot be out of power and does not need a filter change. It is also absolutely non-disturbing with no sound at all. It can be stored anywhere and is therefore incredibly easily accessible. Dusting with a cloth is very satisfying because the results are clearly visible. The cloth was in fact only found to have a few downsides: it is cumbersome to rinse it several times during a cleaning session, interior decorations still have to be moved around and it might leave an unwanted smell.

The cloth was named as the favorite cleaning tool among all interviewees

EFFECTIVE

SILENT

EASY

STORE GOOD

Figure 17
Properties that are wanted from a clean keeping product.

F. THE EXPERIENCE OF CLEANING AND CLEANING PRODUCTS

The results of the interviews were very much about the experience of cleaning. The main finding was that the majority of all pleasure and displeasure comes from seeing, feeling, smelling and hearing dirt or cleanliness. There is pleasure in seeing, feeling and smelling a clean home while seeing, feeling and smelling dirt is displeasurable. It was found that most people don't think cleaning in itself is pleasurable but the results of cleaning are. Noticing the difference while cleaning is also pleasurable, like when you hear gravel going through the pipe of the vacuum cleaner or see the dust being removed from a surface, leaving a glossy finish. The factors presented in the list below were found to affect the user experience of cleaning and cleaning products. The entire user experience analysis can be found in Appendix 10 and a summary is presented later in this section.

- Results of cleaning
- Simultaneous activities
- Time spent
- Capabilities, design and characteristics of the cleaning product
- Dirt smell, feel and looks
- Necessity of cleaning
- Effect on surrounding people

All of those factors affect people and evoke emotions. The most common emotions named in the interviews are presented below. It should be noted that many of the participants meant that they don't feel any emotions for the most of the cleaning time.

- Pleasurable emotions
    - Satisfaction
    - Relief
    - Pride
    - Well-being

- Displeasurable emotions
    - Disgust
    - Irritation
    - Obligation
    - Stress
    - Tiredness
    - Frustration

The found emotions correspond well with the ones named in Electrolux's survey where satisfaction, tiredness and relief were the most named emotions that people feel after cleaning. This study did however consider every aspect before, during and after cleaning. The Kansei inspired scales from the interviews did not result in any conclusive answer regarding specific emotions. However, it showed that people's auditory impression of vacuum cleaners is slightly worse than the visual and tactile impressions. The sound from vacuum cleaners was described as loud and noisy, bothering surrounding people and making it hard to listen to music while cleaning for example. On the positive side, it was also described as strong, contributing to the perception of power.

Ideo-Pleasures and Displeasures

People were found to in general like cleanliness and dislike dirt. Being in a dirty home is displeasurable because we aspire to have clean homes. Cleanliness has become the standard. The effort and time put into cleaning, and the frustration that sometime arise, was found to make cleaning in itself displeasurable. Some people like cleaning but most people don't. The strive to have a clean home make the results of cleaning very appealing and pleasurable however. The interview participants meant that they don't like spending time cleaning, but that they make time because it is necessary. The surprise when a cleaning session ends up being shorter than expected was found to be pleasurable.

Cleanliness has become the standard.

An interesting finding was that people like to do other things while cleaning to make it more pleasurable. Some listen to music, some dance and one of the participants even meant that redecorating the home while cleaning makes it fun. In fact, the Electrolux survey report (2013) showed that as much as 51% of people listen to music or radio while cleaning.

Additionally, people were found to like being in control of the cleaning and the results of cleaning, which is why some people don't trust robots or other people with the task of cleaning.

Socio-Pleasures and Displeasures

Strikingly, most of the participants seemed to be cleaning more for the pleasure of others rather than their own. It was found that people in general care a lot about what others are thinking, both guests and other family members or residents. The interview participants expressed that there is pride in having a clean home in front of others. They also meant that there is pride in being the one cleaning but a feeling of guilt when others are cleaning around you and you are not helping out. On the other hand, it was found that people are worried to disturb others while cleaning, mainly because of the sound of the vacuum cleaner.

There is a pride in having a clean home in front of others.

Psycho-Pleasures and Displeasures

Interestingly, it was found that cleaning is not only a displeasure while cleaning, but also when not cleaning. People meant that it is psychologically wearing to know that cleaning has to be done. It feels like an obligation because of the taste and aspiration to have a clean home. The knowledge that cleaning is no fun in combination with the hassle of preparing all the equipment was also found to create a mental obstacle that makes starting to clean even harder. The interviews also showed that there is mental fatigue and irritation when the equipment is hard to handle and becomes an obstacle in itself. There is however psychological pleasure and relief in being done cleaning because of the very fact that cleaning is not pleasurable. Lastly, it was found that robotic vacuum cleaners create another kind of anxiety. Instead of worrying about having to clean, people tend to worry that the robotic vacuum cleaner doesn't clean enough, or will damage or collect valuables.

A mental obstacle that makes starting to clean even harder.

Physio-Pleasures and Displeasures

Most of the pleasures and displeasures with regards to cleaning are physiological. As described earlier, people meant that the senses heavily affect their perception of dirt and cleanliness, both when cleaning and when not. Seeing, feeling and smelling dirt was the main subject for most participants in this part of the interview. They meant that a home is dirty when dust is visible on a surface or when dirt can be felt on the floor. One participant for example said "Feeling gravel or sand under your feet is the worst!". Another participant meant that "It is disgusting to see the dirt!". It was also found that smell contributes heavily to the perception of a clean home. A fragrance might however be just as bad as cooking odors, which is why neutral smells were found to be preferable. One participant mean that "Vacuum cleaners smell disgusting" and "I can't sleep if there is a smell in the air". Additionally, the interview participants expressed a special fondness to the sound of dirt being collected by a vacuum cleaner. The fact that people like cleanliness was found to make every kind of feedback on difference in cleanliness pleasurable. Hearing gravel through the pipe of the vacuum cleaner, seeing dust bunnies moving towards the nozzle, seeing dust being removed from a black glossy surface or just hearing the sound of suction were some of the examples brought up during the interviews.

Participants expressed a special fondness to the sound of dirt being collected.

The physical nature of cleaning activities was also found to elicit both pleasure and displeasure. The interview participants meant that it is physically demanding and requiring a lot of effort to maneuver the vacuum cleaner and moving interior around. Back pain was highlighted as one of the results of cleaning. One participant did however express pleasure in getting exercise because of cleaning. The sound from cleaning equipment was also found to be tiring. One of the participants for example said "It's so nice to turn it off and hear the silence afterwards", referring to the vacuum cleaner.

What Factors Give the Different Vacuum Cleaners Competitive Edge?

Jordan meant that pleasure in products ads competitive edge. But basic properties have to be fulfilled first. Karlsson (2014) meant that only when a product is functional it can become usable and reliable. And only when it is usable and reliable it can become convenient. When the product is convenient it can become pleasurable. Table 5 below shows a compilation of the user study participants' view on the different vacuum cleaners.

	FUNCTIONAL	USABLE AND RELIABLE	CONVENIENT
Canister	Very functional	Usable and reliable	Fairly convenient
Upright	Very functional	Usable and reliable	Not convenient
Cordless	Fairly functional	Usable and reliable	Convenient
Robotic	Not functional	Usable but not reliable	Very convenient

Table 5
Competitive edge of different vacuum cleaners.

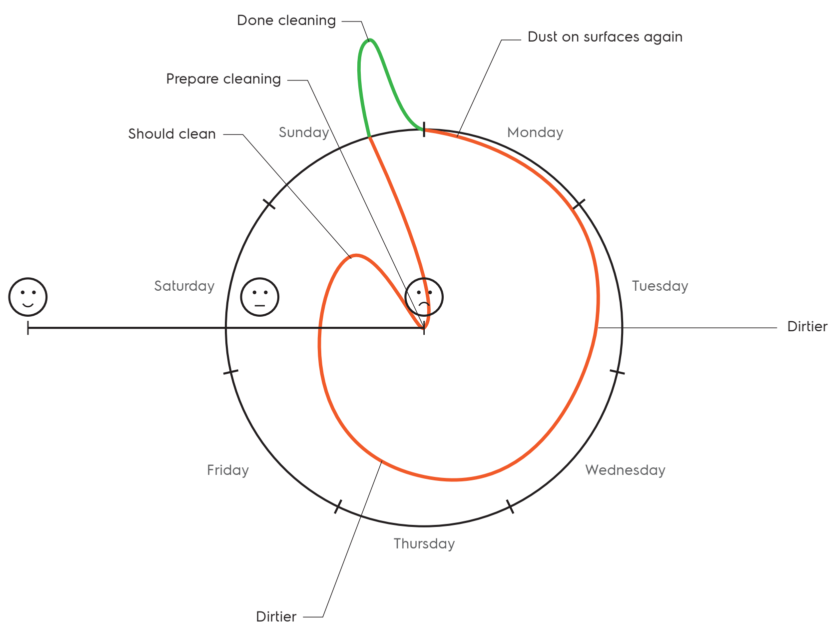
The stick vacuum cleaner was found to have most of the properties wanted from a vacuum cleaner, and still it is not accepted as a main device. Sticks are considered quick, easy and small, but weak rather than effective. In other words, they are usable, reliable and convenient, but not very functional. It was concluded that performance and function is far more important than any other property. In fact, the canister scored the highest on performance and function factors such as effectiveness, versatility, reliability and durability. They were however not found to be especially convenient.

User Journey

In general, it was concluded that most of the pleasure comes from the results of cleaning, immediately after cleaning. There is joy and relief in being done cleaning and people like seeing, feeling and smelling (or not smelling) the cleanliness. Those feelings decrease quickly and end up in indifference. As the home becomes dirtier again the displeasure increases, and as the next cleaning session approaches the feelings of obligation and mental obstacles arise. When those obstacles are overcome and cleaning is started, the displeasure decreases and ends up in pleasure ones again. The user journey of cleaning is presented in Figure 18. It is illustrated as a circle to illustrate the cyclical nature of cleaning. It applies to any cycle length.

As the home becomes dirtier, the displeasure increases.

Figure 18
The user journey of cleaning.



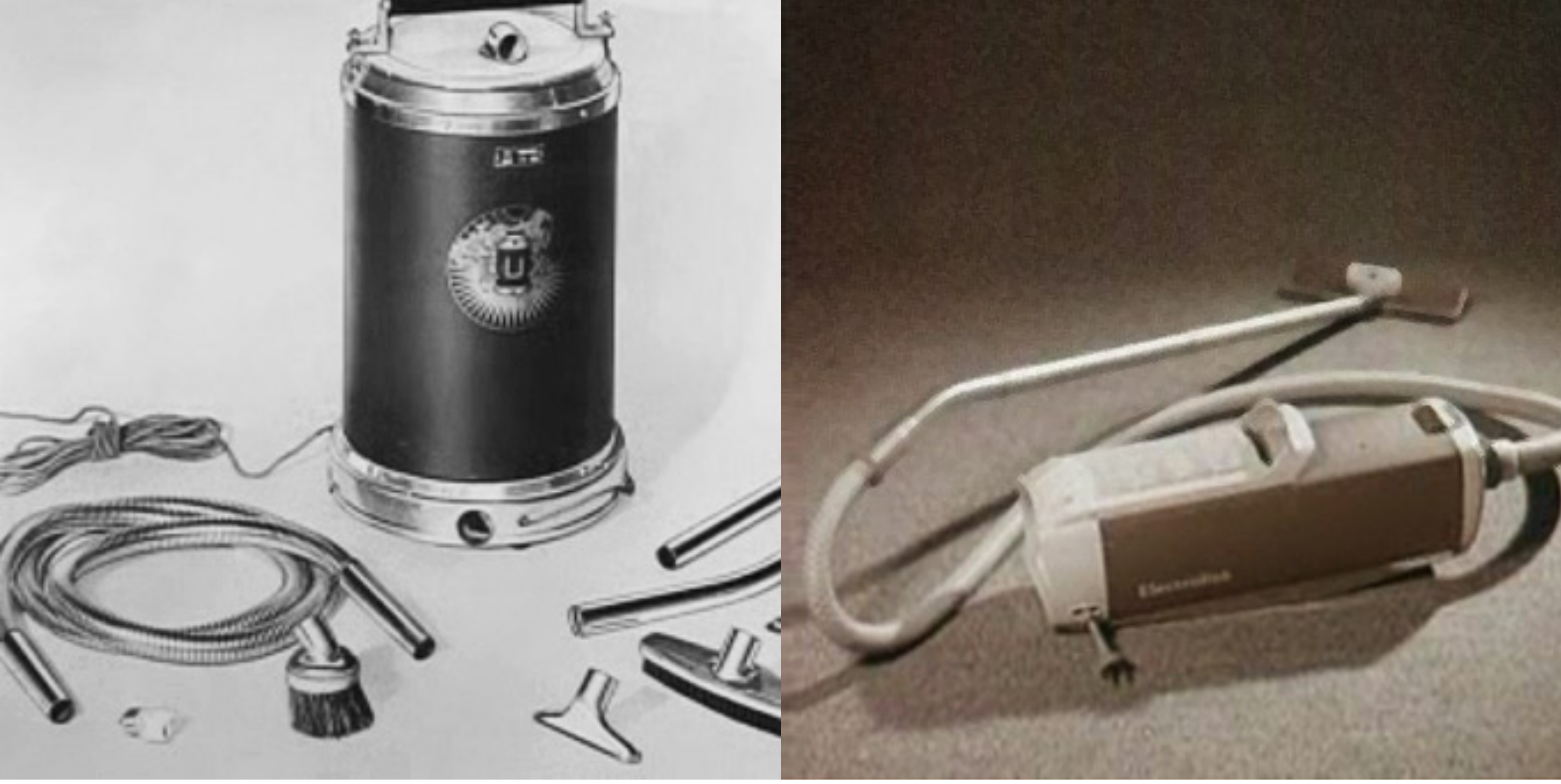


Figure 19
Left: One of the first vacuum cleaners Lux 1. Right: Electrolux's first modern canister Luxomatic. (Source: Electrolux, 2016b)

G. WHAT DOES THE FUTURE AND THE PAST LOOK LIKE?

The trend analyses resulted in several timelines of different products. Those timelines are presented below.

The History of the Vacuum Cleaner

It is general knowledge that the broom is the vacuum cleaner's predecessor, it is its manual counterpart. The broom has been around for hundreds of years and is still a part of the cleaning system, especially in heavy duty cleaning and when no power is available. But the broom is not only the predecessor, it is also the foundation on which the vacuum cleaner is based. In 1860 Daniel Hess was granted a patent for a carpet sweeper, which was basically a semi-automated broom or sweeper. The carpet sweeper included a rotating brush and generated suction. Today, many years later, the vacuum cleaner is still a nozzle with brushes and suction.

According to Electrolux (2016b) (Lux at that time), they introduced their first vacuum cleaner Lux 1 in 1912. As can be seen from Figure 19, Lux 1 was a canister in the form of a cylinder with many of the accessories we still see today. It was notably larger though and therefore more cumbersome to move around.

In 1964 Electrolux introduced the first modern canister Luxomatic. Figure 19 clearly shows the form factor similarities with today's canisters. For the first time their canisters included features such as a cord winder and a dust indicator.

In recent years, vacuum cleaners have changed more. Electrolux introduced the first robotic vacuum cleaner Trilobite in 2001 and the stick vacuum cleaner Ergorapido in 2004. The technical principles were still the same as used in Hess's carpet sweeper but the interaction and use was slightly different. Trilobite was made to reduce the need of human-machine interaction while the Ergorapido was adapted to a lifestyle where cleaning is made where needed, when needed instead of regularly.

That change in design was concluded to mark a shift that allows for new solutions that are designed to fit into people's lifestyles instead of fitting the components that have been in vacuum cleaners since the beginning into a new casing. This project was therefore focused on how people live and behave in order to design products that create better user experiences. Changes on the effect and use levels of Bligård's (2015) model were found to be necessary to find such solutions.

So what will the future of the vacuum cleaner look like? Electrolux (2016c) meant that performance and function are the most important factors for consumers, which is well in line with the results from the analyses of the interviews conducted in this project. As mentioned earlier, it is important that a product does at least one thing really great, which the robotic vacuum cleaner for example doesn't. Electrolux did however also mean that people want high suction power. That statement is in line with the analysis of the online survey, but behind those words is the wish for performance and capability, which isn't dependent on suction, or power for that matter. Electrolux further meant that vacuum cleaners should be well-designed so that they can be visible and therefore easily accessible. The user studies did however show that people do not want to have the vacuum cleaner visible, many of the participants even considered the Ergorapido as "plasticky" and "ugly".

So What Happens in Other Industries?

The TV has its root in the radio just as the vacuum cleaner has its roots in the broom. TVs have also gone through a similar evolution in terms of size, becoming slimmer and slimmer every year. Over the years, functionalities such as color TV, digital broadcasting and remote controls have been added. TV remotes have one problem though, they have yet to adapt to our modern lifestyles. Remotes basically look the same as when they were introduced even though there are hundreds of channels and other content to consume. So what does the TV tell us about the future? The content and content providers have showed how television can fit into modern lifestyles. On-demand services have become the way many people consume media these days. By choosing what you want to see and when you want to see it, you can always fit it into your life between increasing work hours, hobbies and other social activities. The stick vacuum cleaner was found to serve a similar purpose but has not replaced the canister as on-demand services have replaced regular television for many – yet.

A similar evolution can be seen in computers, phones and watches. More technology than ever is packed into smaller and smaller casings. The smartphones and smartwatches of today offer far more capabilities than the first computers. But the real power is that all of that technology and information is in the hands of the users. With almost no effort, it is always there for the user. Just as on-demand TV, apps have changed the world of phones. Apps allow the users to do whatever they want and make their phone into what they want.

One app that hints at where the future is heading is Snapchat. It allows users to send images (called snaps) instantly to friends. Nothing is ever saved, it is all about living in the moment by making interactions much quicker. A snap is viewable for a maximum of 10 seconds, which makes the decision to send one and open one much easier. It is nothing that will take up time or put effort on the user. Compare to posting a picture on Facebook or Instagram, or just sending one as a text. Deciding to take a picture requires overcoming an obstacle in the first place. Then several pictures have to be taken to be able to choose the best one, which in some cases is followed by the addition of filters and text. It can all be so cumbersome that some people decide not to send the picture. All that work furthermore puts pressure on the receiver to answer, which is why they might choose to postpone the reading moment. All that is different with snapchat. Should cleaning be like sending a snap? Maybe. Is cleaning like sending a snap? No. Sticks could be seen as such a solution but they are not. There is still a mental obstacle to overcome and the interactions are still too long.

People's lifestyles are becoming increasingly filled with short interactions at the conditions of the people themselves.

In many ways vacuum cleaners are very different from TVs, smartphones and apps. People actually want to watch series, make phone calls and consume other media. They do not want to clean. What could be concluded from the trend analyses is however that people's lifestyles are becoming increasingly filled with short interactions at the conditions of the people themselves.

What Does the Future of Technology Look Like?

Gartner (2016) listed 10 strategic technology trends for 2016 in a yearly report. Four of the trends were found interesting for clean keeping products: *the device mesh*, *ambient user experience*, *information of everything* and *advanced machine learning*.

The device mesh

Gartner meant that devices have been connected to central units for a long time but that they are not talking directly to each other. Device meshes where devices are communicating directly are emerging. For example, between smartphones, computers and smartwatches. As could be seen in the earlier analysis there are many cleaning devices in the cleaning system but none of them are communicating with each other or other parts of the home.

Device meshes where devices are communicating directly are emerging.

Ambient user experience

A device mesh as described above makes way for entirely new user experiences according to Gartner. Continuous user experiences between devices was named as one of the advantages. That means that the user is surrounded by a seamless mesh of devices, which creates an ambient user experience. Cleaning today was found to be far from seamless. The several activities require different pieces of equipment and are in most cases separate from each other.

Information of everything

Gartner furthermore meant that when all of the devices, and the sensors within the devices, communicate a lot of data is produced. And linking data from different sources gives it meaning and makes it powerful. It is also extremely contextual and individual. Imagine what cleaning would be like if it was optimized based on data on dirt and lifestyles from every home in the world.

Advanced machine learning

According to Gartner, future systems will be able to automatically learn to perceive the world completely on their own. The large amounts of data produced in the device mesh is one of the reasons. It is consequently reasonable to believe that robotic vacuum cleaners could be much smarter than they are today if they had more information at hand.

Who Are the Future Users?

The user studies showed that younger users are more prone to clean spontaneously and also that they don't like cleaning. The younger audience was also found to in general be more open to new technology, for example robotic vacuum cleaners. Since the aim of this project was to create a better user experience while cleaning in the future, young adults were chosen as the main target group. A persona (presented below) was created to represent that group and people between 20 and 30 years old were used in upcoming studies or evaluations.

Filip 28

Figure 20
Filip. (Source: Pixabay 2016)

Filip (Figure 20) is a motivated and eager front end web designer at the Swedish bank SEB. As a designer he values aesthetics and functionality – products should be beautiful and useful. He has therefore put a lot of attention to the interior of his home. He lives in a modern and cozy 3-room apartment along Vasagatan in Gothenburg together with his girlfriend Elisabeth. When they are not at work they like to spend their time together on the couch. On Saturdays they invite their friends over for dinner. Health and food is very important to Filip and he is therefore a hell of a cook.

Filip and Elisabeth like their home clean and tidy. Filip cannot stand feeling of bread crumbs under his feet. He is not especially interested in cleaning but he loves the smell, look and feel of the apartment afterwards. To make cleaning more fun he likes listening to music and tries to make it as quick as possible. He uses their Ergorapido to clean the open floor areas when needed, and they deep clean every Saturday.

Scenario 1 – Weeknight quick cleaning:
Filip has just finished a long day at work and take the tram back to the apartment. He is listening to his favorite Coldplay playlist from his smartphone. Once home, he notices some gravel on the floor and decides to quickly grab the stick vacuum cleaner since Elisabeth has already started cooking. He dances through the apartment, vacuuming in the entrance, kitchen and living room, but only the open areas. He would love if the apartment was always clean because he doesn't like that some areas are left unclean but he doesn't have the energy to do more.

Scenario 2 – Weekend deep cleaning:
Filip and Elisabeth are eating their regular long weekend breakfast while planning their day. They are having their best friends Erik and Maria over for dinner tonight and need to do some shopping and cleaning before cooking. After breakfast Elisabeth goes on dusting around the apartment while Filip prepares for vacuuming. Filip doesn't like dusting because so many things has to be moved around. Before vacuuming he has developed a technique where he first moves all loose objects from the floor and then put the chairs on the table. He grabs their big canister vacuum cleaner from the closet to get started. He sighs because the canister is so much clumsier than the stick, but the stick is not good enough on their carpet and it doesn't reach beneath the couch. Filip starts cleaning in the kitchen and moves on to the living room. He gets slightly irritated when getting close to the couch. Filip is tall so he has to bend way down and there are so many boxes and cables beneath the couch. He just sticks the nozzle in there and hopes for the best, but he is not satisfied because he knows that it is not completely clean and dust that might crawl out later.

Filip's Character

The persona artifact board in Figure 21 represents the character of Filip. Filip is a very composed person that likes when products are both beautiful and useful. He values his time and like when things are quick and easy.

Figure 21
Persona artifact board – the character of Filip. (Sources: Flickr, 2016abc)

What is Filip's Apartment Like?

According to SCB (Swedish Statistics) (2015a), the urbanization in Sweden is increasing. They showed that 85% of the Swedish population lived in urban areas in 2010 compared to the fact that 90% of the population lived on the countryside 200 years before that. SCB (2015b) also meant that the reason is not that people move from the countryside to urban areas, but rather an increasing number of inhabitants. Nowadays, urban areas grow primarily through more births and immigration. The increasing urbanization has led to a housing shortage in big cities according to Boverket (2013). Sweden was short of 40 000 apartments in 2013, mostly in Stockholm and Gothenburg. SCB (2013) further showed that people in urban areas have the least living space. So there are reasons to think that homes will get smaller in the future. Electrolux (2016c) even meant that the number of small households grow worldwide, which increases the demand for small, compact and efficient solutions. Mirror (2016) showed a similar tendency in Britain. They *meant* that Britain's homes are becoming increasingly smaller and referred to similarities to the micro-apartments being sold in Paris. Boverket (2013) did however also suggest that one solution to the huge shortage might be redistribution of the population to make better use of the housing stock in Sweden. Such a change would however require changes in legislation.

Homes will get smaller in the future.

Comparisons of interior pictures showed huge variations between people and countries. It was however found that interior design in general becomes increasingly simplistic. One of the interview participants meant that having a "clean" home is not only about having a home free from dirt but also a clean non-messy simplistic interior design. As mentioned earlier, the user studies also showed that people tend to care a lot about what others think about the tidiness of their homes, which extends to interior design. The persona apartment board was created with simplicity and tidiness in mind. The kitchen, living room and bedroom of Filip's and Elisabeth's apartment are presented in Figure 22, Figure 23 and Figure 24.

Figure 22
Persona Apartment Board – Filip's and Elisabeth's kitchen. (Sources: Flickr, 2016defgh)

Figure 23
Persona Apartment Board – Filip's and Elisabeth's living room. (Sources: Flickr, 2016ijklm)

Figure 24
Persona Apartment Board – Filip's and Elisabeth's bedroom. (Sources: Flickr 2016nopq)

What Will Be the Effects of Automation?

Automation is increasing at a tremendous rate. Vehicles are becoming increasingly autonomous and self-driving cars will soon be on every road. In our homes, automation is growing. There are automated thermostats, lighting and of course robotic vacuum cleaners. So far, those things are helping the users and enhancing their lives, but what will happen when automation grows even further into our homes? What happens when there are ten robots in our homes? One for vacuum cleaning, one for mopping, one for carrying groceries, one for emptying the dishwasher, etc.? One of the interview participants mentioned the "dream of the robot", a dream world where the robot does everything the users don't want to or have time to. In reality it is not "the robot" but many robots that are trying to achieve that dream, which is completely fine – if they work with the user and with each other. Imagine the grocery carrying robot trying to navigate through a terrain of vacuum cleaning and mopping robots without communication. How will the mopping robot even know where the vacuum cleaner has been and not? It is necessary to consider robots as part of our future when designing future products, regardless of their automation level. One thing is certain, robotic units need to communicate with each other, just as mentioned in the section about emerging technology. If automation is the future of cleaning, a web of seamlessly cooperating devices will be important. A holistic view on cleaning, and even living, will be the key. Vacuum cleaning can no longer be seen as a single and separate task; cleaning has to be redefined from the bottom up to create a better cleaning experience that fits into the future of automation.

A holistic view on cleaning will be the key.

H. WHAT IS ELECTROLUX REALLY ABOUT?

Electrolux is the global leader in the business of household appliances. Electrolux and several other household companies, including *AEG* and *Frigidaire,* are part of the *Electrolux Group*. (Electrolux, 2016a)

Product Range

The company offers a wide range of products. Two thirds of their sales come from *kitchen appliances*, which includes cookers, hobs, ovens, hoods, microwave ovens, refrigerators, freezers and dishwashers for the regular household as well as professional kitchens. Within their *laundry* category, they provide washing machines and tumble-dryers. Cleaning ware include *small appliances* – vacuum cleaners, domestic appliances and accessories. Lastly, the *adjacent product categories* include dehumidifiers, air conditioners, water heaters and heat pumps. (Electrolux, 2016d)

Looking closer at Electrolux's cleaning products, they offer a vast range of vacuum cleaners, or more exactly, 51 different types as of May 2016: 30 canisters, 11 stick vacuum cleaners, 6 handhelds and 4 cyclonic vacuum cleaners (Electrolux, 2016e). Many of these 51 devices only vary in color, but they are presented as equal on their website (Electrolux, 2016e). A special focus lies on their green, energy-efficient vacuum cleaners (Electrolux, 2016c). Looking at Electrolux's other cleaning products, they offer several types of central vacuum cleaners as they are the leaders in this market segment (Electrolux, 2016cf). They also offer a semi-professional vacuum cleaner (Electrolux, 2016g). For the US market, Electrolux also offer two types of uprights (Electrolux Appliances, 2016).

SWOT

The company has many *strengths*. Electrolux is a strong brand on the European market, as they have experienced an almost 150% upturn in operating profits the first quarter of 2016 compared to 2015 (BusinessKorea, 2016). They are also experiencing growth in the US market (Financial Times, 2016), proving the power of the brand. Conducted store visits revealed that Electrolux hold a high market share within the vacuum cleaner segment, along with Bosch. One of the reasons is likely the public view of Electrolux products, which also was experienced from the conducted interviews – they are effective and good quality. Electrolux's history also proves that they have a long experience within their area of business (Electrolux, 2016b). Sustainability is nowadays a valuable trait. Thus, another strength of Electrolux is their already established green product line. Electrolux is also very consumer-centered (Electrolux, 2016a).

In spite of their strengths, they also have some *weaknesses* that should be considered. Their products are on the premium side in terms of price, but conducted interview studies showed that people are not ready to spend that much money on e.g. vacuum cleaners. Even though many of their products are viewed as quality products, they lack in this field as well. The stick vacuum cleaners are viewed as "plasticky" (as in low quality) and not trustworthy. Ever since Electrolux introduced stick vacuum cleaners in the beginning of the 21st century, the general public's view on this category of products has remained negative. Electrolux's consumer-centered product development is also a weakness, as they explicitly express that consumers want "great suction power" (Electrolux, 2016c), while our studies show that these words shouldn't been taken literarily – consumers rather want to clean as little as possible. By doing what consumers want them to do, and thus not listening to what the consumers *really* mean and *really* want, Electrolux fall behind in terms of innovation.

Electrolux's *opportunities* lie in their knowledge and established product line. The wide product range creates opportunities to create a mesh of devices that seamlessly interact and are connected, with the simple purpose to make life better. Such a mesh would also create an ecosystem, in which customers can experience Electrolux as a cutting edge company. Reports reveal that Electrolux already has connectivity integrated in their development process (Financial Commentary, 2016). As technology is rapidly evolving and competition is getting tougher, using cutting edge technique creates competitive opportunities. Connectivity is deeply connected to UX (User Experience), which is an area that Electrolux has made progress within, but still is a huge competitive factor. Consumers demand products that are easy to use and that are energy efficient. Electrolux is already, and has for a good while, been on their way of being very energy efficient (Electrolux Group, 2007). Looking at other products and the society, there are clear trends that could create opportunities for Electrolux. Product aesthetics are becoming more important as products have a bigger role in one's self-expression (Forbes, 2016) and housings are becoming smaller (as mentioned earlier).

The wide product range creates opportunities to create a mesh of devices that seamlessly interact and are connected

Finally, what are the *threats?* The supergiant manufacturing company *Bosch* is a force to reckon with, as they have snatched their share of the market. Bosch's newest stick vacuum cleaner Athlet has proven to be as effective as regular canister vacuum cleaners (viivilla.no, 2015), and thus, better than Electrolux stick vacuum cleaners. *Dyson* is a company that is not competing in effectiveness, but on the other hand in innovational level as they offer new ways of picturing vacuum cleaning. As opportunities are seen in incorporating connectivity across Electrolux devices, the *smart* transformation can also become a threat and weaken the quality of the products if the connectivity becomes *obtrusive* rather than relevant to the customer.

Gaps in the Market?

As seen in the product range and opportunities of Electrolux, they have every opportunity to rethink clean keeping by introducing a new system that in accordance to the trends could provide an ambient and seamless user experience. A mesh of devices working together would make clean keeping easier for the users and bring them into the ecosystem of Electrolux where all products would be compatible with each other. Connectivity would be the key to such a system.

Electrolux already has a great focus on environmental sustainability which is more important now than ever. They have the opportunity to extend that to social sustainability as well. Social sustainability could include better user experiences as described above but also increased support for teamwork, better ergonomics and consideration to all family members that might be in the home during cleaning. The ergonomics of vacuum cleaners could for example be questioned. It was found during the tests that they are excellent to clean floors but the stick was on the other hand found to be very heavy and hard to handle on higher heights.

There are reasons to believe that clean keeping products will be visible in the home since the introduction of robotic and stick vacuum cleaners. Electrolux has a clear competitive edge since their products were considered as aesthetically appealing in the interviews. Their products are perceived as plasticky though, which leaves room for improvement.

I. CONCLUSIONS AND GUIDELINES

Designing a product that keeps homes clean requires understanding of every part of the system that includes dirt, home, surfaces, activities, equipment and humans. The most important conclusions are listed below and a set of guidelines can be found in Table 6.

- There are eight categories of dirt but only three of them are common and accumulate over time: particles, fibers and bits.
- Most of the existing cleaning equipment is not compatible with all types of surfaces or types of dirt, but rather purposely designated to a specific cleaning activity.
- Cleaning today requires several completely different and disconnected cleaning activities.
- There are at least 19 different pieces of common cleaning equipment but vacuum cleaners and cloths are the most common and liked ones, due to their effectiveness and versatility.
- Canisters are considered as standard and the definition of the word vacuum cleaner in Sweden. Mostly because of their effectiveness and versatility.
- Canisters and uprights are the only types of vacuum cleaners that are considered as main units. Sticks and robotics are considered as intermediate cleaners.
- The stick is the exact opposite of the canister. It is quick and easy to use but does not replace the canister because of its lower effectiveness.
- Dirt spreads to and from every part of the cleaning system. More within than into and out of the system.
- People dislike cleaning but find pleasure in the results of cleaning. They are mostly affected by the visual, olfactory and haptic aspects of dirt and cleanliness.
- Dirt evokes displeasure or indifference between cleaning cycles. The pleasure after cleaning is very short-lived.
- People like to do other tasks while cleaning, for example listen to music.
- Function and effectiveness are the most important factors required from clean keeping products.

- Peoples lifestyles are becoming increasingly filled with short interactions and increased flexibility.

- A mesh of several connected devices will be key to create seamless user experiences and smarter technology. Communication between devices and a holistic view on home automation will also be important if the dream of the cleaning robot is to come true.

- Homes are getting smaller and interior design is becoming more simplistic.

- Electrolux have every opportunity to take the holistic approach on cleaning to create an ambient user experience because of their wide product range and market share.

GUIDELINES (FUTURE CLEAN KEEPING PRODUCTS SHOULD...)
Focus on dirt that accumulates such as particles, fibers and bits.
Have at least one great capability.
Require minimal effort from the user.
Facilitate and encourage ergonomic use.
Be socially and environmentally sustainable.
Sustain a comfortable indoor climate.
Allow the user to be in control.
Provide pleasurable and satisfying results.
Be pleasurable to use.
Require minimal storage footprint.
Provide effective and reliable operation.
Be easily accessible.
Provide excellent dirt pick-up.
Express effectiveness.
Provide visual, auditory and olfactory feedback on cleaning.
Require minimal time from the user.
Allow for simultaneous tasks.
Allow for short interactions.
Be part of a system.
Interact and communicate with other products.

Table 6
Guidelines found in phase 1.

06.

PHASE 2: **THE VACUUM CLEANER SUCKS – OR DOES IT?**

The user studies conducted in phase 1 indicated that cleaning is not as easy as many may think. Even though the interviewees stressed the great versatility of the vacuum cleaner, they also expressed their dissatisfaction regarding the use of it. The love-hate relationship to vacuum cleaners rose the question whether the vacuum cleaner may be misunderstood. Phase 2 unfolds the story behind the extensive exploration of new ways of reaching the ultimate goal: a clean home. Is the vacuum cleaner really the solution to so many cleaning tasks? Are there maybe new ways of looking at cleaning? The results from phase 2 was an interesting journey from exploring new ideas and back to the vacuum cleaner again.

cleaning
I am coming
Mini robotic
mini robot with suction power
⇒ climbing on walls
Auto-follow
Cleans up dirt where you go
LED Head!
Area still dirty
Area clean
RC car
Vacuums while controlling it
visualization
GOAL!
100%
70%
Taptic feedback
sends signal to smartwatch when dust/dirt has been picked up
tube
when clean
green light = no dirt left at specific position
See dirt!
transp.
visual feedback on cleaning ⇒ effect!
dirt
Gesture control of dust
Dust sucking football
Drones × Wii
Control dust-sucking drone with control
air outlets
Wii/Smartwatch
No pipes
Magnet control
moving the feet will move cleaning device

A. WHAT COULD POSSIBLY BE BETTER THAN A VACUUM CLEANER?

Phase 1 showed that vacuum cleaners are key parts of cleaning. They do however have several problems that make the cleaning experience displeasurable. A new clean keeping device has to be far better at all of the canister's weaknesses. It would also need to provide equal or better effectiveness. The guidelines and findings from phase 1 were analyzed and translated into seven areas. New clean keeping devices were found to need to be better in the following areas to create better experiences:

- **Maneuverability** – The size, weight and clumsy nature of canister vacuum cleaners were found to make them hard and effortful to maneuver. Even stick vacuum cleaners showed to be cumbersome to maneuver after a short period of time. A new clean keeping device needs to be easily maneuverable or require no maneuvering at all.

- **Ergonomics** – The same factors as above were found to lead to poor ergonomics when using vacuum cleaners. A new clean keeping device needs to allow for an ergonomic use.

- **Preparations** – Canisters were found to be cumbersome to prepare. A new clean keeping device needs to be at least as easy to prepare as stick vacuum cleaners.

- **Disturbing factors** – The sound from vacuum cleaners was found to make the user tired and disturb surrounding people. A new clean keeping device needs to provide a non-disturbing experience.

- **Effort** – Maneuverability was found to be one part of the effort while cleaning. The time spent on cleaning is another one. A new clean keeping device needs to require minimal effort and time from the user.

- **Feedback** – People were found to love the sound of dirt going through the pipe of the vacuum cleaner. A new cleaning device needs to provide positive feedback to encourage cleaning and make it pleasurable.

- **Simultaneous activities** – Current vacuum cleaners were found to make it difficult to listen to music simultaneously. A new clean keeping device needs to allow for or provide pleasurable simultaneous activities.

In fact, it was concluded that the seven areas above can be summarized in the following *clean keeping device principles, that became guidelines for the entire project*:

- **Capable** – Includes effective, which refers to performance in terms of dirt pick-up and versatility. The most important principle.

- **Easy** – Includes maneuverability, ergonomics, preparations, effort and feedback. Easy to use and easy to understand.

- **Simple** – Includes maneuverability and preparations. It refers to simplicity, which means focusing on the main function of the product. Simplicity contributes to ease of use and the experience of the product.

- **Best experience** – Includes all of the seven areas of focus, but mainly disturbing factors, feedback and simultaneous activities.

The four principles are similar to the four factors (functional, usable and reliable, convenient and pleasurable) discussed in phase 1, but adapted to clean keeping products. The different types of vacuum cleaners and the cloth are rated in relation to the canister in Table 7.

	CAPABLE	EASY	SIMPLE	BEST EXPERIENCE
Canister	Reference	Reference	Reference	Reference
Upright	0	-	0	0
Stick	-	+	+	0
Robotic	-	+	+	+
Cloth	+	+	+	0

Table 7
Rating of clean keeping products' compliance with the principles.

It was concluded that a new clean keeping device has to be far better in all of the four key areas described above to have a reason to exist. Better than the canister and better than the cloth. Such a device would have every opportunity to succeed.

B. SUCTION IS A NEEDLE IN A HAYSTACK OF TECHNICAL PRINCIPLES

The main function of clean keeping was concluded to be removing dirt from a surface or preventing dirt from landing on a surface in the first place. The brainstorming session resulted in a set of technical principles on how to move dirt or keep dirt moving (see Figure 25). Focus was on maximizing *effectiveness*, minimizing *effort* and minimizing *disturbing factors*.

As it can be seen in Figure 25, there are several technical principles to move dirt. Many of them were discarded in this project due to low feasibility. The remaining ones were categorized into the following categories:

Moving Air

It was found that many technical principles are based on moving air. And that by moving air, dirt will be moved as a wanted side effect. Moving air does however generate sound in most cases, as known from the vacuum cleaners of today.

- **Suction** – All of today's vacuum cleaners are based on suction. The advantage of suction is that it not only moves dirt, but collects it. Reach and coverage is however poor due to low velocity.

- **Blowing** – Low or high pressure jets of air are very effective in terms of reach and coverage. It is for example used to clean electronics and in leaf blowers. Spreading the dirt is a side effect since there is no collection.

- **Blowing + suction** – The idea behind combining blowing and suction was to combine the reach and coverage of the blowing with the collection that comes from suction to create a more effective technical principle.

Electrical Charge

Most particles have an electrical charge, which is why they for example stick to surfaces. Opposite electrical charges could be used to attract dirt but is fairly limited to dust and fibers. Minimal sound levels was found to be one of the main advantages.

- **Electromagnetism –** It is general knowledge that dust bunnies are attracted to electrical cords. The thought behind this technical principle was to take advantage of that attraction instead of trying to work against it.

- **Ionization** – Used in air purifiers/ionizers. Particles in the air are actively charged and a plate with opposite charge attracts those particles. Ionization could potentially be used to attract particles in any space, not only the air. The idea behind this principle was that cleaning could become dramatically more effective by extending the coverage area.

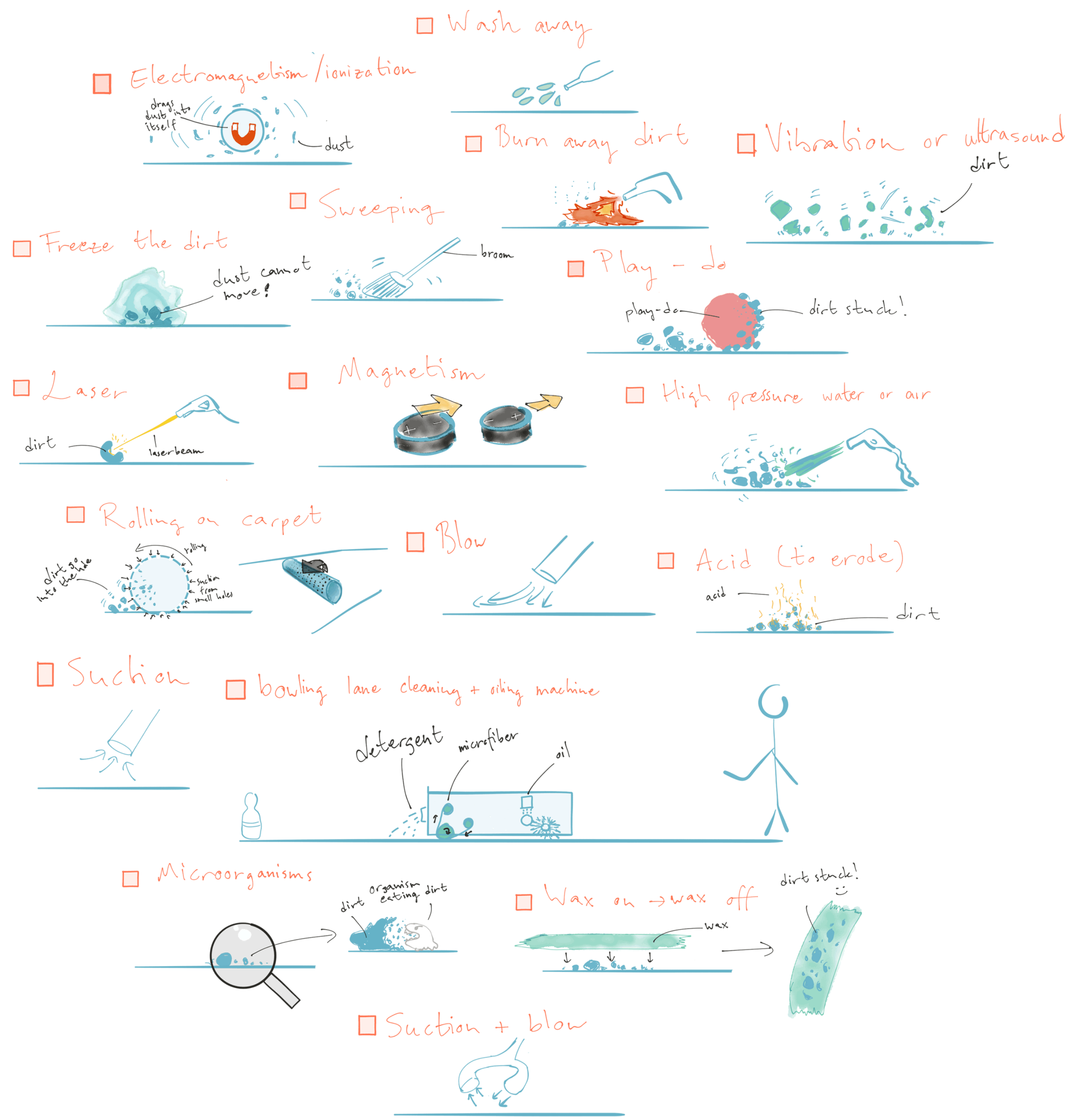


Figure 25
Technical principles to move dirt.

C. CLEAN KEEPING COULD BE LIKE GAMING... OR DANCING... OR LIKE NOTHING AT ALL...

Several ideations resulted in a variety of ideas and concepts on clean keeping. The findings are presented in this section.

Proactive Clean Keeping Is About Dirt Spread Prevention

As mentioned earlier, clean keeping can be removing dirt from a surface or preventing dirt from landing on a surface in the first place. In other words, there are two types of clean keeping; proactive and reactive. Reactive cleaning is removing the dirt when it has already overtaken a space, and is what in popular speech is called *cleaning*. Proactive clean keeping is preventing dirt from overtaking a place in the first place. It was concluded that dirt can be stopped at three different places or phases; at the source, in the transportation media or at its destination. The travel of dirt is of course not linear; dirt will continue to travel to another destination after the first one. The three phases are visualized in Table 8 below.

Table 8
The travel of dirt and examples in the different stages.

SOURCE	TRANSPORT	DESTINATION
Human Outdoors Textiles (e.g. couch, bed, clothes, curtains) Plants Pets	Human (e.g. socks) Pets Air Floor	Floor Interior surfaces Textiles (e.g. couch, bed, clothes, curtains) Plants

Proactive clean keeping is in other words about stopping the dirt at the source or during transport, while reactive clean keeping is about collecting the dirt at the destination or during transport. The source of dirt was actually heavily discussed during the Electrolux workshop. What if textiles for example didn’t release dust, or if they could attract and encapsulate dirt to keep it from spreading? It was concluded that proactive clean keeping is in general equal to dirt spread prevention. The ideations generated several ideas, some of which were related to dirt spread prevention. Some of those ideas are illustrated in Figure 26.

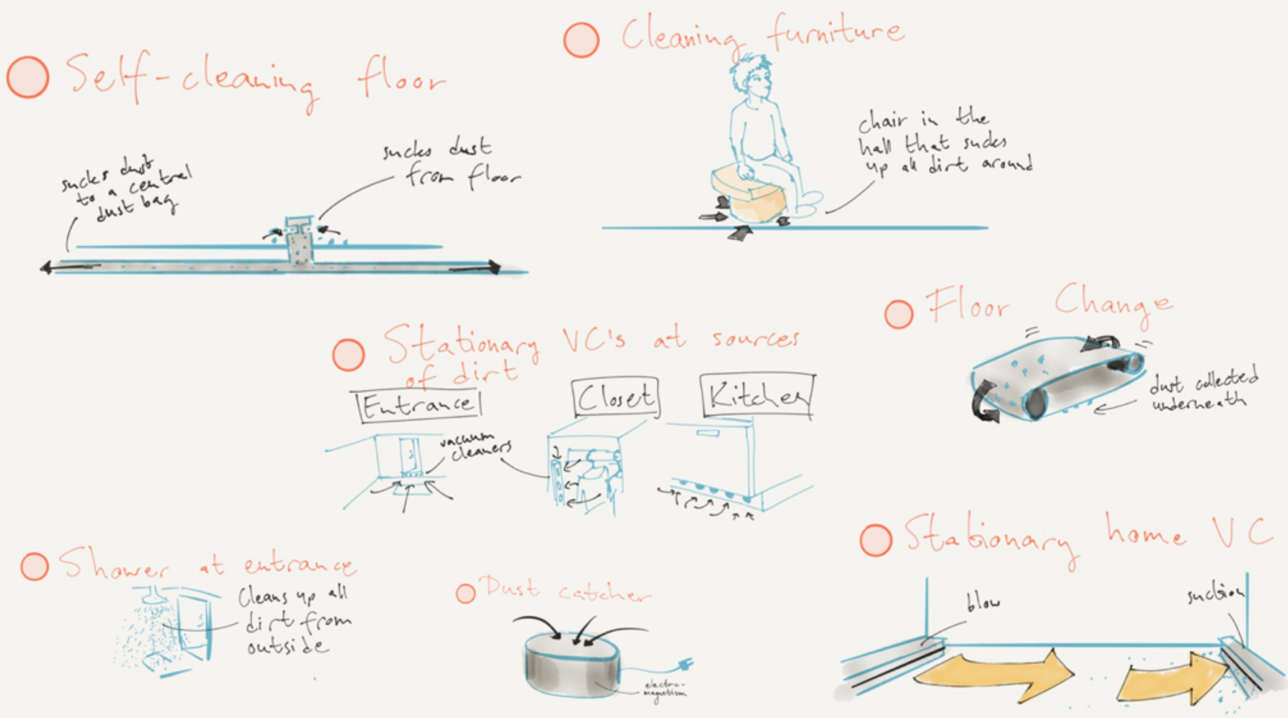


Figure 26
Dirt spread prevention ideas.

Most of the dirt spread prevention ideas were based on preventing the dirt from leaving the source. As can be seen from the sketches, many of them are built into the home. Such solutions open up for completely new possibilities but would require major construction work in existing homes, which is why they were disregarded in this part of the project. Ideas based on standalone devices that catch the dirt such as the dust catcher and furniture with built-in dirt collection were however saved as inspiration in later parts of the project. They are described briefly below.

- **Dust catcher** – Cords attract dust but are cumbersome to clean. The idea behind the dust catcher was to create an area that is even more attractive to the dust than the cords by using electromagnetism. A flat smooth surface would be considerably easier to clean. In the idea of a dust catcher was also air purifiers/ionizers. What if ionizers could be made into clean keeping tools by extending their functionality for example?

- **Cleaning furniture** – There is furniture in every home and the user studies showed that people have limited storage capabilities. Cleaning capabilities built into furniture would solve those problems. The studies furthermore showed that a lot of the dust gathers beneath furniture because there is no movement from walking people for example.

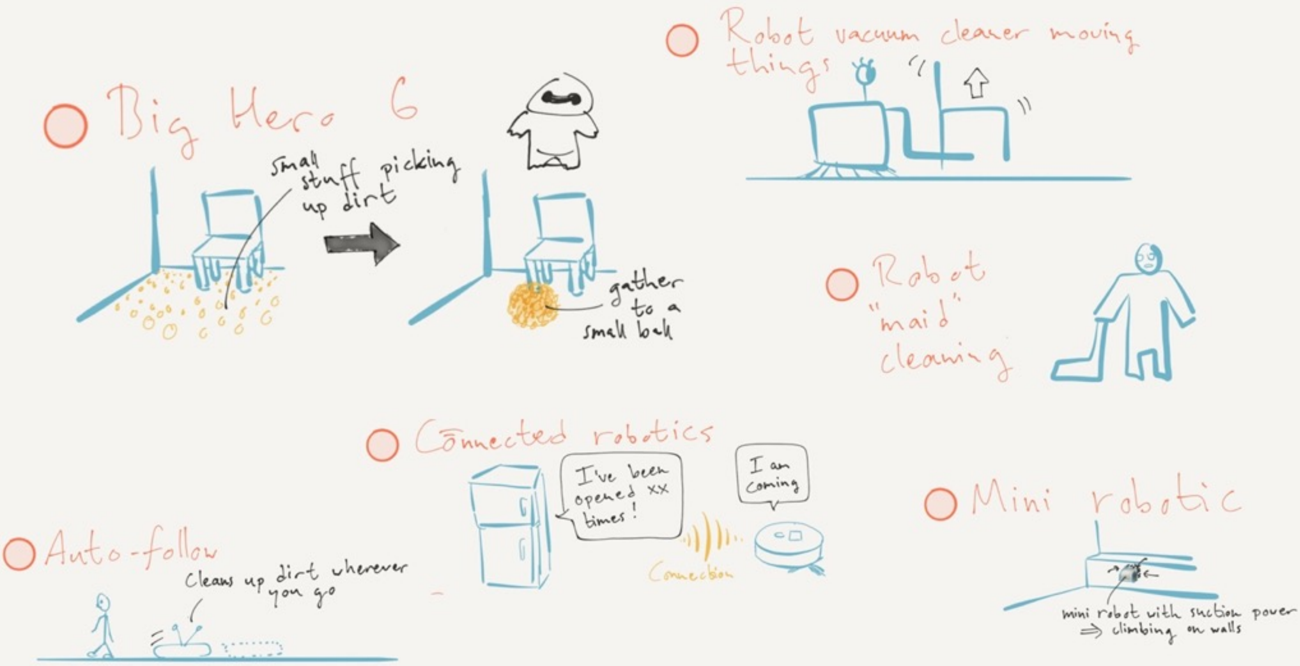


Figure 27
Ideas on automated reactive cleaning.

Reactive Clean Keeping Has Many Unknown Faces

People like the results of cleaning and find pleasure in seeing the immediate difference of wiping a cloth over a surface. Visual, olfactory and haptic feedback was concluded to be much stronger when occurring in close relation to cleaning. Some of the pleasures of cleaning were furthermore found to be related to the fact that the user completes a cleaning session by hand. So there are many reasons to amplify those pleasures and keep at least the fun parts of reactive clean keeping when designing a new clean keeping device. It was concluded that reactive clean keeping can be automated, semi-automated or manual. Some of the ideas on automated reactive cleaning are presented in Figure 27.

The robotic vacuum cleaners of today are of course examples of automated reactive cleaning devices. During the Electrolux workshop it was concluded that robots are interesting since they're actually the easiest solution for the users. Today's robotic vacuum cleaners have several problems but the participants of the workshop meant that technology will evolve so that robotics can become better in the future. The ideas in the sketch above were generated to try to solve some of the problems that robotic vacuum cleaners have. Some of the ideas are briefly described below:

- **Big Hero 6** – The idea to use several robots that can act on their own or together came from the animated Disney movie "Big Hero 6". Small robots would reach into every corner and crevice and could potentially even climb or fly. Together they would make a powerful robot for open floor areas.

- **Robotic vacuum cleaner mover** – The fact that things have to be moved around means that the robotic vacuum cleaners of today cannot reach everywhere. The idea was to introduce a furniture moving robot or add that functionality to robotic vacuum cleaners. It was found in the user studies that a lot of the effort in cleaning comes from moving stuff around to reach everywhere.

- **Auto-follow** – Following people around in the home is an automated and semi-proactive solution. The idea was that a lot of dirt comes from and is spread by humans themselves.

- **Connected robotics** – Another semi-proactive approach would be to clean where dirt comes from. The fridge could for example tell the robotic vacuum cleaner to come clean beneath it because the door has been opened many times.

Most of the ideas generated in phase 2 were however on manual or semi-automated clean keeping, and based on amplifying the pleasures of cleaning. Special focus was on the design guidelines mentioned earlier: easy, simple, capable and best experience. Ease and simplicity were attacked together, while ideas on capability and experience were investigated separately. The results are presented in the following sections.

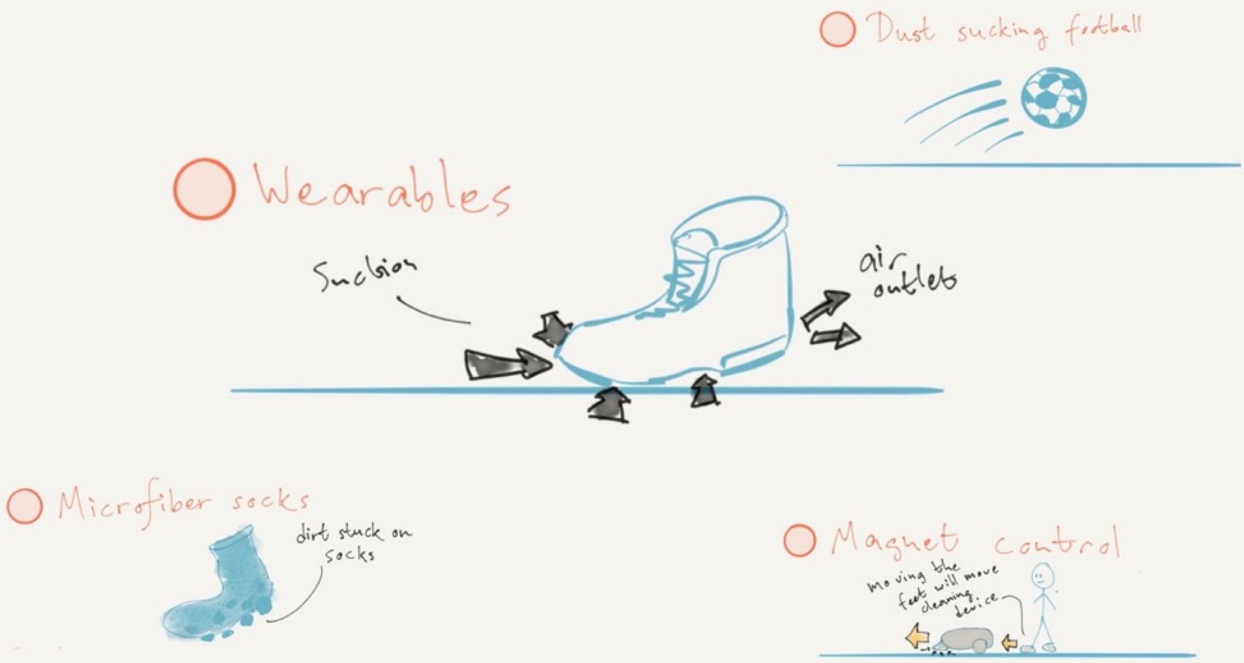
What Is Easy and Simple Clean Keeping?

In the analysis on what other companies do to create innovative products, it was found that creating a new interface might be a way to make a device **easy and simple**. Apple is for example famous for creating simplistic products that are pleasurable and user friendly. The have introduced revolutionizing products such as the Mac, the modern laptop, the iPod and the iPhone. Steve Jobs mentioned in 2007 when introducing the iPhone that a breakthrough technology lies behind every breakthrough product. In fact, all of the products mentioned above included a new, easy and simple interface: the mouse + graphical user interface, the trackball, the click wheel and lastly the multi-touch of iPhone. The interface of a vacuum cleaner is the way in which the user interacts with the product. Two interfaces were found in this project, one is effortful and the other one is simple and easy but results in poor capability:

- **One hand maneuvered pipe** – Canisters, uprights and sticks all offer the same way of interaction, and have done so since the very first vacuum cleaner. They require the user to directly control the floor nozzle by moving a pipe handle back and forth. The one hand maneuver pipe interface is capable as it makes the user *able* to clean a lot of different areas. However, the movement itself is effortful over time, especially with uprights and sticks that weigh considerably more than the canister in the area of interaction. The immediate connection to the nozzle furthermore requires the user to bend over and twist to reach everywhere which makes cleaning even more effortful and painful.

- **Remotely controlled autonomous robot** – Robotic vacuum cleaners require no maneuvering at all. They are initiated, terminated, programmed, etc. through a remote control. Overall, that results in an immensely less effortful experience. The actual interface of the remote control does of course affect the overall usability of the vacuum cleaner, which might make it difficult rather than easy to use. As of today, robotic vacuum cleaners might be easier and simpler than other vacuum cleaners, but nowhere near as capable.

It was concluded that a new clean keeping device needs a new interface. An interface that is easier and simpler than the canisters' and allows for more capability than the robotics'. One hypothesis was that such an interface would lower the threshold and eliminate the mental obstacle to start cleaning. Some of the ideas on new interfaces are presented in the following sections.



Using Your Feet

Ideas on interfaces related to feet are presented in Figure 28. The hypothesis was that feet are closer to the floor and therefore a more natural part of the interaction in floor clean keeping. Fine motor skills are however considerably worse in feet compared to hands.

Figure 28
Ideas on new interfaces – using your feet.

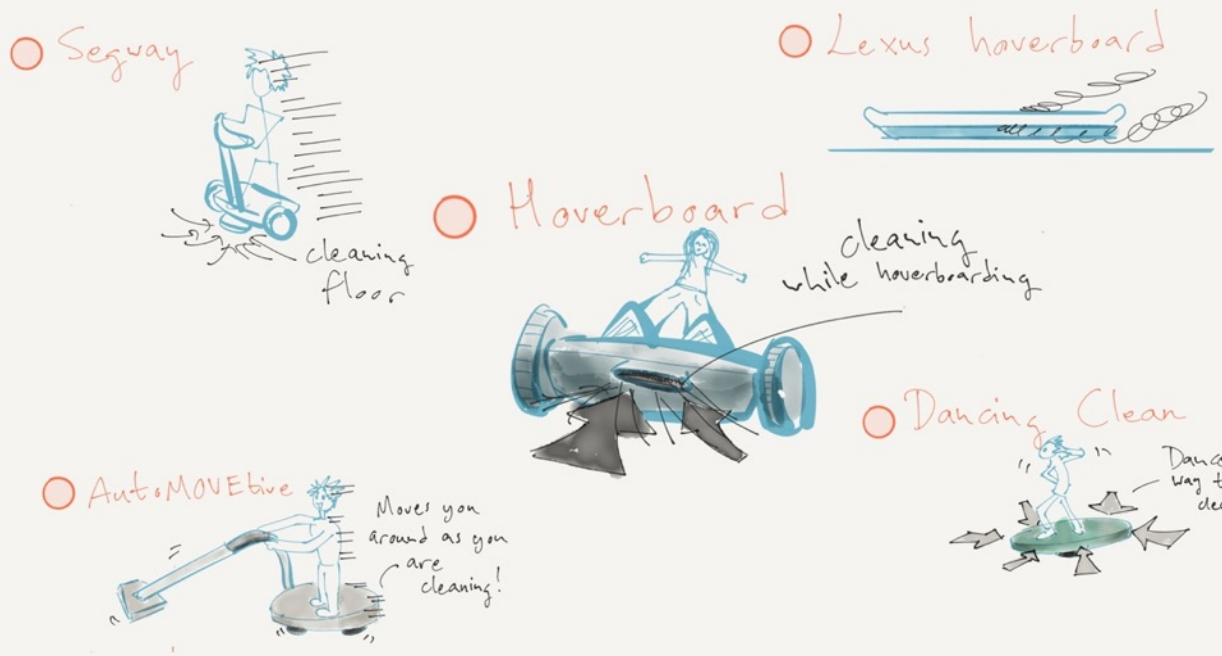
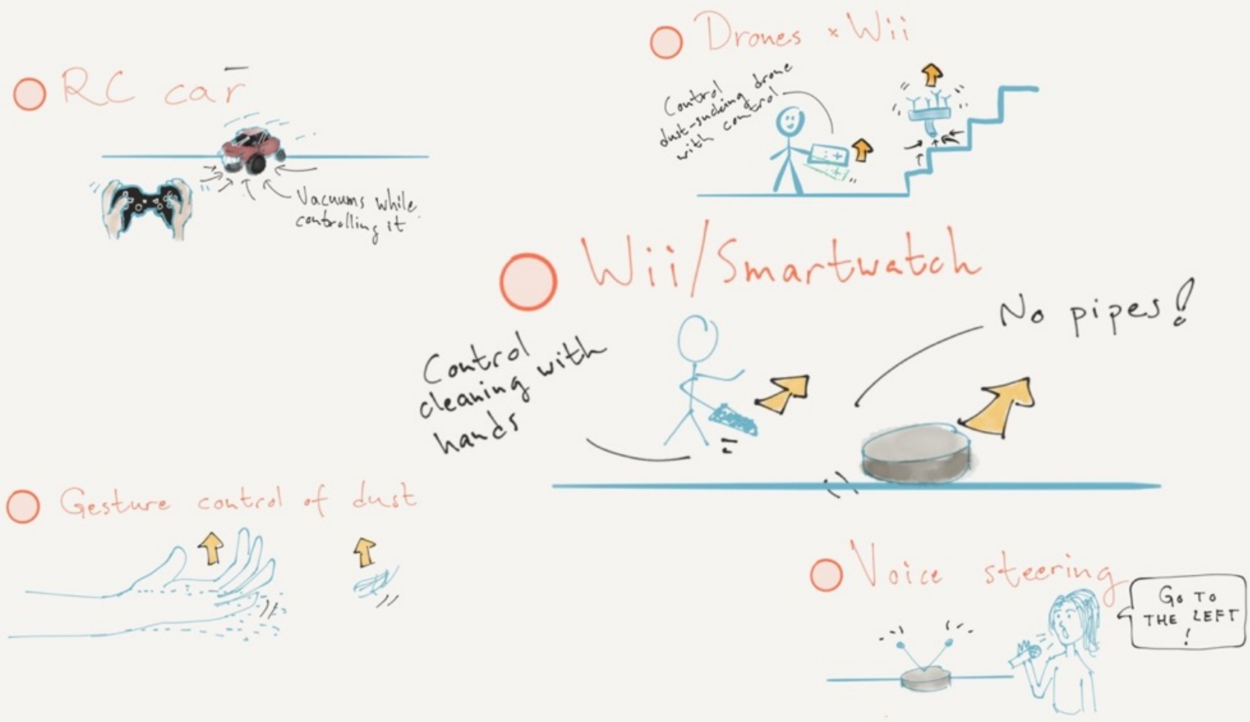


Figure 29
Ideas on new interfaces – ride and clean.

Ride and Clean

Figure 29 shows ideas on interfaces where the function of relocation is moved to the clean keeping device itself and where the user rides along. In that way the user would still be close to the cleaning itself, but with much less effort.



Remote Cleaning Is Easiest and Simplest

To find radically different interfaces and ideas, an ideation session was based around the question *"how would you clean in a dream world?"*. A recurring theme in that session was magic. One idea from the Electrolux workshop was for example to have a field going through the apartment to remove dirt. Or what if clean keeping was as easy as pointing a magic wand at a surface? If cleaning did not have to be thorough, but the results still were? It was found that clean keeping would be much easier if the user would not have to touch every square centimeter of a surface but rather swipe over it at a distance. The notion of *remote cleaning* was invented. Four categories of ideas on remote cleaning were found.

Figure 30
Ideas on remote cleaning - remote control.

Remote Control

Figure 30 shows ideas on clean keeping devices that are remotely controlled. Inspiration came from video games. Making cleaning into a game could make it more fun. A lot of the worries about robotic vacuum cleaners are related to their ability to navigate correctly and to not get stuck. Remotely controlling a robot is a semi-automated solution that puts the user in control but assigns the effortful tasks to the robot itself.

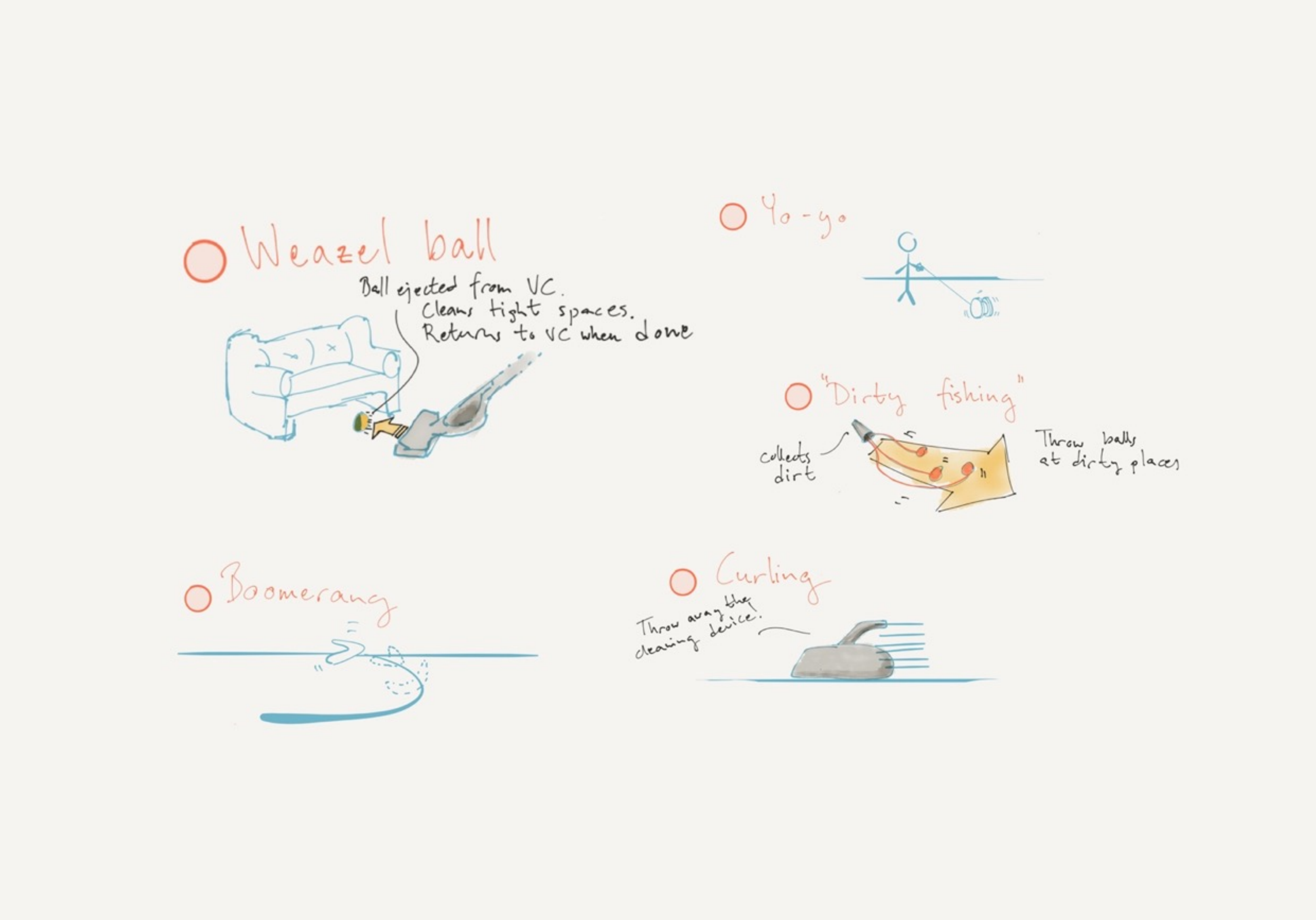
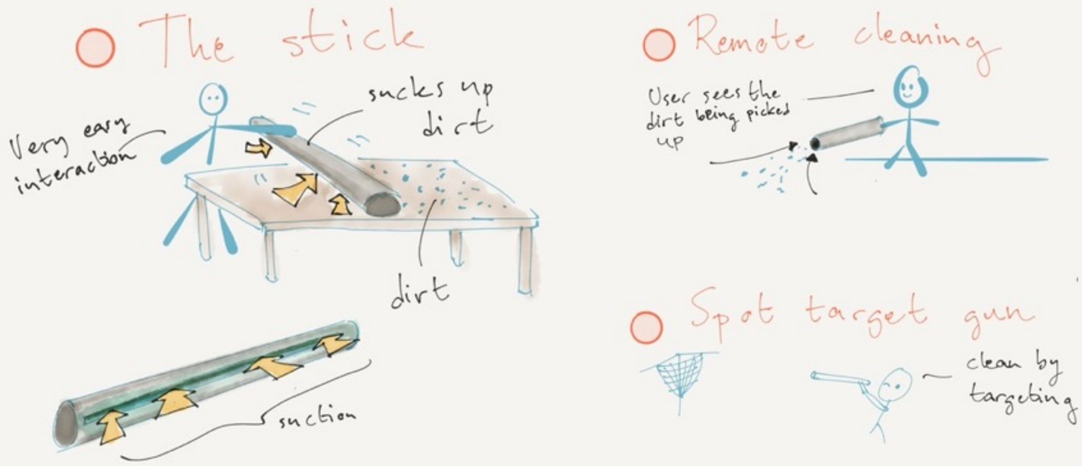


Figure 31
Ideas on remote cleaning - throw and retrieve.

Throw and Retrieve

Reach was one of the biggest topics from the online survey in phase 1. The ideas in Figure 31 are therefore all about reaching those tricky places. The main idea was to throw away something that can capture the dirt and then retrieve it. By easing the effortful parts of cleaning, cleaning should become easier in general.



Magic Wand

The core of the concept remote cleaning was magic. Figure 32 shows ideas that bring some magic to cleaning. The main idea was to target a surface from a distance to make it clean. Such a solution would make one swipe cover huge areas instead of just a few square centimeters.

Figure 32
Ideas on remote cleaning – magic wand.

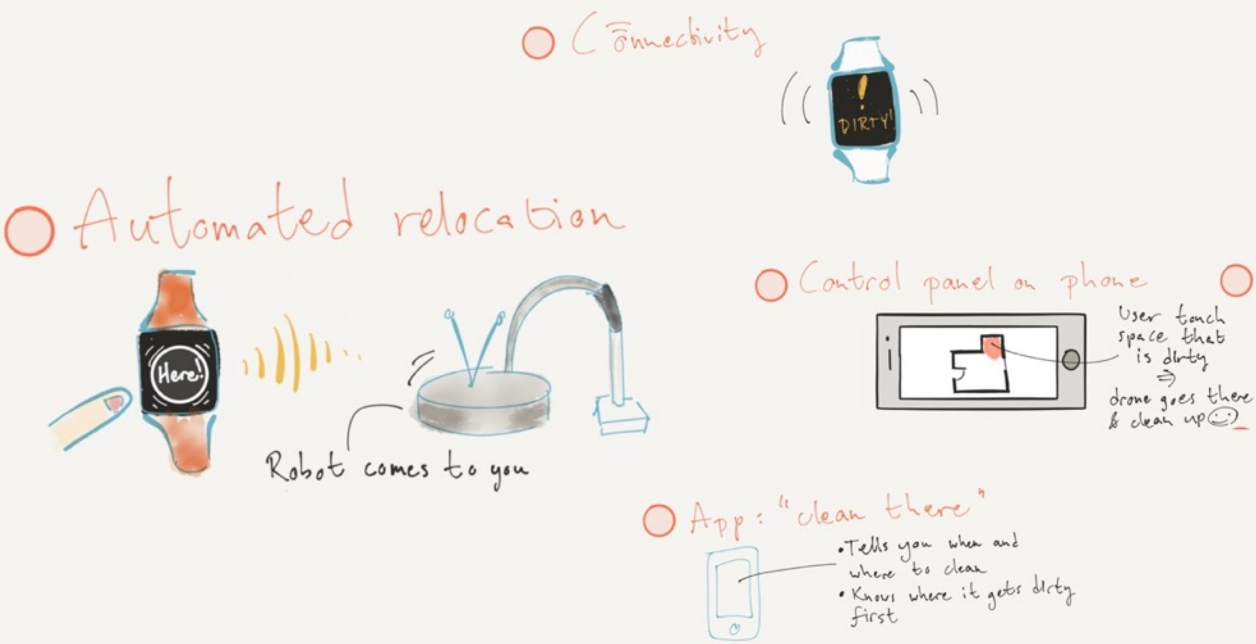


Figure 33
Ideas on remote cleaning – connectivity.

Connectivity

Cleaning could become much smarter. Figure 33 shows ideas on how connectivity could create interfaces that help the user during cleaning and in-between cleaning sessions. A graphical interface in combination with connectivity could for example put the user in control, but also provide feedback and help on cleaning and cleanliness.

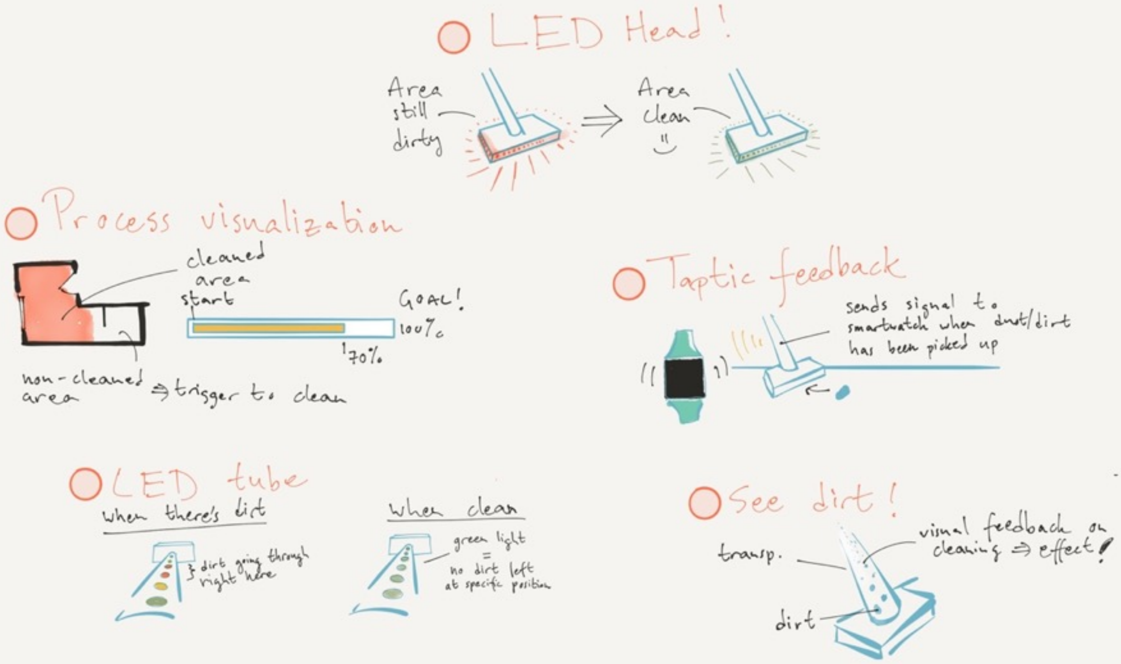


Figure 34
Ideas on how to create the best experience – amplified feedback.

The Best Clean Keeping Experience

As can be seen from the ideas presented so far, there are several ways to make clean keeping easier and simpler by introducing new interfaces and therefore new ways to interact. An easier and simpler way to clean creates a better user experience but it was found that there are some areas in which added value could enhance the experience even more. Ideas on how to create the **best experience** are presented below.

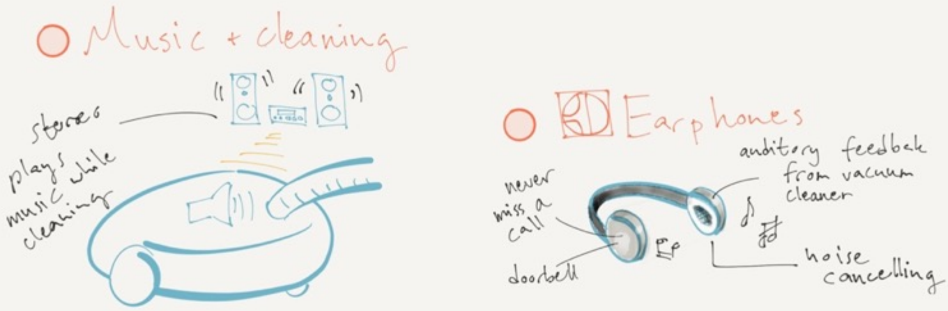
Amplified Feedback

Since seeing the difference when cleaning and the results of cleaning is pleasurable, amplified feedback should increase the pleasure and encourage people to clean. A lot of the feedback from vacuum cleaners today is auditory, which conflicts with the wish to listen to music while cleaning. Focus was therefore on transferring auditory pleasure to haptic and visual pleasure by generating ideas on visual and haptic feedback. The hypothesis was that showing progress and rewarding the user would be motivating. Ideas on amplified feedback are presented in Figure 34.

Figure 35
Ideas on how to create the best experience – gamification.

Gamification

What if the simultaneous pleasurable activity during cleaning was the cleaning itself? Figure 35 shows ideas on gamification. Making cleaning into a game should motivate users to clean, especially the younger ones. The idea was to make cleaning into dirt hunting and thereby to collect points. In that way, different family members could compete against each other or work together when cleaning.



Music

Since the studies showed that a huge amount of people like to listen to music while cleaning, clean keeping products should support that. Figure 36 shows ideas on the combination of music and cleaning. A set of earphones could for example reduce the noise from the vacuum cleaner but also allow for pleasant auditory feedback while listening to music or making calls.

Figure 36
Ideas on how to create the best experience – music.

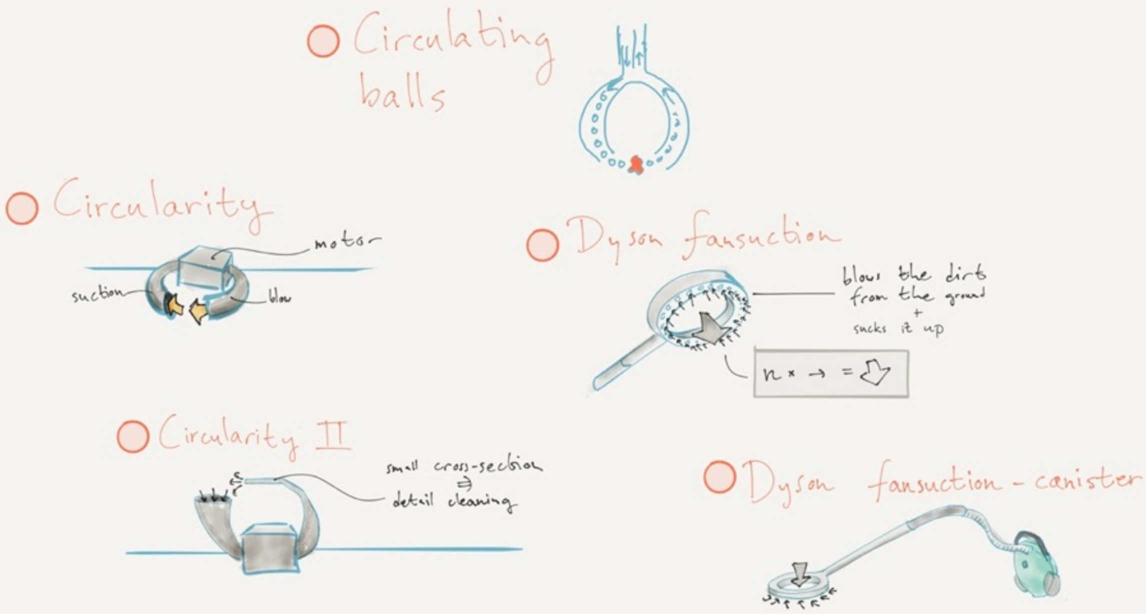


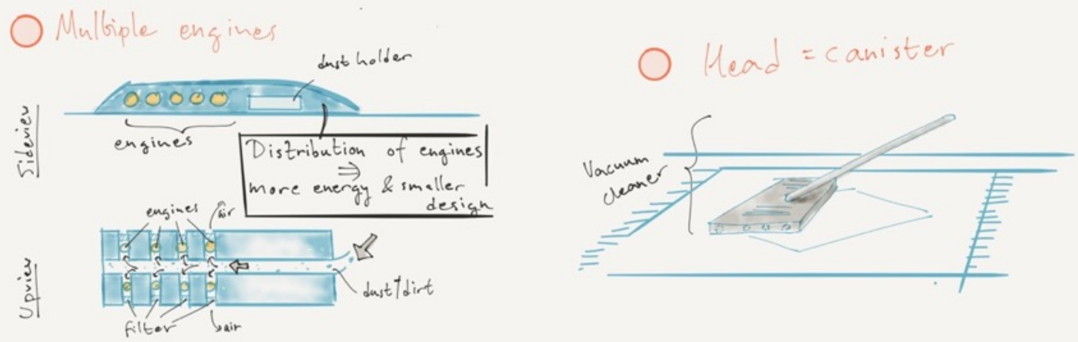
Figure 37
Ideas on how to increase capability - blowing + suction circularity.

The Most Capable Clean Keeping

As mentioned several times, the effectiveness or capability of a clean keeping device is absolutely crucial to its existence. It doesn't matter if the device is easy, simple and provides the best user experience if it is not capable of fulfilling its main function. Ideas on how to increase the **capability** of a vacuum cleaner are presented below:

Blowing + Suction Circularity

Combining blowing and suction was one of the technical principles that were found to have the opportunity to make clean keeping more effective. Blowing can release dust from a surface at a distance and therefore also make cleaning more efficient. Figure 37 shows ideas on the combination of blowing and suction. One interesting factor is for example that vacuum cleaners, and any cleaning tool for that matter, reemit dust into the air while cleaning. By recirculating that air into the system again, cleaning should be more effective.



Several Motors and New Form Factors

Vacuum cleaners are locked into certain form factors because of the similar components in all of them. Figure 38 shows ideas on how to allow for new slimmer designs while keeping or improving capability. Several smaller motors would for example make it possible to design canisters, uprights and sticks in new ways. Or even completely new products. Slimmer designs would also make it easier to reach into those small and tricky places.

Figure 38
Ideas on how to increase capability - several motors and new form factors.

D. EVALUATION OF IDEAS – THE VACUUM CLEANER MIGHT ACTUALLY BE GOOD ENOUGH

All of the ideas generated in phase 2 were evaluated along the axes of innovation and realizability. The following ideas were disregarded due to lack of innovation or low level realizability:

- **Solutions built into the home** – Many of the proactive clean keeping ideas were based on building them into the home. Such solutions would be feasible if looking at a very long-term perspective when building new homes, but were found to require too much construction work in existing homes.

- **Climbing and flying robots** – Developing flying or climbing robots was concluded to be too expensive to reach the masses. Such robots were furthermore found to risk to interfere with peoples living and could require permanent home installations.

The general concept of *remote cleaning* was found to be one of the most innovative and realizable ones and the remaining ideas were all considered as innovative and realizable enough. All of the ideas were therefore showed and discussed at the Electrolux workshop. The workshop resulted in several good opinions and findings:

- **Don't make cleaning into more than it is** – While many of the presented ideas would provide a better experience for some people initially, the workshop participants meant that the positive experience might fade over time. They recommended to disregard ideas such as "ride and clean" and "gamification". They furthermore emphasized the importance of fulfilling one function to the full extent and to not overcomplicate such a simple task as cleaning.

- **The best interface is no interface** – The participants in the workshop meant that a new interface could make a huge difference but that, in the end, people don't want to clean anyway. No interface would mean no worries about cleaning, cleaning equipment or cleanliness in general.

- **Keep the positive parts of cleaning** – The concept of amplifying the pleasures of cleaning was well received during the workshop. The participants meant that every positive aspect of cleaning should be kept and amplified, while focusing on making the difficult and displeasurable things more pleasurable. They especially talked about the fact that people like the results of cleaning. How could a lasting experience be created?

To keep the positive parts of cleaning also referred to keeping the cleaning equipment that is actually good. The participants questioned whether **the vacuum cleaner is good enough** or not. They meant that the vacuum cleaner might be good enough to clean open floor areas and that the difficulties of cleaning are in reaching beneath furniture and moving decorations around to clean everywhere. Two interesting areas were mentioned:

- **Surfaces apart from open floor areas** – The participants in the workshop meant that most of the improvements to cleaning could be made where it is difficult to reach. Surfaces like beneath the couch, on a shelf or on a coffee table.

- **Air** – This project's focus on the entire cleaning situation and context was well received. The participants in the workshop liked the concept of air quality as cleanliness. Such a view includes both clean surfaces and good air quality, which creates an overall better indoor climate. It was furthermore noted that the air in Sweden is very clean compared to other countries. Keeping the air clean is therefore interesting on a global level.

E. FURTHER VACUUM CLEANER TESTS

Since discussions from the workshop led to the question whether the vacuum cleaner is better at cleaning certain areas than other areas, participatory observations including testing of Electrolux Ergorapido (stick vacuum cleaner), Electrolux UltraOne (bagged canister vacuum cleaner) and a regular microfiber cloth on different types of surfaces were conducted with one of the thesis authors being the participant (see Figure 39). The tests generated valuable insights about the different cleaning tools and their capabilities on different types of surfaces.

Figure 39
Different pieces of equipment, surfaces and positions tested.

The Bagged Canister Vacuum Cleaner

Open floor areas where there are no tables and chairs are by far the easiest areas to clean with the canister, due to the canister's long range and wide floor nozzle. Areas beneath tables and chairs are a bit more problematic: chairs need to be moved several times and to reach and vacuum beneath tables was expressed as a bit strenuous. What's even more strenuous though is to reach beneath drawers, as the participant needed to almost lie down on the floor to reach.

What's common for all tasks that require vacuuming above floor height with the canister is that it's strenuous for the upper body – the handle and its tube expose the user to a constant weight load. On the positive side, the round, add-on brush was perceived as very helpful as it facilitated the removing of dirt from the surfaces.

Moreover, the vacuum cleaner was a struggle to take out from its storage as the main unit weigh a lot and the tube got caught in other cleaning tools inside the storage. On the other side, the weight of the vacuum cleaner was not a problem when actually vacuuming on a hard floor.

The Stick Vacuum Cleaner

Similar to the canister, the stick vacuum cleaner proved to be very manageable on open surfaces. But due to its heavy weight, cleaning beneath tables and chairs was more strenuous than with the canister vacuum cleaner. Furthermore, its big size (in terms of maximum cross-section) did not allow to reach beneath drawers with narrow gaps.

The stick vacuum cleaner in this test (Electrolux Ergorapido) had a built-in handheld vacuum cleaner, which invites the user to clean on surfaces above floor height as well. With the add-on brush, such activities proved to be possible, but very burdensome – the nozzle of the handheld is narrow and thus requires more time to clean the same space than with the canister and its large add-on brush. Furthermore, the handheld unit is very heavy and causes pain in the hand, arm and shoulder if used for more than half a minute.

In contrast to the canister, the stick vacuum cleaner is very easy.

In contrast to the canister, the stick vacuum cleaner is very easy to start using – it consists of only one piece of product (compare to the canister, which consists of a main unit, the tube and the pipe with the floor nozzle), it requires very little lifting (only when lifting it out of its charging station) and does not require the user to handle a chord (again, compare to the canister which requires the user to pull out the chord, find an outlet, insert the chord into the outlet and be aware of the chord while vacuuming).

The Cloth

The cloth was by far the best for cleaning smaller surfaces on heights around 100-150cm, such as shelves and interior decorations. By the wording "best", the participant expressed satisfaction about the effectiveness of cleaning with a cloth. Surfaces become almost "shiny". The cloth also makes sure that everything that is being wiped becomes clean. The cleaning tool is versatile as it can be shaped in almost any way in order to reach the narrowest of spaces.

However, the downside of the cloth is that it requires regular rinsing, rubbing and wringing during the cleaning session, which is seen as burdensome. When there's a lot dust on a surface, wiping it with a too wet cloth can instead result in making the dust wet, which makes the dust much more difficult to remove from the surface.

The cloth was not tested on floor areas, due to the obvious, exhaustive nature of the task.

F. THE FORTE OF THE VACUUM CLEANER: OPEN FLOOR AREAS

One interviewee from the user studies had a very interesting insight: *"Actually, cleaning a home with no furniture is quite easy…"*. With the result of the vacuum cleaner tests and the Electrolux workshop in mind, it evidently became very clear that the vacuum cleaner, whether it's a bagged canister or stick, is excellent for cleaning of open floor areas! In terms of ease of use, time and ergonomics, the interface of the vacuum cleaner is far more optimized for cleaning open floor areas than for cleaning e.g. beneath tables or on shelves. Looking back at the design guidelines for clean keeping devices, the vacuum cleaner is the *best experience*, *easy*, *simple* and *capable* for clean keeping of open floor areas.

The cloth on the other hand is very suitable for areas such as shelves and tables. The satisfactory result of the cloth is difficult to compete with, since vacuuming these areas is ergonomically burdensome and does not remove dirt as effectively.

G. CONCLUSIONS AND GUIDELINES

The exploration and evaluation of ideas, and as well as inspiration from other product categories, resulted in many insights. Conclusions from the second phase of the project are listed below, followed by guidelines elicited from these conclusions in Table 9.

- The design guideline for a new clean keeping device includes four principles: it should be *capable, easy, simple* and offer the *best experience*. A new clean keeping device needs to fulfill these principles far better than the canister and the cloth.

- Technical principles that concern *moving air* and *electrical charge* in order to move dirt are the most feasible ones.

- There are two types of cleaning: *reactive* and *proactive*.

- Proactive clean keeping is equal to dirt spread prevention.

- Reactive cleaning can be *automated*, *semi-automated* or *manual*.

- A new, breakthrough clean keeping device needs a new interface – simpler and easier than the canister vacuum cleaner, and allowing for more capability than the robotic vacuum cleaner.

- Cleaning would be made easier if the user did not have to touch every square centimeter of a surface – *remote cleaning*.

- Keep the positive parts of cleaning. Pleasure from cleaning comes from *visual*, *olfactory* and *haptic* feedback – while cleaning and after cleaning.

- The best interface is no interface. Simplicity in the solution lies partly in not making a cleaning device that requires advanced user knowledge and a complicated product interface.

- Do not make cleaning into more than it is. Overcomplicating a simple task as cleaning by e.g. games and dancing is not sustainable in the long run.

- The vacuum cleaner is *optimized for cleaning open floor areas*.

- Cleaning of air and areas other than open floor surfaces are in need of improvement.

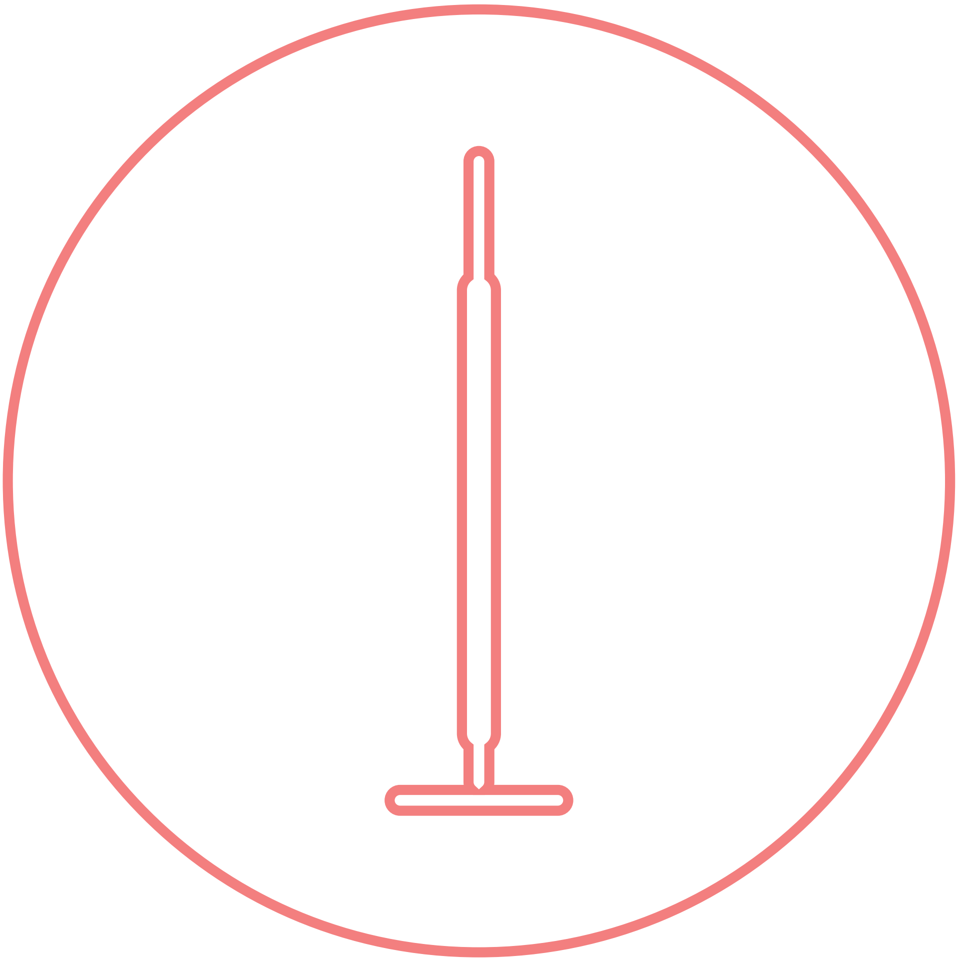
GUIDELINES (FUTURE CLEAN KEEPING PRODUCTS SHOULD...)
Offer improvements from today's cleaning in terms of maneuverability, ergonomics, preparations, disturbing factors, effort, feedback and simultaneous activities.
Be easy, simple, capable and offer the best user experience.
Be as proactive as possible.
Apply feasible technical principles for moving dust such as suction, blowing, blowing + suction, electromagnetism and ionization.
Be extremely smart if fully automated.
Introduce a new interface to the market that is as down-scaled and simplistic as possible
Feel like magic
Not be based on positive experiences that are temporary, such as "gamification" and dancing
Consider the vacuum cleaner as the optimal solution for open floor surfaces
Consider air quality

Table 9
Guidelines found in phase 2.

07.

PHASE 3: **STICK TO THE STICK**

An important conclusion from phase 2 was that vacuum cleaners and their interfaces are optimized for cleaning open floor areas. Thus, cleaning beneath e.g. furniture and on tables with vacuum cleaners are way more difficult in terms of effectiveness and ergonomics. In other words, the vacuum cleaner is not *easy*, *simple*, *capable* and does not provide the *best experience* when cleaning these kinds of areas in the home. Phase 3 investigates the future role of the vacuum cleaner in clean keeping. What about reallocating some of its functions to other devices? May the vacuum cleaner play a smaller part in something much bigger? As in several devices working together to enhance the cleaning experience?



A. LET THE VACUUM CLEANER BE A VACUUM CLEANER

It was concluded in phase 2 that the vacuum cleaner is good, or even really good, for cleaning of open floor areas. So what are the other things a vacuum cleaner can do and why are they not as good? The regular floor nozzle is used to clean open floor areas, but to clean other surfaces it was found that the user need to use other nozzles. The 3-in-1 nozzle that is included in most vacuum cleaners and presented in Figure 40 can for example be used on several surfaces. A description of each nozzle is presented in the list on the next page.

Figure 40
3-in-1 nozzle. Top-left: crevice nozzle. Top-right: brush nozzle. Bottom: furniture nozzle. (Source: Electrolux, 2016h)

- **Brush nozzle** – The mini brush can be used to clean hard surfaces or tight spaces. It is an alternative or complement to the cloth and is suitable for shelves and tables for example. The fact that it is attached to a tube or vacuum cleaner makes it heavy and cumbersome to maneuver and use though.

- **Furniture nozzle** – The nozzle that looks like a mini floor nozzle is especially made for furniture and other textile surfaces. It is probably one of the best ways to clean such surfaces, but it is just as cumbersome as the brush nozzle.

- **Crevice nozzle** – The crevice nozzle can be used to reach really tight spaces such as corners and crevices. The corner between a floor and a wall is one example. The problem is that such a nozzle is hard to maneuver from standing height, so the use requires bending over in many cases. As with the other nozzles, it suffers from being attached to the vacuum cleaner.

It was found that while many of the functions that the nozzles provide are wanted, they are all compromises in their current execution. All of them are in fact cumbersome and effortful to use above floor height over time, and also hard to maneuver from a distance. It was concluded that all of the extra functions they provide are added to a platform that is not made for them in the first place. In fact, TV remote controls suffer from a similar problem. When remotes were introduced they were great for switching channels, adjusting volume and turning on/off. Over time, several buttons, functions and channels have been added. Such additions have increased the number of functions but reduced the usability of TVs in general. The same goes for vacuum cleaners. Their main function – to clean open floor areas – is still great but the efficiency of the other functions is limited. Based on that analysis it was concluded that the vacuum cleaner should be reduced to its main function to make it simpler and more purposeful.

All of the extra functions they provide are added to a platform that is not made for them.

Whether all of those functions really should be removed or not can be discussed since they, in fact, are useful. Vacuum cleaners are at their best when cleaning open floor areas, and that experience can be improved by making vacuum cleaners even simpler, easier and more capable. Removing the extra functions is one way to do that. Such suggestion is also based on the fact that all of the extra functions could be improved if assigned to another part of the clean keeping mesh that constitutes the future clean keeping system. Focus for the vacuum cleaner should be on optimizing and creating the very best experience of cleaning open floor areas by making it easier, simpler and more capable.

B. WHAT IS THE STANDARD?

Users meant that the canister is the standard of vacuum cleaners and it was concluded that the canister's capabilities are what makes it so hard to beat in phase 1. So what is considered as standard or good capabilities? To make it easier for consumers, the European Commission (2013a) developed a set of regulations around vacuum cleaners' capabilities.

The store visits during phase 1 of the project showed that most of the modern canister vacuum cleaners are rated A or B (on the scale A-G where A denotes great performance and G denotes a performance just above the legal, acceptable limit) on hard floors, and B or C on carpets. Canisters furthermore showed to re-emit very small amounts back into the air with A or B ratings. It was therefore concluded that those are the standards for new clean keeping devices to live up to – in terms of capabilities.

C. STICKS WILL SOON BE AS GOOD AS CANISTERS

Since the user studies showed that stick vacuum cleaners have many desirable properties, such as ease of use, quickness and small size, it was decided to investigate their biggest weakness further. Many people had the perception that sticks are not powerful and effective enough, and therefore only good for quick temporary intermediate cleaning. As mentioned in phase 1, many people were extremely surprised by the actual dirt pick-up up of the Ergorapido however. Further investigation showed that sticks actually have comparable dust pick-up to some canisters. Electrolux (2016i) claimed that their stick vacuum cleaner *Ultrapower* has dust pick-up capabilities that are comparable to a canister from AEG (AE7810). Bosch (2016a) also claimed that their stick *Athlet* provides the same cleaning results as canisters, specifically their own canister BGL32400. Viivilla.no proved that claim true by testing the Athlet and concluded that Bosch's stick is capable enough if the user is living in an apartment or small house. The dust pick-up abilities of Athlet and Ultrapower were further specified using the European Commission's rating scales. The ratings presented in Table 10 are based on ratings of the comparable canisters (the capabilities of Bosch BGL32400 are similar to Bosch BGL3ALLGB and therefore to the Athlet (Bosch, 2016b)).

The Stick *Bosch Athlet* provides the same cleaning results as some canisters.

Table 10
Stick vacuum cleaners' capabilities.

	ELECTROLUX ULTRAPOWER	BOSCH ATHLET
Dust pick-up on hard floor	-	D (Bosch, 2016b)
Dust pick-up on carpet	D (Welt der Technik, 2015)	D (Bosch, 2016b)
Dust re-emission	-	-

As can be seen from the table above, the sticks from Electrolux and Bosch are, in fact, similar to canisters. That is a modified truth since most modern vacuum cleaners perform better, but it also means that the sticks are closing the gap to canisters in terms of capability. It was therefore concluded that it is reasonable to think that stick vacuum cleaners could replace canisters in the future – at least for cleaning open floor areas.

It was noted that sticks are not rated in terms of dust re-emission, neither in their specifications or in the comparisons to canisters. A sales person during the initial store visits did however mean that sticks are not as suitable for allergists since they don't filter the air as well, which is reasonable since sticks don't have the same advanced HEPA-filters. It was therefore concluded that, if the stick is the future of vacuum cleaners, dust re-emissions must be tackled, either by reducing them or by taking care of them as a part of the clean keeping system.

Above analysis shows that it's safe to assume that sticks will be as capable as canisters in the future. Sticks have become more powerful, while canisters have become smaller and more efficient. It is reasonable to believe that canisters will continue to become more effective but future sticks will likely become at least as effective as the canisters of today, which are quite effective as of the standard of today. An analogy could be drawn to computers by comparing laptops with desktops. The latter barely exists in general homes anymore.

D. THE STICK LOOKS WEAK

So if stick vacuum cleaners are actually pretty capable in terms of dust pick-up, what are the problems? And why are they not perceived as capable? In further analysis of the initial user studies it was found that the general expression of sticks doesn't represent their capabilities. It was concluded that stick vacuum cleaners need a new expression that is congruent with their actual capabilities if they are to be accepted by a bigger audience. A new expression must radically differ from today's products' to leave any heritage to weaker vacuum cleaners behind. The following interrelated expressions were found to be related to sticks: weak, dishonest and sleek.

The general expression of sticks doesn't represent their capabilities.

Weak

The general perception of sticks was found the be that they are weak. Three semantic properties were concluded to contribute to that perception:

- **Plasticky** – As mentioned earlier, participants meant that sticks look plasticky. They were not referring to the fact that the products are made out of plastic per se, but to the fact that the plastic looks cheap and dishonest. From a quick semantic analysis of the Ergorapido it was found that the glossy finish of the surface in combination with its form highlights flaws – from wear and tear but also from imprecise manufacturing.

- **Fragile** – Some participants perceived sticks as fragile compared to canisters, which were found to be perceived as robust and durable. They meant that sticks break easily. The plasticky feeling was mentioned as a related property.

- **Colorful** – The Ergorapido is available in many colors and the participants' general impression of sticks are that they are colorful. Some see that as a fun property. Others did however mean that it makes the stick look like a toy. It was furthermore mentioned that such an obtrusive expression is unwanted if the vacuum cleaner is supposed to be on display in the home. One participant even named the Ergorapido as "so ugly!".

Dishonest

Sticks are perceived as dishonest, unreliable, untrustworthy and dissatisfactory by some people. People in the study meant that they think or want the sticks to be more capable than they actually have proven to be. It should be noted that those people didn't try the Ergorapido used in this project, but rather based their opinion on previous experiences. It was therefore concluded that sticks suffer from their past, they carry a heritage of products that actually were weak and incapable, starting with handheld vacuum cleaners many years ago.

Sleek

The Ergorapido was also perceived as sleek among the participants. It was referred to as "sporty" and "cool", but also "masculine" and "like a razor". The masculine expression made four of the female test persons dislike the product but the sleek expression was in general a wanted property – however not as in sporty and masculine.

E. THE STICK HAS OTHER PROBLEMS THAT ARE SOLVABLE

Apart from being perceived as weak, ineffective and incapable, several other issues would have to be solved. It was concluded that sticks evoke worry in several areas and that the anxiety is the main problem. The ideation session on the below presented issues and solutions further led to the conclusion that all of the problems that the stick has are solvable in one way or another.

Power

People are worried about how long a charge lasts, how long it takes to charge the battery, how often the battery has to be charged and if power is needed where the stick is stored. They feel anxiety. But the problem has been solved before. Some of the ideas on solutions are presented below:

- **Super-fast charging** – If charging was super-fast, people wouldn't have to be anxious. No worries that it would take time to charge the device, neither that the charge wouldn't last, because a new charge might be just seconds away. A Tesla can for example reach 270 km on a 30-minute charge (Tesla, 2016) and an Apple Pencil gives the user 30 minutes of use on a 15-second charge (Apple, 2016a). Such a solution would also allow the user to store the stick anywhere.

- **Several Batteries** – Multi-battery solutions have been used in construction tools for years. It allows the user to use the device continuously by replacing the battery ever so often. Only the charger and battery needs power so the main device can be stored in a closet for example.

- **Other power sources** – Charging is a result of the use of electrical power. Using compressed air would for example eliminate that need. Such solutions would however require the user to refill air or some other substance.

Weight/Size/Maneuverability

The Ergorapido was perceived as heavy, clumsy and hard to maneuver after some time using it. A more simplistic design without any 2-in-1 or 3-in-1 features would make it possible to make a simpler, slimmer and lighter product that is easier to maneuver.

Reach Beneath Furniture

A slimmer product would also make it possible to reach beneath furniture. But as concluded earlier, the function to clean beneath furniture should be assigned to another part of the mesh within the clean keeping system.

Dirt Container

The participants meant that a stick has a much smaller dirt container compared to a canister. On the other hand, the dirt containers in stick vacuum cleaners are often made out of a transparent material. A visible dirt container makes it much easier for the user to confirm the vacuum cleaner status compared to canisters which hide the dirt. The anxiety is really in emptying the container though. A solution could be to let the stick empty itself into a docking station with a considerably larger capacity. Designing a simplified emptying procedure would also be a solution that enhances the experience.

Sound

People were found to have split opinions regarding the sound of sticks. Some meant that they are noisy while others thought they are silent. One reason might be that the stick is perceived as a quick tool, and that sound is therefore not as bothering. If the stick is to become a main device, it has to be quieter though. It was however concluded earlier that the sound contributes heavily to the perceived effectiveness. It was for example found during the initial store visits that the Bosch Athlet has a very different sound from the Ergorapido. It was concluded that the frequency of the sound is key to the experience, the lower-frequency sound of the Athlet was perceived as considerably more effective and also less bothering. The sound level could also be considerably lowered by using for example compressed air to power the device.

Dust Re-Emissions

As mentioned earlier, sticks re-emit more dust into the air than canisters. Those re-emissions could be reduced at the source or taken care of by another device within the mesh of devices that constitutes the future cleaning system.

F. A COMPOSED EXPRESSION

An expression association web was created to solve the anxiety around effectiveness and the weak expression. The new expression was developed to create a congruency between semantics and actual capability. The possibility of having the device on display at home was taken into consideration in the development of a new expression and inspiration was taken from Dieter Rams' 10 principles for good design (Vitsœ, 2016). His designs have proven to stand the test of time and were therefore concluded to represent the opposite of weak and fragile. The expression described below applies to any clean keeping device.

Composed

The persona Filip's character was described as **composed**. Composed refers to gathered and confident, and represents the opposite of weak and fragile in general. The expressions described in the following sections (thorough, unobtrusive, confident, trustworthy and seamless) were concluded to contribute to a composed general expression.

Thorough

Good clean keeping device design is thorough (precise) instead of plasticky and fragile. Thorough in design choices, manufacturing and details. It also represents the thoroughness in the clean keeping device's capabilities.

- Thorough as in exquisite surface continuities and curvatures
- Thorough as in precise surface transitions
- Thorough as in materials, surface finishes and forms carefully crafted in tandem
- Thorough as in a minimal number of parting lines
- Thorough as in carefully chosen refined parting lines – in material meetings for example

Unobtrusive

Good clean keeping device design is unobtrusive (simplistic) instead of sleek and colorful. A clean keeping device is a tool and should not try to be a work of art, neither in use or between uses, especially not if it is to be put on display and fit into any home.

- Unobtrusive as in simple shapes
- Unobtrusive as in neutral colors
- Unobtrusive and simplistic as in symmetry
- Unobtrusive and simplistic as in few and ordered elements

The expression of a clean keeping device should be...

THOROUGH

UNOBTRUSIVE

CONFIDENT

TRUSTWORTHY

SEAMLESS

Confident

Good clean keeping device design is confident instead of weak and dishonest. Confidence in the actual capabilities of the device, and confidence in its own form and design.

- Confident as in sharp meetings between different surfaces, materials and textures
- Confident as in contrasts between colors, surface finishes and materials
- Confident as in well-defined curvatures
- Confident as honest about function

Trustworthy

Good clean keeping device design is trustworthy instead of weak and dishonest.

- Trustworthy as in long-lasting materials and technology
- Trustworthy as in materials that age with dignity
- Trustworthy as in honest about function

Seamless

Good clean keeping device design is seamless instead of fragile, plasticky and sleek. Also refers to a seamless experience and interface.

- Seamless as in carefully placed and hidden parting lines
- Seamless as in smooth transitions between devices
- Seamless as in non-disruptive interfaces

Pictures of materials, metaphors, artifacts, colors and forms that represent the expression and the “form drivers” (e.g. “seamless as in…”) above were used to visualize the expression in an expression board. The expression board in Figure 41 shows clear examples on carefully chosen materials, surface transitions and parting lines for example. Products that people actually want to put on display in their homes were used as a foundation for the development.

Figure 41
Expression board.

G. THE NEW STICK WILL BE PART OF A BIGGER SYSTEM

In summary, in phase 3 it was concluded that vacuum cleaners are excellent for cleaning open floor areas, that the stick will be as capable as canisters in a near future and that all of the problems of the stick are solvable. Those conclusions assume that the stick will be part of a new mesh of clean keeping devices, illustrated in Figure 42. They assume that there are one or more devices that make cleaning easier in every area apart from open floor areas.

It was concluded that there were two paths to proceed on in the project. One was to design a stick according to the developed expression and the other one was to invent a device that complement the stick and make the entire cleaning experience better. The former was considered too incremental, which is why the project focused on other floor areas and surfaces in the last phases. There was still a gap in the market to fill and an unexplored area to explore. The stick was kept as a part of the system throughout the project since communication will be key to the mesh of devices – it was not further developed though. Furthermore, the stick was kept because many people put the vacuum cleaner at the heart of cleaning and because it actually provides an excellent and unprecedented experience of open floor area cleaning. Such properties should definitely be part of a future system. By reducing the number of functions and making the stick a hero, it becomes a great part of a mesh.

Communication will be key.

The developed expression and ideas are applicable to new cleaning devices as well. The findings in phase 3 will however be key to further development of the stick – by Electrolux of course.

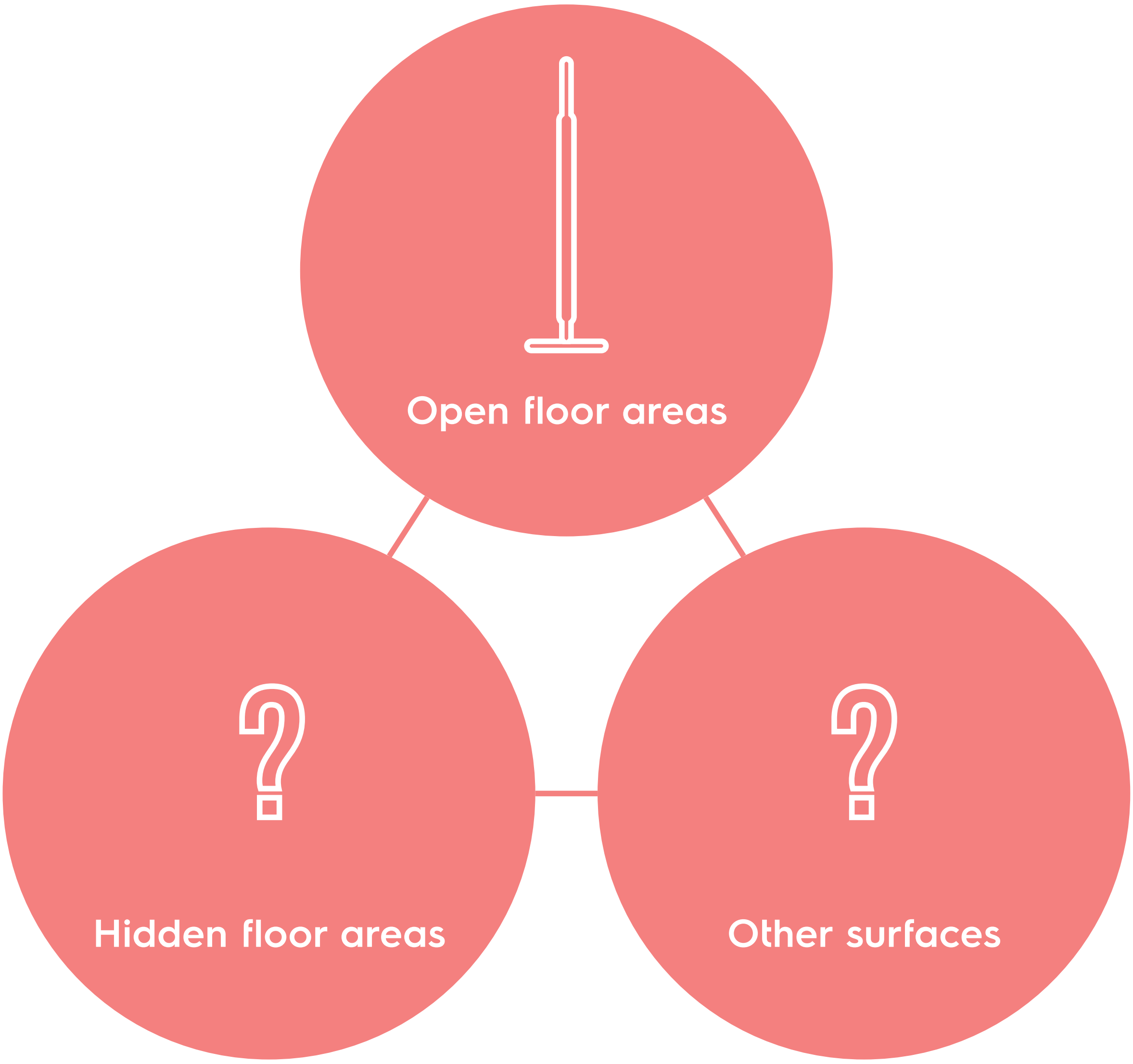


Figure 42
The future clean keeping device mesh.

H. CONCLUSIONS AND GUIDELINES

Apart from uncovering the future for vacuum cleaners, the conclusions from phase 3 concern functions and semantics. The conclusions end with a table of guidelines that put the conclusions into hands-on effects (Table 11).

- The vacuum cleaner should be reduced to its main function in order to make it simpler and more purposeful – to *clean open floor areas only*. The *3-in-1 nozzle* is a compromised feature in its current execution, which is proved by the cumbersome use of it.

- Stick vacuum cleaners are becoming as effective as canister vacuum cleaners. But the sticks possess a semantic heritage that *expresses ineffectiveness*. Thus, stick vacuum cleaners need a major revamp of their semantic expression that is congruent with their actual capabilities.

- A *correct semantic expression* is the key to also make the users want to have the stick vacuum cleaner on display at home.

- Apart from semantics, the stick vacuum cleaners need new battery/charging solutions, better maneuverability, well thought through dirt container and an unobtrusive and powerful sound in order to replace the canister and in order to *lower the anxiety* that users have towards sticks.

- The future of clean keeping is a *mesh of devices*. In this mesh, a revamped stick vacuum cleaner is included with the sole purpose of cleaning open floor areas.

GUIDELINES (FUTURE CLEAN KEEPING PRODUCTS SHOULD...)
Express the effectiveness that they actually withhold.
Not evoke anxiety.
Have a general expression of being composed.
Be thorough, unobtrusive, confident, trustworthy and seamless.
Make the users want to put it on display.
Not substitute the stick vacuum cleaner, but be a complementary device in the mesh of clean keeping devices.

Table 11
Guidelines found in phase 3.

08.

PHASE 4: **DUST IS IN THE AIR**

As a more capable and simplified stick was defined in phase 3, *Stick to the Stick*, it was concluded that a revamped version of the stick is the future of the vacuum cleaner. The future of the vacuum cleaner also implicate that the vacuum cleaner cannot do everything it does today – in its current execution, the vacuum cleaner does a lot of things at the expense of user experience, ergonomics and effectiveness. Thus, phase 4 focused on the problem areas in the home environment that the future stick vacuum cleaner is not meant to cover. What are those areas? Should a mesh of devices work together in order to cover the whole home environment of Filip and Elisabeth? Phase 4 resulted in several new ideas and ultimately the choice of one concept out of three.

A. SURFACES BENEATH FURNITURE AND ABOVE FLOOR HEIGHT ARE ESPECIALLY CUMBERSOME

As concluded in phase 3, there are several surfaces and areas that the vacuum cleaner is not optimized for. Surfaces such as those on shelves and other pieces of furniture, but also tight spaces like corners. It was concluded that those surfaces are hard to clean partly because the design of vacuum cleaners but also because moving decorations around is time-consuming. The initial user studies furthermore showed that limited abilities to reach beneath furniture such as a couch is a weakness of many vacuum cleaners, that also results in back pain for some. In other words, cleaning is difficult and cumbersome in areas that are hard to reach because there are decorations or pieces of furniture. That statement is true for vacuum cleaners as well as for cloths. As one of the participants said: "An empty home is not difficult to clean". It was concluded that the areas that are cumbersome to clean can be divided into two categories (presented in the list below). Those are the areas where dirt is continuously accumulated (see Figure 43), compared to open floor areas where the movement of people and the use of vacuum cleaners keep it clean. Over time, as the amount of dirt increases, it starts to spread to other areas such as open floor areas and the air. Such spread should be stopped or controlled.

"An empty home is not difficult to clean."

- **Surfaces beneath furniture** – Surfaces beneath furniture, especially furniture close to the floor, are cumbersome to clean because they are hard to reach. The user either has to bend over or move the piece of furniture to reach. Such areas are many times also stuffed with other things, such as boxes and electrical cords.

- **Surfaces above floor height** – Almost any surface above floor height is cumbersome to clean. Shelves and tables full of decorations, couches covered in textiles and skirting on very low height. The surfaces as well as the decorations have to be cleaned, which means moving things around several times. And moving things around means moving dust around. Some of the user study participants even meant that surfaces above floor height require dual cleaning due to that reason.

In general, it was concluded that cleaning the areas listed above result in physical demand, poor ergonomics and most of the time-consumption. Further definitions of the two area categories are presented below.

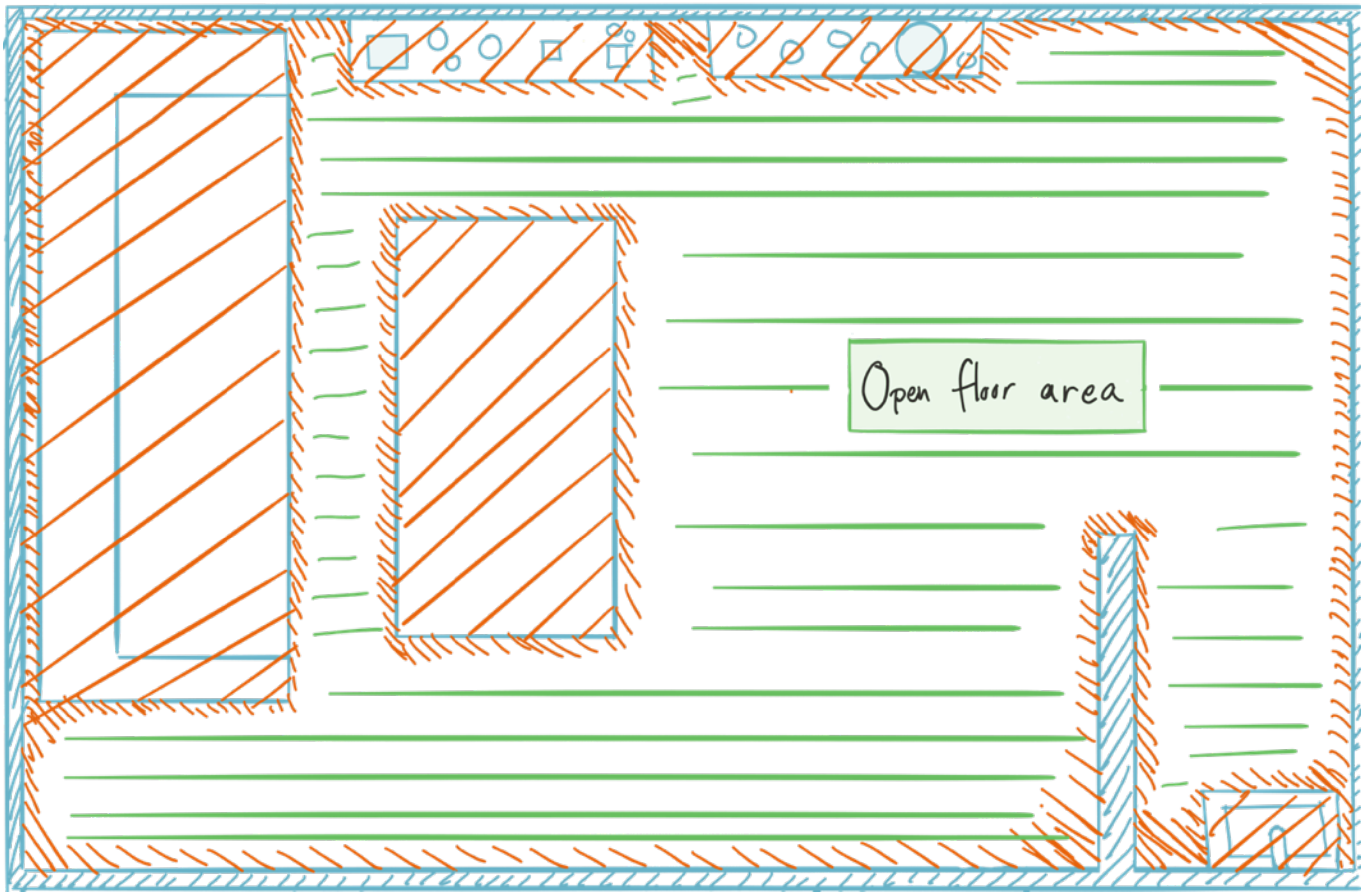


Figure 43
Areas where dirt is accumulated (orange) in a room: surfaces beneath furniture and surfaces above floor height. A couch, a table, two shelves and a sink represent pieces of furniture.

Surfaces Beneath Furniture

Cleaning beneath furniture requires several capabilities, it does however reduce the scope to a certain area and three kinds of dirt. The most common capabilities needed are highlighted in peach in the cleaning capabilities model (Figure 44) below.

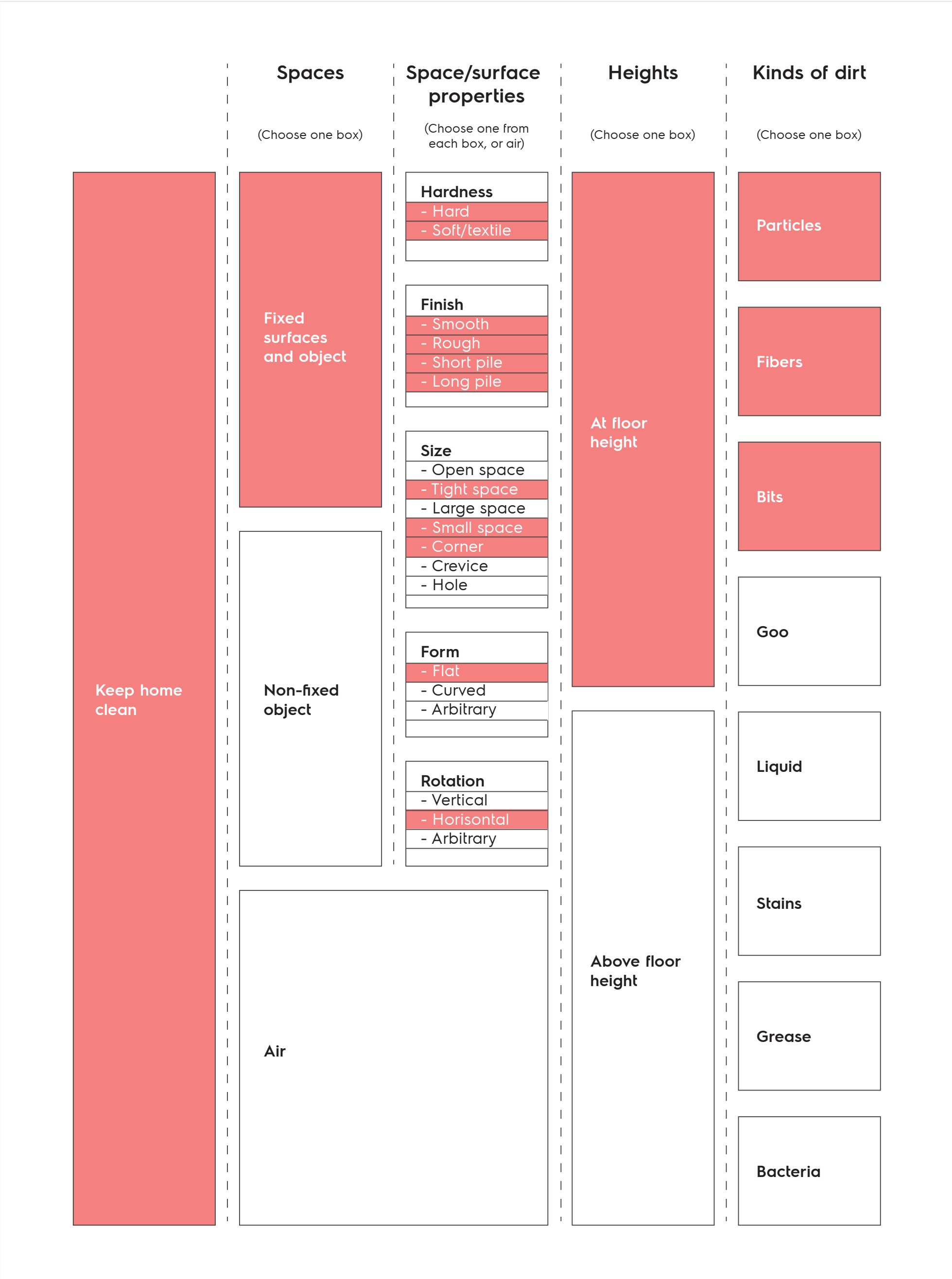


Figure 44
Cleaning capabilities for surfaces beneath furniture.

As can be seen from the model, cleaning beneath furniture is just a small part of the entire cleaning. It reduces the kinds of dirt to particles, fibers and bits, and focuses on floor height surfaces. The complexity of the problem is in the tight space that could include several floor types and carpets, and even other objects. The link analysis in Figure 45 clearly visualizes the problem.

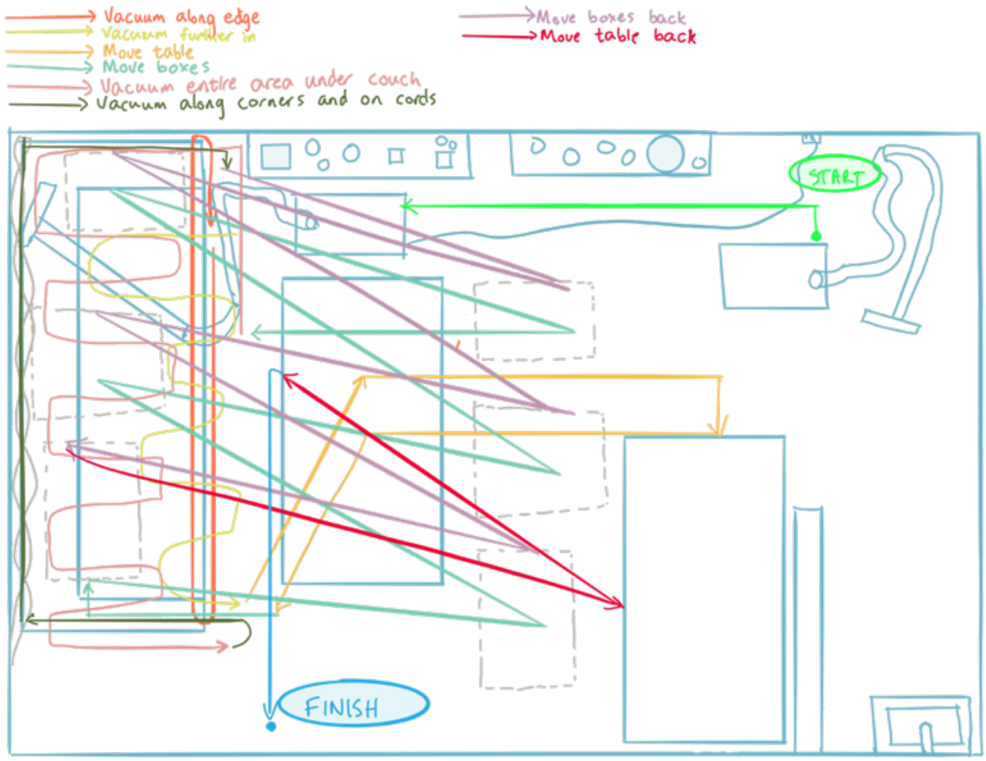


Figure 45
Link analysis of cleaning beneath furniture.

It is clear that cleaning thoroughly beneath a couch requires moving things around in the entire room. Furniture around the couch has to be moved before clearing the area beneath the couch and then the actual cleaning. As it is today, cleaning beneath furniture requires a tremendous amount of steps. The HTA and the entire use case is presented in Appendix 11 and Appendix 12 respectively.

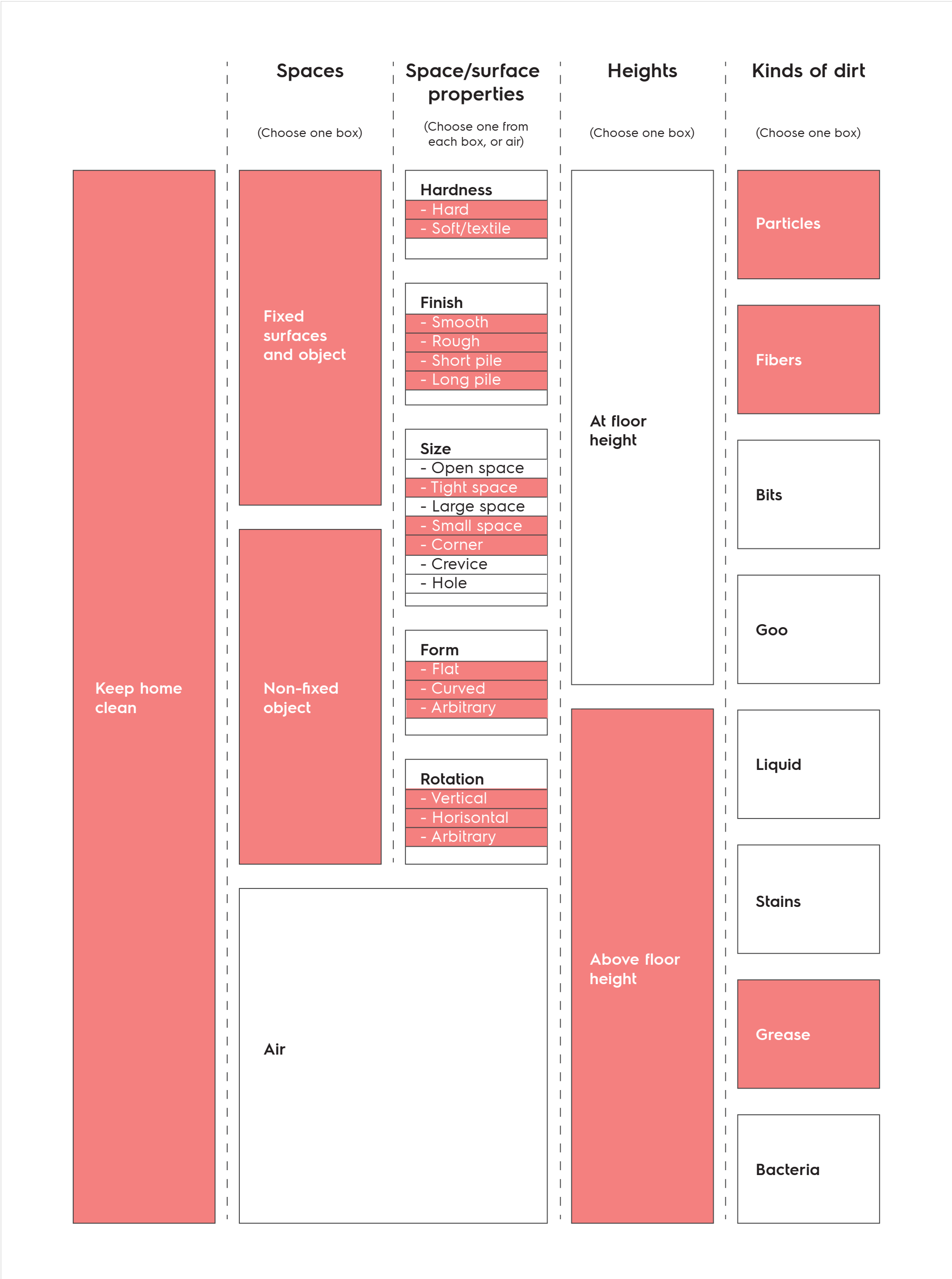
The limited amount of space and low height of the task further require the user to vacuum in several positions. During the tests of different vacuum cleaners, it was found that the user might have to bend over, squat and sit on their knees to reach everywhere (see Figure 46). Ergonomics analyses using REBA and RULA gave results ranging from 10 to 12, and 7 respectively, meaning that risks are very high and that changes should be implemented immediately. However, regular vacuum cleaning in home environments is not very frequent (often 1-2 times per week), which makes the REBA numbers deceptive. Nevertheless, it was concluded that a clean keeping device must not require the user to interact at floor level.

Figure 46
Vacuuming beneath furniture requires several positions.

Surfaces Above Floor Height

The second category of areas that are cumbersome to clean are surfaces above floor height. Such areas are defined by lots of decorations in different shapes and sizes. The capabilities needed to keep areas above floor height clean are presented in Figure 47.

Figure 47
Cleaning capabilities for surfaces above floor height.



In terms of dirt, smaller particles such as dust and grease particles are more common in areas above floor height. The decorations that are often present make the number of possible different surfaces huge, ranging from the rough textile of a couch to the glossy smooth curved surface of a vase. Those surfaces are however more accessible than the ones found beneath furniture. Just as in the case of surfaces beneath furniture, logistics is a big part of the problem. The link analysis in Figure 48 visualizes how decorations are moved from one surface to another, and back.

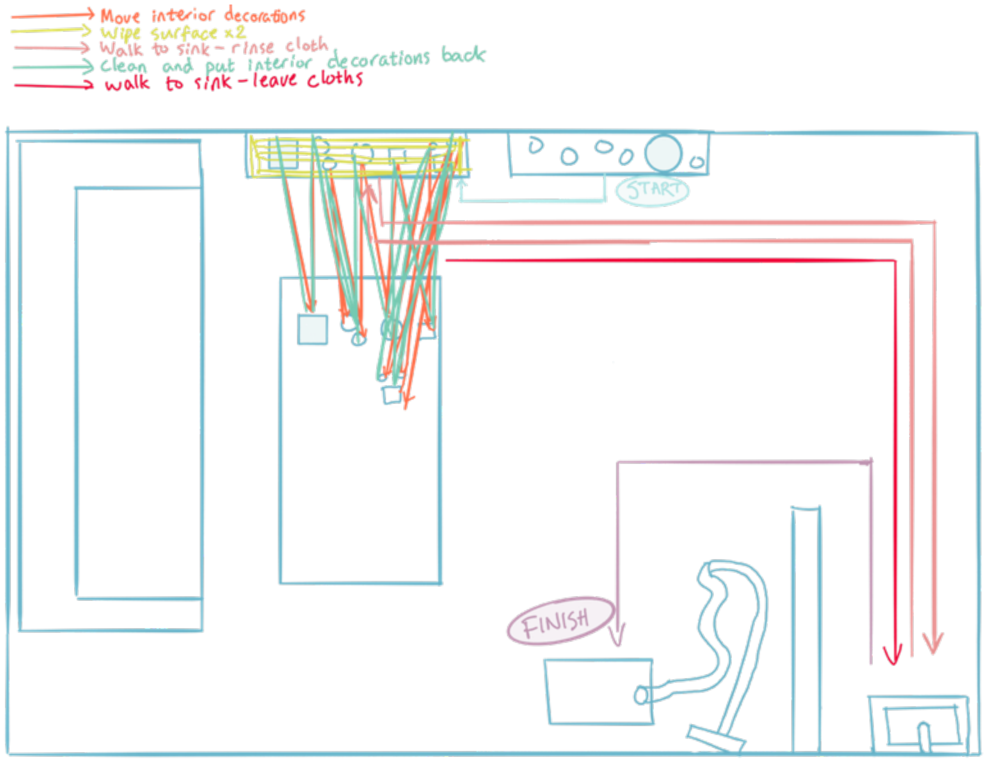


Figure 48
Link analysis of cleaning surfaces above floor height.

Cleaning surfaces above floor height does not require as much movement as cleaning surfaces beneath furniture but includes just as many operations. If a cloth is used, the user also has to walk over to a sink to rinse it several times during the cleaning session. The HTA and the entire use case is presented in Appendix 11 and Appendix 12 respectively.

Wiping such surfaces with a cloth was used as a benchmark in terms of ergonomics. Two cases were analyzed: wiping surfaces at dinner table height and wiping surfaces above shoulder height (see Figure 49). The REBA and RULA analyses resulted in scores from 8 to 9, and 7 respectively, meaning that the risks are high and that investigation is needed. It was concluded that clean keeping should not require the user to bend over or work above shoulder height.

Figure 49
Positions when wiping using a cloth.

B. THE COMEBACK OF GREAT IDEAS

The workshop resulted in a huge amount of ideas on both technical principles and cleaning concepts. Many of the ideas were similar to the ones presented in phase 2 and many of them had already been discarded. Other ideas were simply not feasible. But some ideas were great and contributed with new perspectives. Those ideas are presented in this section.

Surfaces Beneath Furniture

Several of the ideas on how to keep surfaces beneath furniture clean were based on the technical principles of blowing and suction and the combination of the two. Ideas on gamification and integration into interior or furniture were discarded due to the problems discussed in phase 2. The remaining ideas were sorted into the following categories:

- **New vacuum cleaner nozzles/pipes –** Cleaning beneath furniture could be made considerably easier by redesigning the pipes and the nozzles of vacuum cleaners. By redesigning the vacuum cleaning to be more ergonomically fitted in other words.

- **Stationary vacuum cleaners beneath furniture** – Small stationary vacuum cleaners beneath all pieces of low furniture would take care of the dust people and air push into those spaces, and therefore prevent spread of dust. It would allow the user to vacuum open floor areas only. Such devices would also fit perfectly into the mesh of devices.

- **Stationary blowers beneath furniture** – Putting stationary vacuum cleaners in several places results in a lot of maintenance when emptying is needed. Stationary blowers would on the other hand move the dirt to the vacuum cleaner, which would be the only device to be emptied. Blowing devices would assist the user when vacuuming open floor areas and increase the total effect and efficiency of cleaning. They would also fit perfectly into the mesh of devices. A variant would be to use an electrostatic carpet that attracts and moves dust to one side of the piece of furniture.

- **Continuous cleaning –** If the air above the surfaces beneath furniture were always kept clean in a continuous fashion, reactive cleaning would not be needed. What if particles were destroyed already in the air or if interior decorations constantly cleaned for example? Such a concept would, just as the ones above, allow the user to clean open floor areas only and fit well into the mesh of devices. It would also be applicable to surfaces above floor height.

The stationary devices ideas are similar to the ones around remote cleaning in phase 2. They allow the user to keep areas beneath furniture clean at a distance and fit perfectly as a companion to the stick in the mesh of devices. Continuous cleaning was found to be a new way to look at proactive cleaning and was therefore saved for later development. New nozzles and stationary vacuum cleaners were however discarded. New nozzles wouldn't offer the user much value apart from slightly better ergonomics and stationary vacuum cleaners would require maintenance that would probably feel burdensome for the user.

Surfaces Above Floor Height

Many of the ideas on how to clean surfaces above floor height focused on moving decorations with tools or automatically. Despite their interesting aspects, those ideas were discarded since they didn't include cleaning per se, but also because they would spread dust to other surfaces, which would require a second device to collect. Gamification and furniture integration ideas were also discarded, as previously stated. Most of the clean keeping device ideas focused on suction and blowing in this ideation phase as well, with the addition of high pressure air. The ideas were categorized into the categories below. Ideas on continuous cleaning came up here as well.

- **Huge nozzles** – A huge nozzle, almost like a hood, could be lowered from above towards decorations and surfaces to enable cleaning without moving decorations. A combination of blowing and suction within the hood would free the dirt and collect it in a controlled manner. Such a nozzle could also be ceiling mounted and as big as a table.

- **Blowing + suction stick** – Using a stick that blows and also provides suction would allow the user to clean any surface above floor height at a distance without moving anything. The idea is similar to the ones around remote cleaning in phase 2, especially the magic wand idea. A variant of the idea is to use high pressure micro-nozzles to easily release the dirt from surfaces and increase both effectiveness and efficiency.

- **Decorations with cleaning capabilities** – Placing small vacuum cleaners and/or blowers in the form of interior decorations on surfaces that are hard to keep clean would allow the user to focus on more accessible areas and therefore make cleaning easier. Such an idea would be very compatible with the blowers beneath furniture.

Even though huge nozzles would make cleaning easier, they would still require a lot of effort. The huge variety of surfaces and decorations, in size and weight, also makes the idea less feasible, which is why it was discarded. Blowing + suction stick and decorations with cleaning capabilities were kept and technically evaluated later.

C. HOW DOES NATURE KEEP ITSELF CLEAN?

To further investigate the design space and to put the already found ideas into context, nature was made into an inspiration source. Benyus (2009) meant that we are surrounded by genius in nature and that organisms most certainly already have solved the problems that we are trying to solve. She mentioned that sharks' skin denticles (fish scales) are designed in a way so that bacteria cannot land. Inspiration from the pattern in sharks' skin has for example been used to design surfaces that repel bacteria in hospitals. In the same way she meant that our red blood cells have been filtering out salt from water by using hourglass-shaped pores forever.

Inspiration from Nature

Further research and ideations resulted in new categories of ideas.

Repelling or Resistant Materials

Many surfaces in nature – such as surfaces on leaves, flowers and sharks – are designed to repel water, bacteria or dirt in general. Such surfaces keep the objects clean by making it hard for dirt to stick but also by making them easy to clean. Materials in homes could be designed in similar ways to reduce the amount of cleaning needed and to make cleaning easier. It would be a reactive and proactive approach to clean keeping – the outcome would be a home in less need of cleaning, but when it's in need of cleaning, it would be easy to clean.

Blowing and Flushing

Weather and wind has been keeping nature clean for billions of years, and nature still looks pretty good! It is, of course, about redistribution of dirt, but it is also part of a natural recycling of matter. Wind blows the dirt away – moves the dirt. Rain also moves dirt, but additionally it encapsulates dirt and reduces spread so that the dirt can be transported to the sea for example. Blowing and flushing dirt away would be just as effective in homes and was part of the earlier ideas in the project. Flushing was discarded as a technical principle due to obvious implementation challenges.

A huge amount of small helpers

Thirdly, nature has a tremendous amount of organisms that help in the clean keeping process. Everything from bees moving matter from one flower to another, to the immune system of our bodies keeping us healthy and "clean". Every little helper has its own specialty and purpose, making everyone into an expert. A similar approach would be applicable in clean keeping of homes by making certain devices specialize in certain spaces and on certain types of dirt.

Feasibility of the Biomimicry Ideas

The ideas from the biomimicry ideation were in general fairly similar to the previous ideas. The idea on repelling and resisting materials was discarded since it would require entire homes and interiors to be redesigned. Blowing as a technical principle was already part of many ideas – the interesting new aspect from biomimicry was the large scale however. Blowing to keep homes clean in general on a larger scale was kept as an idea that needed further investigation. Small helpers were also kept since such an approach would fit perfectly into the mesh of devices.

D. BLOWING IS BY FAR THE MOST EFFECTIVE TECHNICAL PRINCIPLE

Since blowing and the combination of blowing and suction were found to be interesting in the several ideation sessions, they had to be put to the test. Suction is already the technical principle of vacuum cleaners and was therefore not extensively tested, but still investigated in some special cases. The results from the tests are presented below.

Suction in New Ways

Vacuum cleaners rely on the fact that a nozzle is in close contact with the surface that is to be cleaned. Could suction be used as a method of remote cleaning (cleaning from a distance)? And what happens if suction is concentrated to a small nozzle? Some of the prototypes that were built are presented in Figure 50 below.

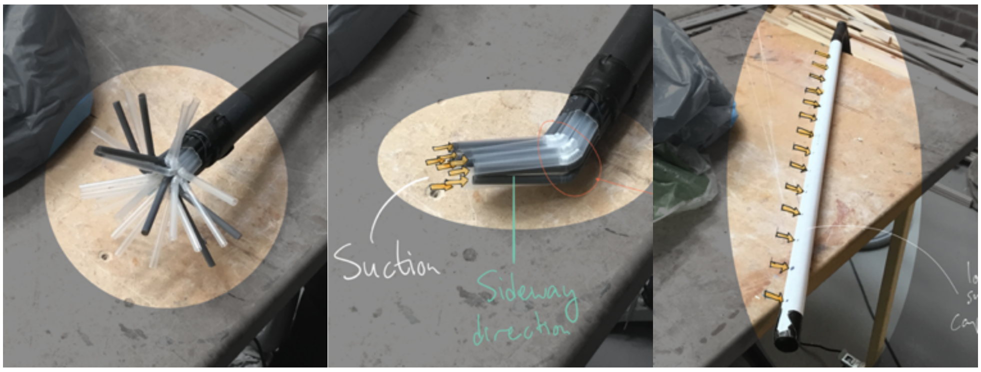


Figure 50
New suction nozzles, from the left: directed straws, spread straws, holes in a pipe.

It turned out that air velocity and therefore dirt velocity decrease significantly at a small distance from any nozzle when using suction. The use of straws and holes spread the total suction between several smaller nozzles and therefore decrease effectiveness vastly. Directing suction was also found to be difficult, as it turned out that suction does not have a direction like blowing. A nozzle that provides suction spreads the suction power around the nozzle, no matter the nozzle. It was concluded that suction alone is not the solution to remote cleaning. The pipe with holes was however interesting since it covers a much larger area than the nozzles of today. However, the performance was terrible.

Blowing Is Superior

Blowing is already used in cleaning for specific purposes, for example to clean electronics or to remove dirt from really tight spaces like crevices. How does it work on a larger scale? In general, it was found to be very effective. Some of the findings from the test are listed below:

- **Blowing reaches further** – Compared to suction, blowing affects air and particles on a much greater distance – up to meters in some cases. That allows for cleaning at a distance and increases efficiency significantly.

- **Air velocity is critical** – The velocity of the air is what makes blowing so much more effective. The computer fan had significantly less effect on particles for example, while the blow dryer was found to be very effective even at a distance. High pressure air was found to be even more effective but only at very close distances to the surface. It was concluded that air velocity is much more important than air pressure.

- **All particles are not released** – No matter what air velocity or pressure, all particles are not released from a surface – most of them are though. Both the blow dryer and the high pressure air effectively removed most of the visible dust from several surface types. The high pressure air was found to be slightly more effective on a very close distance.

- **Blowing is fairly directed** – It was further found that blowing can be directed to a much greater extent than suction. The airflow spread into the air but affect particles on a limited area in the direction of the source.

- **Nozzles have little effect** – Several different nozzles were tested, but they did not have a major effect on the effectiveness of blowing. Nozzles were however useful to direct the airflow. The nozzles are discussed later in this section.

In general, blowing was concluded to be a very effective and efficient way of moving dust from a surface. Further investigation would be needed to evaluate if blowing can remove a satisfying amount of dirt from surfaces though. It was of course also found that blowing spreads rather than collects. In fact, the interviewees agreed that blowing seems effective but the main concern was spread of dust. They meant that dust will spread everywhere in an uncontrolled way. They also argued that it depends on where you blow – some were for example worried about spreading dirt from the floor to surfaces above floor. Dirt from the floor or toilet feels more disgusting than dirt from a shelf for example. Some of the interviewees meant that it might be a good method if the dirt is collected immediately, by suction for example. They referred to the need of controlling the dirt, instead of blindly spreading it. It was also noted that blowing is seen as a great method of cleaning bookshelves and other areas that are hard to reach, since that is “a pain in the ass”.

Figure 51
Different blowing nozzles, from the left: spread blowing, two-directional blowing, field of air.

Just as in the case of suction, blowing was tested with specially designed nozzles. The different nozzles are presented in Figure 51. The tests confirmed that blown air can be easily redirected. It is possible to create almost completely directed fields of air, but also spheres of blown air using several straws. The holes in the PVC pipe for example created a field of air that covered large surfaces when in use. It clearly showed that blowing is a good technical principle for remote cleaning because of its reach. Spreading the air in different directions proved to be less effective though. It was concluded that directed air was the way forward in this project.

Blowing + Suction Is Difficult but Could Be Powerful

Since the spread of dirt is one of the obvious difficulties when using blowing as a technical principle, the combination of blowing and suction was evaluated. Blowing was used to release dirt from a surface and suction to collect the released dirt. Firstly, a pipe providing blown air was attached to a similar pipe providing suction (see Figure 52). It was found that the much higher velocity of blown air just blew particles away from the suction nozzle, which resulted in almost no dirt being collected. The concept was improved by lowering the velocity of the blown air. That change did however result in decreased effectiveness and the nozzle had to be very close to the surface to collect any dirt.

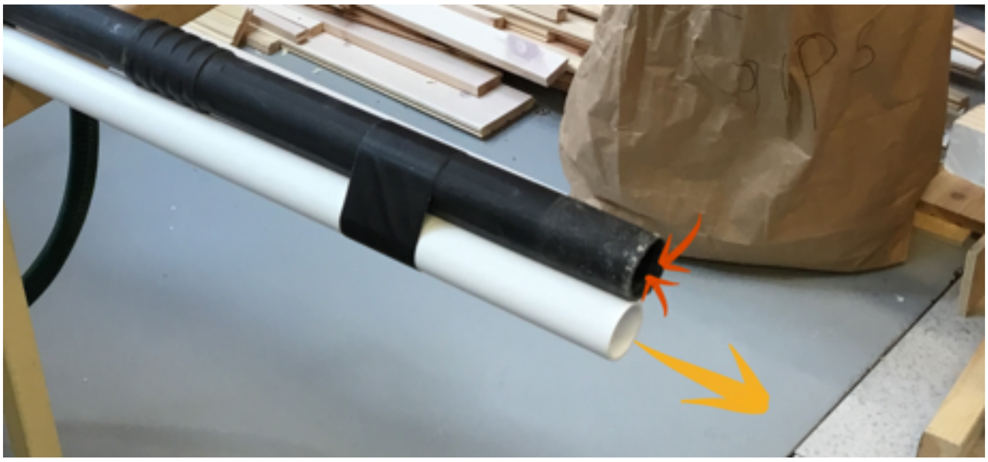


Figure 52
A blowing pipe attached to a vacuum cleaner pipe.

To solve the issue of blowing the dust away from the nozzle two nozzles separated from each other were created. The test included blowing towards the vacuum cleaner nozzle with a pipe connected to the blow dryer (see Figure 53). Due to the same direction of the air travel, this method was concluded to be much more efficient. It was still found to be difficult to match the speed and direction of the blown air to the suction from the vacuum cleaner nozzle. Using suction in combination with blowing was concluded to be a feasible principle, but a principle that requires very fine adjustments.

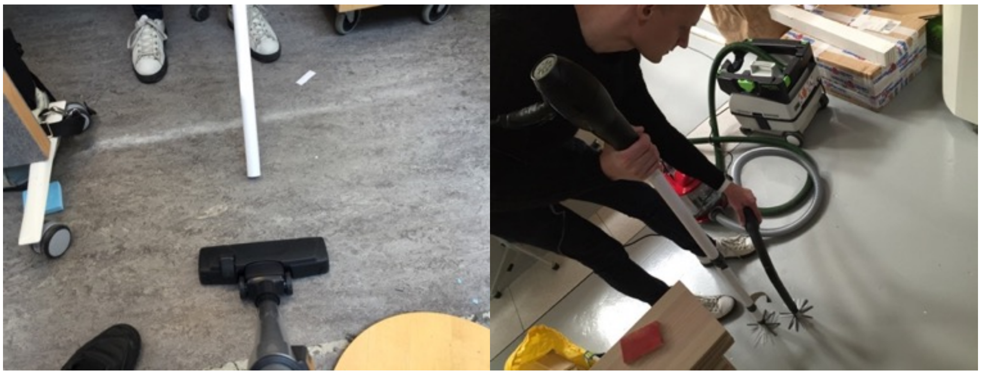


Figure 53
A blowing pipe used to blow air and dirt towards the vacuum cleaner nozzle. A variant using straws to the right.

The difficulties during these tests raised the question whether blowing + suction would work better in large scale, like in nature. What if blown air went through the home to a destination of suction for example? Similar to ventilation but as a clean keeping method? Those ideas were not tested at this stage of the project but saved until later.

E. MIND-BLOWING CONCEPTS

Ideations and combinations of ideas and technical principles resulted in two different concepts. Focus was on using blowing and suction and how to make them work together. It was found that they work best together at a distance from each other, and also if the suction nozzle is larger than the blowing nozzle. The concepts were based on the device mesh and they were designed to be perfect mates with the stick or something similar to the stick. The two concepts are presented in this section.

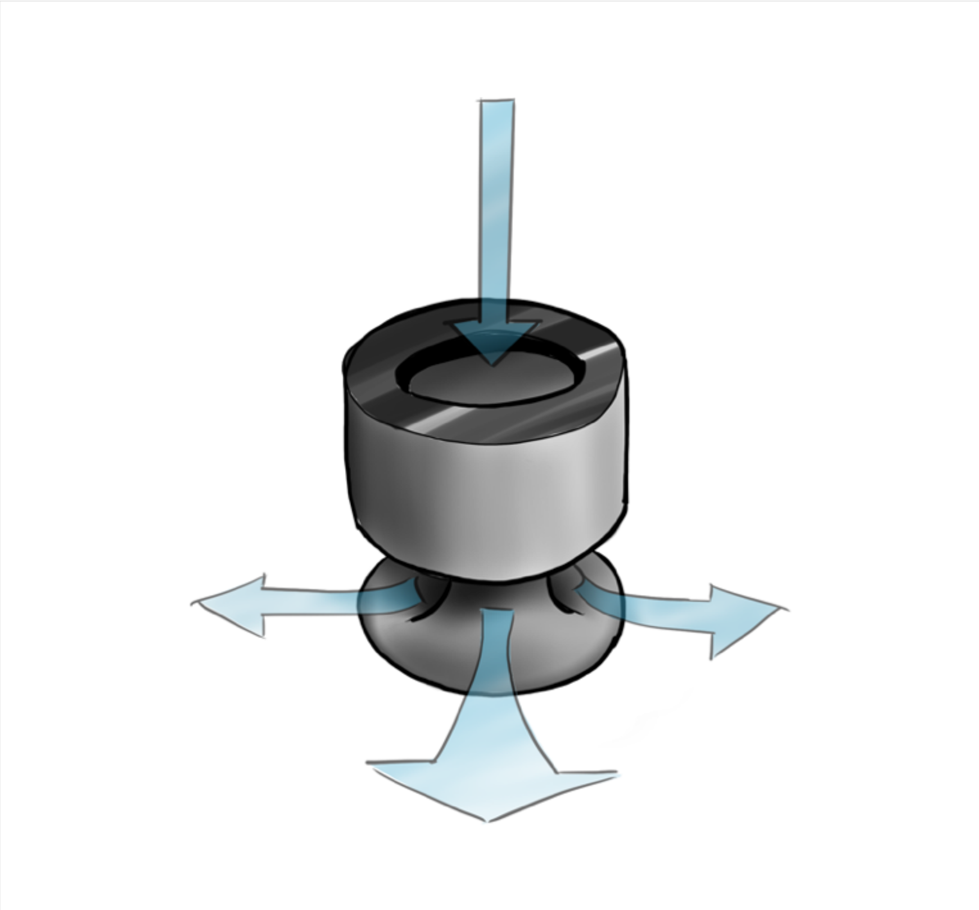


Figure 54
Weasel - a blowing device put beneath furniture.

Weasel

Weasel (Figure 54) is a small helper placed beneath low pieces of furniture. It is blowing air from the back of the couch for example to the front end where a vacuum cleaner can collect the dirt. Since it is blowing, no maintenance is needed.

The process of cleaning with Weasel is illustrated in Figure 55. Weasel is a standby stationary device, put beneath furniture. Several Weasels work together beneath one or several pieces of furniture to direct dirt to a place where it is more accessible to a vacuum cleaner. No air is blown if there is no vacuum cleaner nearby a Weasel device. When the stick vacuum cleaner (that is also part of the mesh) approaches the couch, a signal is automatically sent to the nearby Weasel devices, using NFC (Near Field Communication) for example. The Weasels start blowing and the vacuum cleaner collects the dirt in a synchronized manner. When finished, the Weasels go back to standby mode and the user can continue the cleaning session without thinking about it. In that way, Weasel allows the user to actively clean only open floor areas even though every floor area is actually being cleaned.

Figure 55
How Weasel works.

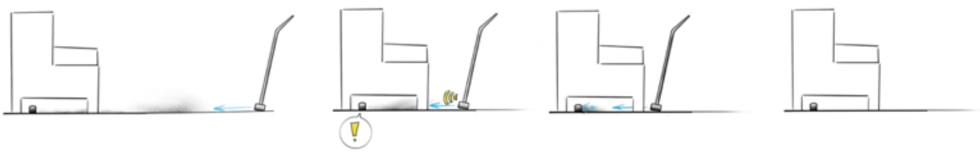
Figure 56
SUR - a suction device put beneath furniture and a stick blower.

Sweep Under the Rug (SUR)

SUR (Figure 56) is based on the classical idiom of sweeping something you don't like under the rug. Instead of sweeping the dirt under the rug, the user sweeps it beneath a piece of furniture. SUR is in that way the opposite of Weasel. A suction unit is placed beneath a piece of furniture and the stick vacuum cleaner is replaced by a stick blower. Replacing suction with blowing in the stick makes cleaning of open floor areas much more efficient as well. Furthermore, all the dirt is collected in the stationary unit, which makes the stick much lighter.

The process of using SUR is similar to Weasel's and presented in Figure 57. The unit beneath the couch is a standby suction unit. The user uses the stick blower to clean open floor areas and when they approach the couch a signal is automatically sent to the suction unit, which starts to collect the dirt and thereafter goes back to standby mode.

Figure 57
How SUR works.



Ideas Applicable to Both Concepts

At this stage of the project, many ideas from the early phases had been revisited and kept or discarded, and ultimately resulted in the two concepts presented above. Ideas specifically on increased user experience were however still applicable to the new concepts. Increased connectivity with other devices, amplified feedback on cleaning and music integration would for example enhance the cleaning experience further. It was decided not to integrate those ideas into the system before the actual cleaning capabilities had been verified. Some new ideas on how to even further improve the two concepts arose in the process of making them though. Some of them are presented in Figure 58 and in the text below.

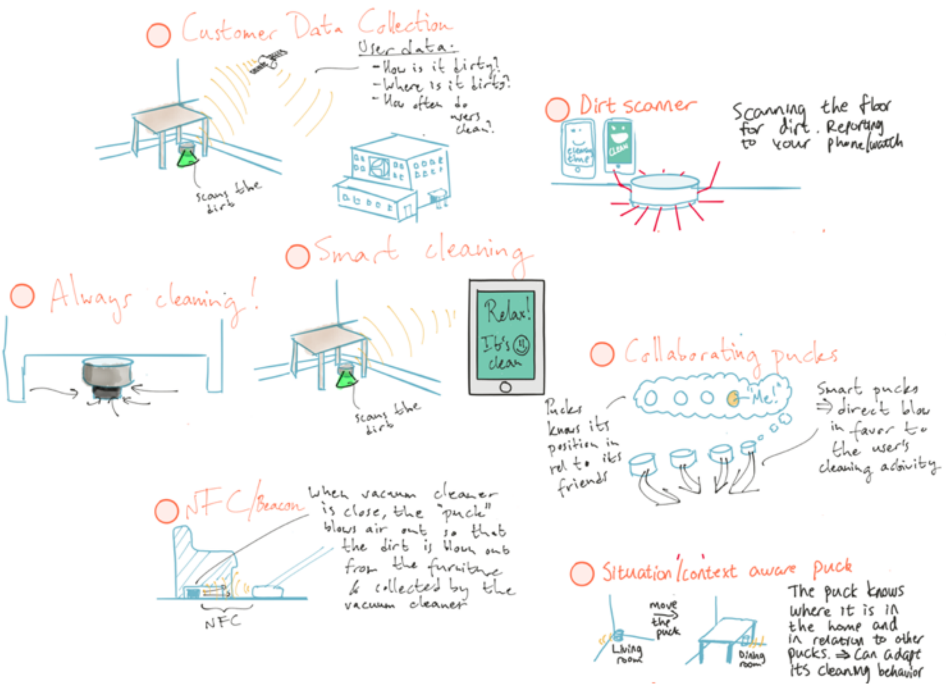


Figure 58
New ideas on how to make cleaning smarter.

Placing stationary devices such as the Weasel or SUR at specified parts of the home, allows for analysis of the cleanliness in that area but also for collection of data on user's cleaning behaviors. Such data could be used to tell the user when cleaning is or is not needed and also to make the devices smarter over time. It could also be useful to Electrolux to learn more about cleanliness and people's cleaning behaviors to adjust the mesh of devices and create an even more efficient clean keeping in the future. With connectivity and software, devices such as Weasel and SUR could even be updated to optimize their function. Electrolux might for example learn that people are in fact cleaning more often than the surface beneath the couch needs cleaning and therefore adjust the behavior of those units. They might also learn that a constant airflow is more suitable in some homes, which leads to the idea that the units beneath furniture could constantly provide a slow flow of air instead of being standby. They could even be used to chill feet in front of the couch on a sunny day.

F. BLOWN AIR IS HARD TO CONTROL

The tests of the technical principle blowing + suction are presented in the previous sections. Further tests of that principle as it is used in the two concepts were needed in order to evaluate their functionality. The results of those tests are presented in this section.

Blown Air Can Move Dirt from One Floor Area to Another

A prototype of Weasel was built from wood and a computer fan. The prototype, shown in Figure 59, is a box open at the top and bottom with the fan in-between. It was tested on different heights and also on its side as the figure shows. The tests clearly showed that a computer fan does not create an airflow that is strong enough to move dirt from one side of a piece of furniture to the other. Even when laying on its side, the prototype was only able to move the dirt two to three decimeters. It was concluded that a more powerful fan is needed and also that a flow directed horizontally is more effective than a vertical flow.

Figure 59
A prototype of Weasel. The paper strips were used as airflow indicators.

To verify the hypothesis about increased airflow and direction of the airflow, a second test was conducted. As Figure 60 shows, a blow dryer was used in different directions and on different heights to further evaluate the feasibility of the Weasel. The test showed that the airflow velocity of a blow dryer is more than enough to move dirt from beneath furniture to open floor areas. Both vertical and horizontal airflow worked but horizontal was found to be considerably more efficient. In conclusion, the function of Weasel is realizable in terms of moving dirt from one floor area to another by using blowing. The test therefore also confirmed that the stick blower of SUR should be realizable.

SUR was further evaluated using a blow dryer and a vacuum cleaner nozzle (see Figure 61). The test showed that such a concept is feasible. It cleans the floor significantly more efficiently that a vacuum cleaner since it cleans an area many times larger than a vacuum cleaner nozzle from dirt. In addition, it actually turned out the be fairly controllable due the design of the vacuum cleaner floor nozzle. A custom nozzle was built (also Figure 61) to test if the floor could be even more controlled and directed forwards. That nozzle showed that blown air can move dirt in a fairly defined and limited area in front of it (see Figure 62).

Figure 60
Increased airflow with a blow dryer.

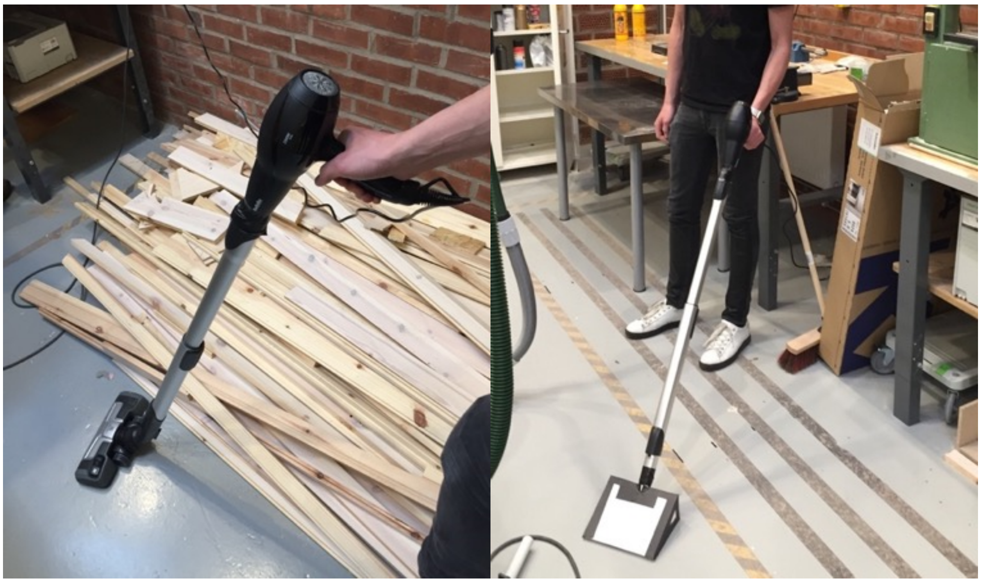


Figure 61
The SUR stick blower prototypes.

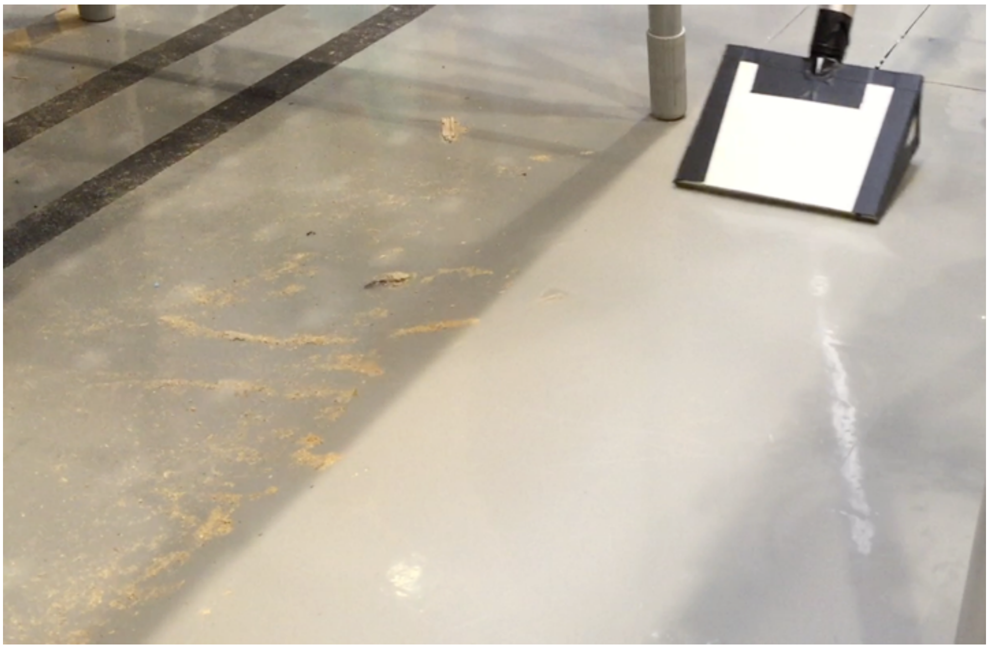


Figure 62
The SUR stick blower cleans in a controlled manner.

It Is Difficult to Collect Dirt from a Blown Airflow Using Suction

So it could be confirmed that moving dirt with blown air is possible. The rest of the tests were conducted to evaluate if it is possible to collect the dirt that the blown air moves. The blow dryer and the custom nozzle described above was used in combination with an Ergorapido stick vacuum cleaner to verify the function of both Weasel and SUR. The two devices were placed on opposite sides of a table according to Figure 63.

Figure 63
The stick blower and stick vacuum cleaner used during the test.

The test clearly showed that timing is key. The activation of blown air and suction must be in perfect sync for the concepts to work. Synchronization like that was concluded to be solvable with technology such as NFC. Another finding was that the dirt is not only spread to other floor areas but also the air above the floor. As can be seen in Figure 64, the Ergorapido did not even get the chance to collect all of the dirt because most of it was blown into the air. Several nozzle angles and two airflow velocities were tested, and all gave similar results. It was concluded that the airflow would have to be considerably more controlled in order for the concepts to work in this setup.

In an attempt to create a more laminar and controlled airflow, the custom nozzle was modified. As Figure 65 shows, the nozzle was elongated in the horizontal direction and straws were added to the outlet to create several airflows – each with a smaller turbulence. Similar methods are used to create laminar flows in water fountains for example. Tests using a piece of string showed that the airflow was actually fairly laminar – at least over the first half meter in front of the nozzle (see Figure 66).

Figure 64
Dust in the air in front of the Ergorapido.

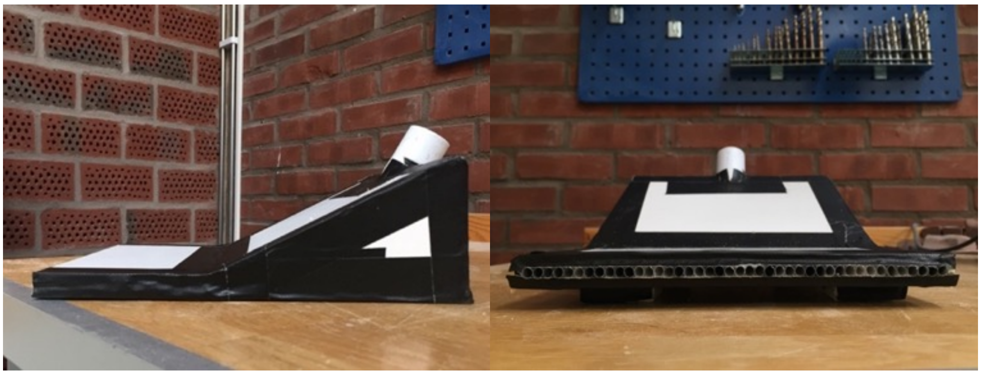


Figure 65
Modifications of the custom nozzle.

Figure 66
Laminar airflow in front of the nozzle.

Figure 67
Dirt still in the air in front of the Ergorapido.

Further testing using the modified nozzle showed that dirt still spreads into the air. Figure 67 shows that there was dirt in the air above and in front of the Ergorapido. The result was much better though. It was found that the air, and therefore dirt, stayed on the ground for a much longer distance than with the previous nozzle. The turbulence seemed to build up further away. It was however concluded to be difficult to collect a satisfying amount of the dirt in this design of the concepts.

Words from an Expert

Senior lecturer at Chalmers University of Technology and fluid mechanics expert Niklas Andersson was consulted to understand if a more controlled flow could be created to keep the dirt closer to the floor. The following conclusions were made during the consultation:

Turbulence Is Useful

Niklas meant that the use of several straws would not create a laminar flow but rather several jets but that turbulence shouldn't be seen as a problem. He argued that turbulence would be useful to release dirt from a surface.

The Airflow Will Grow

He furthermore said that turbulence is not the reason to why the dirt spreads into the air above. Due to entrainment, every airflow will attract surrounding fluids to follow along and therefore grow with increased distance from the nozzle. An illustration of this phenomenon is shown in Figure 68. Dirt will therefore always spread into the air if it is not physically controlled.

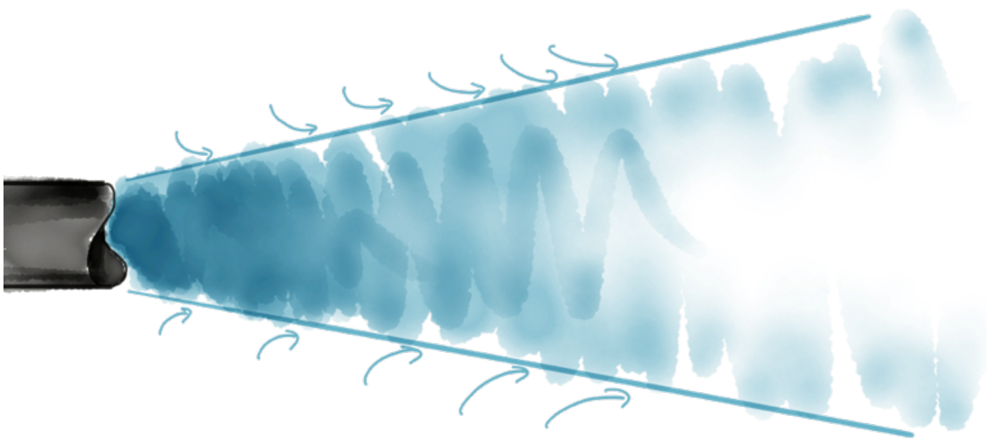


Figure 68
Entrainment leads to a growing airflow.

The Velocity at the Surface Is Zero

Niklas also argued that particles very close to the surface will not move because the airflow velocity at the surface is zero due to friction. The velocity increases above the surface according to Figure 69. Since particles rise above the surface due to their thickness, Niklas meant that particles should be able to move anyway.

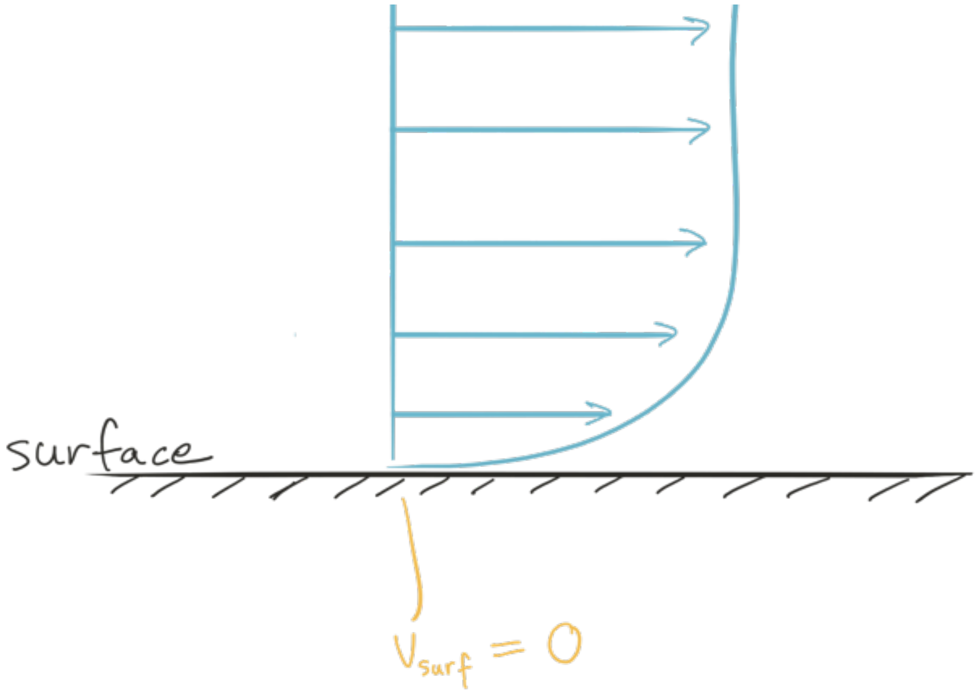


Figure 69
The velocity of an airflow is zero at a surface.

Take Advantage of the Turbulence

Niklas furthermore confirmed the finding that blown air creates high-speed and directed airflows while suction creates low-speed and spread airflows. Previous tests had already proved that blown air can move a satisfactory amount of particles from a surface. It could however be concluded at this stage that an airflow cannot be controlled enough for a regular vacuum cleaner nozzle to collect the dirt within it. Consequently, the plan to prototype and find ways of *reducing* turbulence was omitted. Thus, it was decided to take *advantage* of the turbulence and growing airflow instead of working against them.

Blowing Is Too Promising to Let Go

A lot of factors spoke against using blowing as a technical principle, blowing alone and blowing combined with suction. People showed to be worried about spreading dust into the air and several tests showed that the principle was hard to control. The efficiency benefits are however overpowering. It was also proved that spreading dirt is not a problem if it is properly controlled and collected.

G. IMPROVEMENT OF CONCEPTS

The concepts Weasel and SUR were kept despite the difficulties around collecting dirt described above. An ideation session actually resulted in a couple of feasible ideas that make the concepts feasible as well. Some of the ideas were:

- **Add suction inlets** – Both Weasel and Sur would benefit from suction inlets in all directions – especially upwards. Such an inlet would not collect all dirt in the air, but most certainly the particles close to the inlet.

- **Combine suction and blowing with ionization/electromagnetism** – The blowing units of the concepts could charge the particles when moving them and the suction units could attract the same particles with positive charge to collect even more particles.

- **Increase the size of the suction nozzle** – The suction nozzle could be designed as a hood and therefore physically stop and collect particles at greater heights.

- **Reduce the airflow velocity** – Different airflow velocities were tested during the tests, but variations were limited to the equipment. Such velocities would probably not be needed since the dirt was moved beyond what is necessary. Slower velocities would not entrain as much surrounding air and therefore not grow as much.

It was concluded that there were enough of ideas and reasons to move forward with the concepts, further testing was saved until later in the project.

H. INVESTIGATION OF AIR QUALITY

As seen above, the two concepts are feasible but the problem of dirt spreading into the air raised some new questions. What if spreading dirt into the air is not a problem? What if cleaning the air is the best way of keeping a home clean? What if blowing and suction were used at a larger scale? It was found in phase 2 that dust is in the air at some point of its "lifetime". And phase 1 also concluded that dust spreads to and from every part of the clean keeping system, even *from* clean keeping equipment. So the users are spreading dirt even when they are cleaning – dirt that makes the surfaces dirty again. In fact, a quick test showed that a surface become dirty just hours after a complete cleaning session.

Surfaces become dirty just hours after cleaning.

Figure 70 clearly shows that cleaning today is really about redistributing dust and does therefore not last very long. Most people probably recognize the sight of dust in the air when the sun is shining through – the dust is there all the time. That was concluded to be one of the reasons to why people have to clean so much and so often. A lasting result – a lasting impression – is needed to create a much better experience. Keeping the air clean is one of the solutions to that problem. But what is clean air really? And what is a good living environment?

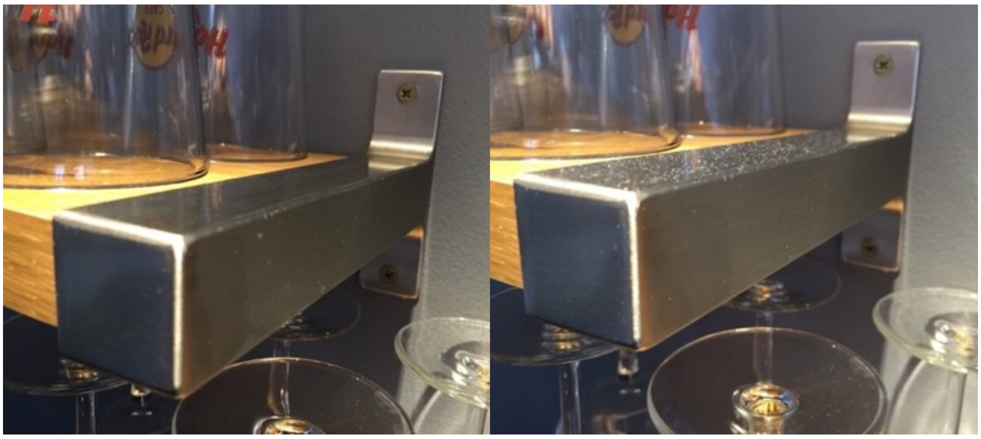


Figure 70
Cleaning spreads dust. Left: immediately after cleaning. Right: Hours after cleaning.

A Nice Living Environment Is Much More Than Free from Dirt

As previously mentioned, people are heavily affected by what they see, feel, hear and smell. The senses affect our feeling of pleasure. The Swedish Work Environment Authority for example considers lighting, noise, air and temperature as indoor environment factors (Arbetsmiljöverket, 2015). It was found during the brainstorming session that several factors in our homes and in the air affect the senses. Some of them are presented on the next page.

- **See** (visual)
    - Dirt on surfaces
    - Dirt in the air
    - Lighting and sunlight

- **Feel** (e.g. haptic)
    - Dirt on surfaces
    - Dirt in the air (irritating noses for example – allergies)
    - Heat and cold
    - Air humidity
    - Air pollutants, grease, etc. (affecting our skin for example)
    - Air quality – oxygen (breathing)

- **Hear** (auditory)
    - Dirt on surfaces (walking on sand for example)
    - Noise from clean keeping equipment
    - Noise from ventilation, radiators, fridges, etc.
    - Noise from outside

- **Smell** (olfactory)
    - Smell of a clean vs dirty home
    - Smell from cleaning equipment
    - Smoke

It was concluded that many of the factors that contribute to our living environment are related to the air. Keeping the air clean could for example mean:

- No dust in the air and therefore a reduced amount of dust on surfaces
- No other pollutants in the air
- Comfortable air humidity
- No unwanted smells, smoke or other particles in the air
- Reduced need of active cleaning and therefore less noise

Keeping the air clean was concluded to provide so much more value than only keeping surfaces clean. Clean air would create a better indoor living environment, which would increase the quality of the user's lives in general. Homes would be more pleasurable to live in and cleaning itself would be more pleasurable, less frequent and last longer.

Ionizers Are Only Halfway There

Of course someone else have thought about cleaning the air before, but rather as a way to improve air quality than as a general clean keeping method. Livestrong.com (2015) meant that ionizers effectively remove pollutants from the air, which can provide health benefits. According to them, ionizers use an electrically charged wire to send charged molecules (ions) into the air. Those ions interact with particles, such as dust and other pollutants, in the air and force them to an electronically charged plate inside the ionizer where they are collected. Some ionizers use a fan to spread the ions in the room or home faster. Some air cleaning devices even combine ionization with HEPA filters and fans to remove dust, smoke and pollen more effectively. According to livestrong.com (2015) there are also built-in whole-house ionizers, those were however not considered in this project since they require extra construction work when being installed.

It was concluded that ionizers are in fact a fairly good solution, but very few people seem to use or buy one. They seem targeted towards allergists and asthmatic people. And they are not seen as cleaning devices, even though users are reporting a reduced need of cleaning when using one according to one of the participants of the Electrolux workshop. The problem is that one unit tries to keep the air clean in an entire home. It is not there when someone makes the bed, plays or fries meatballs – it might very well be at the opposite side of the home. Therefore, many particles have the time to spread throughout the home and land on surfaces and in people's noses. The result might be cleaner air, but dust is still covering the surfaces of the home and meanwhile the user will have to smell the cooking fumes.

Ionizers are not seen as cleaning devices, even though users are reporting a reduced need of cleaning when using one.

Robotic ionizers or air cleaners are closer to a solution since they can move but they are only halfway there. Ecovacs Robotics (2016) for example offers the Atmobot A3 series, which is a robotic air cleaner. It is basically built like a robotic vacuum cleaner and therefore suffers from the same problems in terms of navigation. Furthermore, it can move but it doesn't know where to move. Ecovacs Robotics' solution is also incredibly obtrusive and close to the user at times. As discussed earlier, such a design is not the future of robots. It will result in a home with several robots that all in all risk to bother the user while being at home. A smarter, simpler and more capable solution is needed to create a better experience.

It was concluded that there is definitely room for a smart clean keeping product that focuses on the air but keeps the entire home clean – creating a much better living environment – and that creates the pleasure of a lasting impression.

I. THE BIRTH OF PURIFY – A SMART WAY TO KEEP THE HOME CLEAN

The stick is used during such a small amount of its life, and is most of the time only standing there or charging – taking up space in the home. The clear benefits of focusing on the air and the entire living environment begged the question: could the stick be something else when not being used as a vacuum cleaner? Could the stick also be an environment clean keeper? Or could the stick work together with an environment clean keeper in the mesh of devices that is the future of cleaning? The development of such a concept is described in this section.

What Could the Stick Be?

Further ideation on the subject of what the stick could be like resulted in several distinguishable ideas.

The Stick Is Also an Environment Clean Keeper

If the stick could also clean the air while cleaning, cleaning would be much more effective and long lasting. Such a solution would also allow the stick to clean the air while standing by in a corner or when being charged. The user could for example vacuum all the way to the bed, put the stick to the side and make the bed while the stick collects the dust that the sheets spread into the air. Similarly, it could be in the kitchen while cooking meatballs to prevent the cooking fumes from spreading to the entire home.

The Stick Charging Station Is Also an Environment Clean Keeper

The charging station could be more purposeful, both when charging the stick and when just standing there. It could complement the general clean keeping by keeping the air clean simultaneously. It would be like having a stationary ionizer and stick.

The Stick and the Charging Station Are Also Environment Clean Keepers

Making both units into air cleaners would add the benefits of both ideas. The charging station could keep the entire home cleaner in general and the stick could collect dirt due to activities such as bed-making. When on charge, the stick could amplify the effect of the charging station to create an even more powerful air cleaner.

The Stick Works Together with a Robotic Environment Clean Keeper

A robotic air cleaner would make perfect sense. It would be able to clean the air where the dirt or other particles are to prevent further spread in the home. It would be able to operate both when the user is home and away and therefore increase the general cleanliness. Such a device could act like an assistant when the user is cleaning and afterwards. It could for example follow the user from room to room and for example collect the dust that is spread into the air while dusting or making the bed, but also just stay in a room after cleaning to make sure that it is as clean as possible.

The Stick and the Robotic Environmental Clean Keeper Is One Unit

A robotic air cleaner could also act as the docking/charging station of the stick. In that way they could make each other stronger while being together but still have the advantages of being separable. That would also allow the stick to be transported to where the user is instead of the opposite.

Other Ideas

The ideation sessions also resulted in ideas on what else such a device could do. It could for example also include air-conditioner, humidifier, dehumidifier, shoe dryer, clothing freshener, radiator, etc. Those ideas were taken into consideration when developing a concept later on.

The Stick Should Work Together with a Robot

Evaluations of the ideas listed above led to the conclusion that a separate robotic environment clean keeper would provide the most benefits. That would let both devices to do what they do best. Building the functionality into the stick itself would make the effectiveness questionable and probably turn the stick into a clumsy device. Making the charging station into the environment clean keeper would on the other hand be like a separate air cleaner that is never where it needs to be. Lastly, combining the stick with a robot would make the robot clumsy, but above all, it would mean that the user never knows where the stick is, which defeats the purpose the product. It was therefore decided to develop a concept based on a separate robotic environment clean keeper that works together with a separate stick to keep the home clean.

Robots Must Be Smarter

The robotic vacuum cleaners of today are not smart enough. They have no structured way of moving and they don't know where cleaning is needed or not – they clean the area either way. The initial user studies actually showed that these facts are some of the reasons why people don't like or trust robotic vacuum cleaners. It was concluded that a new robotic device must know where to travel, how to avoid obstacles, and most importantly, where the dirt is and what kind of dirt it is. Such a device must be smart enough to know when someone is making the bed, cooking or cleaning, to prioritize and optimize clean keeping. It must also know when and where people are in order to not bother them. The user should never notice the device if they don't want to, and they should never have to see dirt on a surface or smell unwanted smells. It was concluded that the environment has to be constantly analyzed to provide the very best experience and performance.

The environment has to be constantly analyzed to provide the best experience and performance.

The type of analyzing functionalities discussed below are already part of the ideas to Weasel and SUR. Those ideas are based on the fact that the clean keeping units themselves are distributed throughout the home. In a brainstorming session on the subject it was found that a smart analyzing unit for example would need a motion sensor and a smoke detector to detect how much people are moving and where smoke particles need to be taken care of. It was found that those types of sensors are already part of many people's homes in the forms of smoke detectors, fire alarms and home alarm systems, which led the idea of designing a ceiling mounted unit, similar to smoke detectors, that can be mounted in any room. One unit in each room would be part of the device mesh together with the robotic environment cleaner. Such a unit could retrieve data from several sources that are listed on the next page:

- Motion sensor
  - Where are the people? – don’t disturb
  - Where have people been moving? – likely more dirt in those areas
  - Where is the robot? – navigation help

- Smoke detection sensor
  - Where, how much and what kind of smoke? – clean air in area or start fire alarm

- Gas detection sensor (e.g. carbon monoxide)
  - Where, how much and what kind of gas? – clean air or start alarm

- Particle detection sensor (e.g. dust, smell, pollen)
  - Where, how much and what kind of dirt? – prioritize and optimize cleaning

- Humidity sensor
  - Where and how humid? – adjust humidity

- Video camera, RADAR or LIDAR
  - Where are the people? – don’t disturb
  - Where have people been moving? – likely more dirt in those areas
  - Where is the robot? – navigation help

- Connectivity to other products (e.g. fridge)
  - What products are the people using and how much? – prioritize and optimize cleaning

- Thermometer
  - What is the temperature? – adjust the temperature

- Resident’s calendars
  - When are people home vs. away from home? – don’t disturb. Prioritize and optimize cleaning

- Internet
  - What is the weather like? Pollen? – adjust cleaning. Proactive cleaning
  - Is it sunny? – use solar power to charge

The strength and smartness would of course be in analyzing and combining the data from the different sources to draw smart conclusions. The system could for example decide whether there is a fire or if the smoke is less dangerous based on data from the smoke detector sensor, gas detection sensor, video camera and thermometer. It could also make feasible judgments on the cleanliness of different rooms based on data from the motion sensor, gas detection sensor, particle detection sensor, video camera, connectivity to other products, resident's calendars and internet. Such a smart system would be able to clean where it's needed and when it's need – without disturbing the residents. It would also allow the robot to navigate in a smart and efficient way. Problems that robotic vacuum cleaners have today would not be present in such a system. The ceiling mounted sensor units could furthermore have other functions such as auditory and visual feedback on cleaning and other voice messages – it could be the only interface the user would have to interact with. It could even be a convenient night light and a speaker to add more value.

Such a smart system would be able to clean where it's needed and when it's needed – without disturbing the residents.

The robotic environment cleaner and ceiling mounted sensor units were combined into a system where every unit work together to create a smarter clean keeping that lasts longer and keeps the general cleanliness at a higher level than today. The concept *Purify* was born.

Purify

Purify (Figure 71) is a proactive and reactive clean keeping system. It consists of a floor traveling environment clean keeper and ceiling mounted sensor units in each room. The sensor units prioritize and organize the clean keeping to make it as effective and efficient as possible. The user doesn't need to interact with the product, which makes it very *easy* to use. It is *capable* of keeping the entire home clean, not only from dust, but from several other particles in the air, and therefore on surfaces. The solution is *simple* and almost unnoticeable from the user's perspective. It leaves a clean result that lasts without disturbing the user and therefore provides the *best clean keeping experience* yet.

The automated clean keeping process is exemplified in Figure 72. The sensor units detect that a user is making the bed in one of the bedrooms and page the robot to come clean. The robot can easily navigate through the home with the help of the sensor units and therefore arrives just moments later. The dust that the sheets spread into the air is taken care of and the robot returns to charging or another mission. The user gets feedback from the sensor units built in LED lights.

The process described above is of course applicable to many other situations. Purify is there to assist the stick when the user is cleaning and to remove cooking fumes while cooking for example. It will even take care of smelly shoes when the kids arrive home.

Purify is also a reactive cleaning device according to the process visualized in Figure 73. It can for example move around in a room and blow on turbo effect to release dust from surfaces and thereafter collect the dust from the air – of course when the residents are not at home. In that way it works to keep the cleanliness at a very high level at all times.

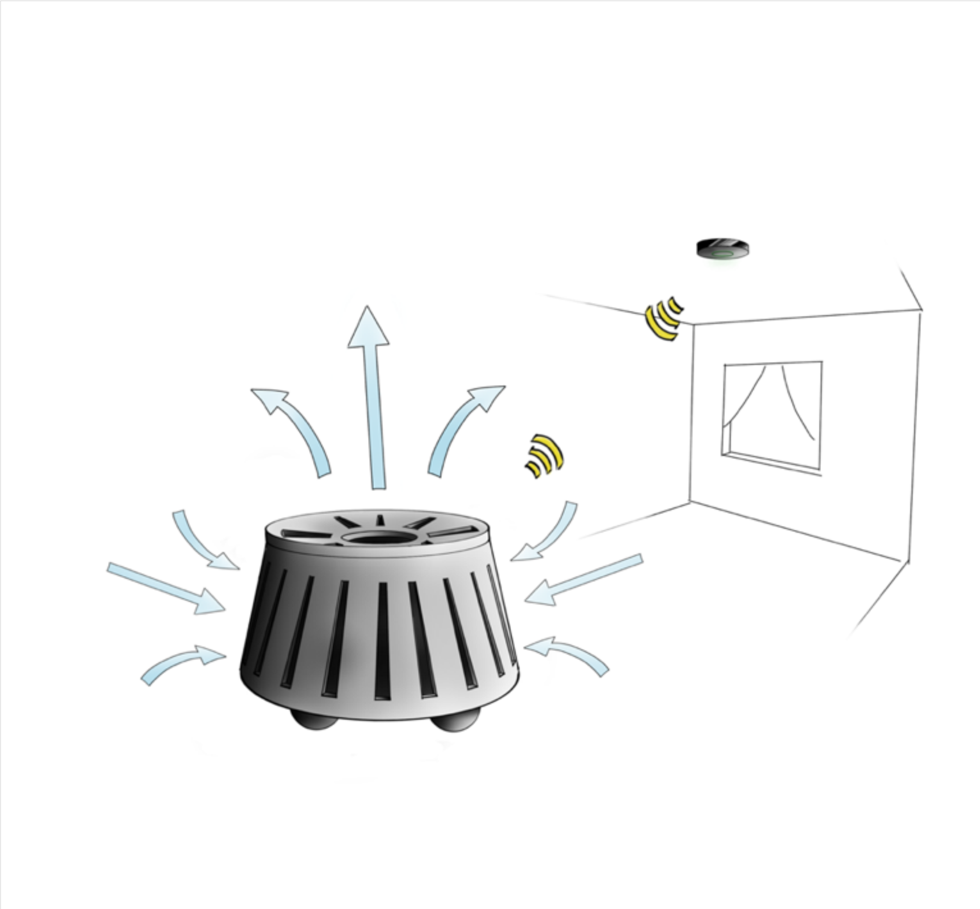


Figure 71
Purify - a robotic environment cleaner and ceiling mounted sensor units.

Figure 72
The automated clean keeping process of Purify.

Figure 73
The automated reactive cleaning process of Purify.

J. PURIFY IS SUPERIOR

Previous ideas specifically on experience such as e.g. music has been discarded since cleaning should no more disturb the residents. The best experience is instead sought and found in making the cleaning itself better. Increased feedback and lasting results are parts of what makes the experience better, and were thus considered in the evaluation of Weasel, SUR and Purify. The concepts are indeed very different from each other, but what did people think about them? What are the pros and cons of each concept? And which one is the best?

The best experience is sought and found in making the cleaning itself better.

Weasel – Clever! But Effective?

People's initial reaction to concept Weasel was that it's very smart. It takes care of the burdensome task of cleaning beneath furniture and beds, according to the interviewees. One participant told that *"It is [the dirt beneath furniture] a big problem that you ignore!"*. *"Exciting!"* expressed another participant. Looking at the result from the Pugh matrix, Weasel is within many areas better than the vacuum cleaner at cleaning beneath furniture. It's small, reduce effort, cause less disturbance of side users than the vacuum cleaner does when cleaning beneath furniture and makes it cleaner in the house over time. For a full presentation of the Pugh matrices, please see Appendix 13.

There are however downsides to Weasel that need to be taken into consideration. The interviewees were all worried about control of the dust since, as earlier proved, blowing spreads dirt in the air. *"Can the vacuum cleaner suck from above, so that it catches the dirt that rise in the air as well?"* asked one participant. Thus, some trust issues related to the concept were highlighted. Another worry was that they imagined that a lot of Weasels are needed in the home (beneath every piece of furniture) in order to fully make full use of it. One participant actually ideated around this problem and suggested *"Maybe the Weasel can follow you around when you're cleaning? It can run beneath the furniture closest to you and stay ready to blow out the dirt. That'd be cute!"*. Other issues that rose from the interviews were e.g. about clean keeping of Weasel itself. Cables, boxes and other stuff beneath furniture could also prevent Weasel to do its job. Issues that arose from the Pugh matrix was that dirt other than dust could be difficult to blow away.

Sweep Under the Rug (SUR) – Satisfying, But Good?

The evaluation of SUR showed that the concept gives clear feedback when cleaning, due to the user being able to see when dirt is being "air swept". It's very versatile due to the ability to easily clean anything on floor level by blowing. *"Good, since the couch is kept clean!"* said one interviewee.

SUR was however the concept that received the most criticism. The participants from the interviews were mainly concerned about the controllability of SUR. *"To blow dirt beneath the furniture is more difficult than sucking up the shit that's beneath the furniture"* and *"Blowing? Well, I can imagine how dirty the couch will become"* were some of the comments from the participants. From the Pugh matrix, it was also clear that the use of SUR probably will require higher mental demand than the today's canisters do: to control the dirt so that it ends up beneath the couch requires technique – compared to just collecting same dirt with a vacuum cleaner.

Purify – Brilliant! But What About Gravel?

"After dusting off the apartment, things get dusty again immediately. Purify would've helped a lot!" was a comment from one participant in the interviews. The participants thought in general that it's an interesting concept as it is *"something new"* and *"nice!".* From the Pugh matrices, it was understood that it reduces the effort of cleaning and is time-efficient since the user needs to clean the home less frequently. Purify decreases the amount of allergens in the home environment and increases the actual and perceived cleanliness since it's constantly cleaning. The manual cleaning is facilitated since it takes care of the airborne dirt.

On the other hand, it doesn't clean anything else than air. One participant said *"Purify would've helped me to 20%. My dog brings home a lot of gravel"*. Another participant worried about its size and how it could fit into their small apartment. It was also noted from the Pugh matrices that feedback is a shortcoming, since the effect of Purify comes after days or even a week; cleaning the air does of course not clean surfaces immediately.

I Choose You!

All concepts have their pros and cons. But how good are they in relation to each other? And which is the best? The Pugh matrices found in Appendix 13 clearly visualize that. All in all, concept Purify is the best. Purify does not directly help to clean in the moment of cleaning, but it makes it possible for the user to clean less often, and when actually cleaning, becoming satisfied with the result. If there's none or very little dust in the air, the surfaces will continue to be kept clean even after the cleaning session. In short:

- The proactive, semi-automated nature of Purify is a relief
- Knowing that it isn't getting dirty directly after a cleaning session is satisfying
- It enhances the manual cleaning by taking care of the airborne dust by cleaning less and cleaning faster.
- The user cleans less often, allocating the time to something more fun.

Looking at the other concepts, Weasel was second best according to the Pugh matrices. It makes cleaning beneath furniture easier as it is good at what it does, but many Weasels are needed in order to release its full potential. Is it worth it? Some improvements are needed. SUR evoke a lot of doubt. Blowing the dirt doesn't seem to be a great idea, since the dirt becomes uncontrollable.

The conclusion from the interviews is that people were excited about both Weasel and Purify. They saw good potential in those concepts, but they also saw that improvements are needed. SUR wasn't a favorite at all.

Purify got most points from the Pugh matrix, and the participants showed a lot of positive interest and anticipation for the concept. Purify is also a concept that represents a **gap in the market** – there's no active product for clean keeping of air and automatic product that keeps surfaces clean longer. Thus, it became clear that Purify was the concept to develop further in the last phase.

K. CONCLUSIONS AND GUIDELINES

The explorative process resulted in many important insights. The conclusions from phase 4, *Dust is in the Air*, are presented in the list below and guidelines can be found in Table 12.

- Surfaces *beneath furniture* and *above floor height* are cumbersome and not ergonomically pleasing to clean with the products that are offered on the market today.

- Dirt on surfaces beneath furniture are *less likely to travel further* and thus stays there.

- *Biomimicry* hints about blowing as clean keeping on a larger scale.

- Collecting dirt by *suction from a distance* is not feasible.

- *Blowing is an effective and efficient* way of moving dust, even from a distance. But blowing also *spreads* the dirt.

- *Blowing and suction* in combination, as a technical principle, requires *timing* and great *precision* in order to make it work well. In a larger scale however (e.g. ventilation system), blowing and suction could be more feasible.

- Today, cleaning is about *redistribution of dust*, especially *from surfaces into the air.* Physical activities also spread dust into the air. Those are the reasons why people need to dust their homes often.

- *Keeping air clean* brings many positive effects to the actual and perceived cleanliness of the home.

- A robotic air cleaner exists, but it was concluded to be obtrusive and not that smart. There is room for a clean keeping products that focus on the air, but also keep the entire home clean. In other words, there is a gap in the market.

- To build air cleaner functionality into the stick vacuum cleaner is to complicate both air cleaning and floor cleaning.

GUIDELINES (FUTURE CLEAN KEEPING PRODUCTS SHOULD...)
Keep surfaces beneath furniture and/or surfaces above floor height clean.
Support the user to clean in an ergonomic manner.
Not build extra functionalities into the stick vacuum cleaner other than those of floor cleaning improving characteristics.
(If it is a robotic device), know surely where to travel, how to avoid obstacles and where the dirt is.
(If it is an air clean keeping device), know when someone's making the bed, cooking or cleaning.
Analyze the environment in order to provide the very best efficiency and effectiveness.

Table 12
Guidelines found in phase 4.

09.

PHASE 5: **SAY HELLO TO HALO!**

Throughout the project, users were interviewed, workshops conducted, vast and deep analyses made, mock-ups built, tests done and a lot of ideas generated. Phase 4 ended with an evaluation of three concrete concepts and the choice of the concept *Purify* – an environment cleaner that cleans the air from all kinds of impurities. Sensors mounted in the ceiling make it into a smart helper. Cleaning the air will ultimately keep surfaces clean longer, and thus, keep the surfaces beneath furniture clean longer.

The intended effect, and partly also the intended use, architecture and interaction of Purify are all parts of the results from phase 1 to 4 presented in the previous chapters. The fundamental idea of Purify was developed, but what does it *actually* do? And what should it look like? The result from phase 5 is a visual manifestation of the vision of future clean keeping devices. The journey from Purify to the final concept *Halo* is presented in this chapter.

A. EFFECT

The intention of Halo is, above all, to create a clean keeping experience that is considerably better than cleaning today. During the course of this project it was found that there are several reasons why cleaning brings so little pleasure. The intended effect of Halo is summarized in this section.

The Main Problem and the Solution – A Lasting Impression

People were found to like the results of cleaning but dislike the activity of cleaning – before, during and after. Part of the problem is that cleaning is physically demanding and time consuming. The frequency and time needed to keep a home clean does not fit into people's modern lifestyles where everything rely on quick interactions. But the main problem was concluded to be that *the results of cleaning are not lasting*. That phenomenon decreases pleasure and increases displeasure. Halo makes cleaning easier and simpler by requiring less active cleaning from the user and by relying on a much simpler stick vacuum cleaner as a companion. It is furthermore capable of creating a better environment and *a lasting impression* of cleaning by increasing the general cleanliness, which increases the pleasure and creates the very best clean keeping experience yet.

Less active cleaning from the user.

Users and Context

Halo targets future home owners and clean keepers and therefore focuses on the young adults of today. The persona Filip presented in phase 1 represents the target group and was part of the entire development towards Halo. He represents the modern lifestyle which is why Halo is such a radically different clean keeping device.

It was found in the future trends analysis in Phase 1 that homes will likely become smaller. That conclusion was found to be key to some of the decisions in the project. The new stick vacuum cleaner is for example a perfect fit for slightly smaller homes. One or several sticks would of course also fit into larger houses though. Filip's apartment presented in Phase 1 represents the targeted context, which for example includes a simplistic and minimalistic interior design.

Capabilities and Values

Halo is capable of actual proactive clean keeping by cleaning the air. It actively and directly clears the air from various particles, not only dust but also smell, smoke, pollen, etc. By doing so, it also keeps surfaces clean indirectly. The capabilities of Halo are presented in the clean keeping capabilities model in Figure 74. As can be seen from the model, Halo keeps every part of the home at a generally higher level of cleanliness. It is limited to airborne kinds of dirt, such as particles, grease and bacteria. The remaining dirt types were found to be more common on open floor areas or easily accessible surfaces, such as a dinner table, and therefore easy to clean with the new stick or a cloth. Liquids, goo and stains were furthermore concluded to be part of accidents rather than regular dirt accumulation.

Looking back at the user values from phase 1, it can be concluded that Halo have every opportunity to meet most of them at this stage of phase 5. A walkthrough is presented in the following sections.

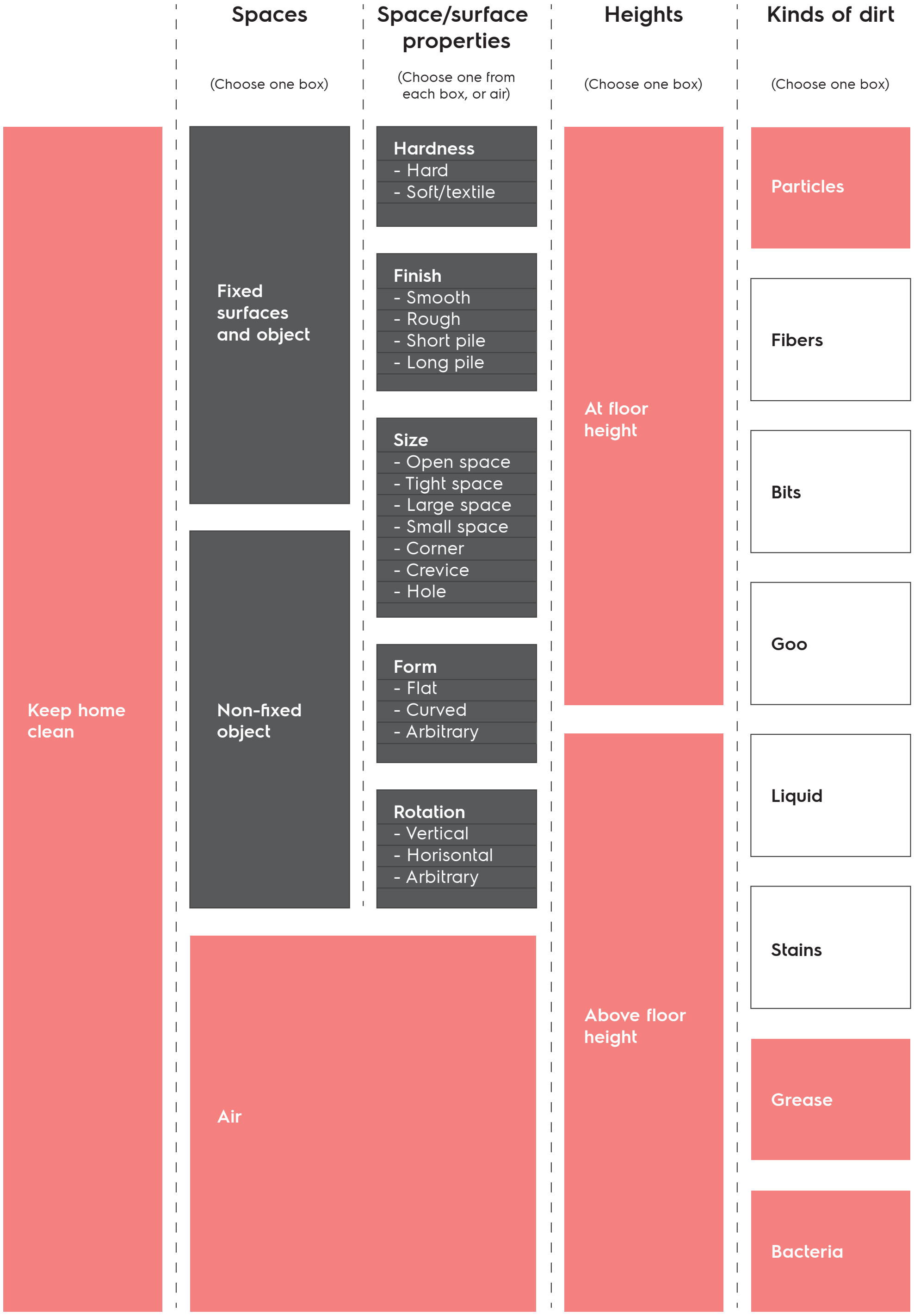


Figure 74
The cleaning capabilities of Halo. Peach: Active clean keeping. Dark gray: Indirect clean keeping.

Require Minimal Effort from the User

Halo takes over a lot of the general clean keeping and reduces the need of active cleaning from the user. Maintenance will only be needed to clean or replace filters. The user doesn't have to worry about the floor traveling unit getting stuck, since it uses much more reliable navigation information from the ceiling mounted sensor units.

Facilitate and Encourage Ergonomic Use

Halo is an automated device that requires minimal interaction. A lighter and simpler stick is used to clean open floor areas only which should enhance the ergonomics of the total system drastically. An ergonomics analysis of the final concept is also presented later in this chapter.

Be Sustainable

Halo is both environmentally and socially sustainable. By using sensors, it can prioritize and optimize clean keeping, and even tell the user when cleaning is not needed. The overall amount of cleaning is therefore reduced, which should result in reduced energy use. The sensors also make the product safer for humans, pets and the interior. Since it can operate where there are no users, it will furthermore not disturb anyone watching TV for example. The fact that Halo keeps the air clean should also improve the lives of allergists and asthmatics.

Sustain a Comfortable Climate and Environment

Halo is at its core an environment cleaner. It sustains a clean home and a comfortable home environment like no other clean keeping device.

Allow the User to Be in Control (Enable Manual Control)

The user is still in control of the general clean keeping. Cleaning is part of the system and the user controls the cleaning devices, such as the new stick. The user is not in complete control of Halo, but they shouldn't have to be either. Need of such interaction would be a fail and defeat the purpose of the product since it would require more time and effort from the user.

Provide Pleasurable Results

Halo does not only provide pleasurable results by creating a better living environment, it also extends the pleasure of the results of cleaning.

Be Pleasurable to Use

Halo requires no interaction, and the new stick facilitates better ergonomics and focuses on open floor areas only which should promote a more pleasurable clean keeping in general.

Require Minimal Storage Footprint

Halo is meant to be out in the open at all times and therefore doesn't require any storage per se. It will need space when cleaning and charging though. The design and form is discussed later in this chapter.

Provide Effective and Reliable Dirt Control

Halo spreads dirt into the air, but it also collects it reliably. Air cleaners have proven that kind of functionality for quite some time. The results from further testing are presented later in this chapter.

B. INTENDED USE

Halo is in general intended to be used to keep the overall cleanliness at a higher level and to make cleaning more efficient by making the result last longer. But what does that exactly mean and what else will it do? The intended use of Halo is defined in this section.

A General Use Scenario

A story from Filip's and Elisabeth's life with Halo is presented below:

Filip and Elisabeth are both at work. Meanwhile, there is a constant analysis going on at home. The ceiling mounted sensors of Halo analyze every room in their home to determine the cleanliness and living environment. The sensors conclude, from movement history and analysis of particles in the air and on surfaces, that there is extra dirt in the kitchen – probably because Filip and Elisabeth had friends over last night. They call the floor traveling unit of Halo to come clean. Halo arrives in the middle of the kitchen and starts cleaning the air. When no more particles are found in the air, Halo turns on a turbo fan to create movement in the air, after which it returns to cleaning the air.

Filip and Elisabeth arrive to a fresh home, but Filip notices that there are still crumbs on the floor in the kitchen so he grabs the new and beautiful stick vacuum cleaner. He starts vacuuming in the kitchen and thereafter move along into the living room, but Halo knows that barely no one has been in the living room and it is not really dirty. The ceiling mounted sensor unit in the living room therefore turns on a green LED and tells Filip that he can relax with a voice message: "Relax Filip, good job in the kitchen, you don't have to vacuum here!". Filip is relieved and goes back to the kitchen for some cooking. Meanwhile, Elisabeth makes the bed in the bedroom – they were too tired after last night dinner to make it this morning. Halo notices an increased movement and particles in the air in the bedroom and sends the floor based unit in there when Elisabeth is done. The dust in the air is taken care of, and Halo leaves the room fresh again.

When Filip and Elisabeth are done eating, they move in to the living room to watch their favorite series on Netflix. Halo notices the cooking fumes in the kitchen and silently moves to the kitchen to clear the air and then returns to the charging station again.

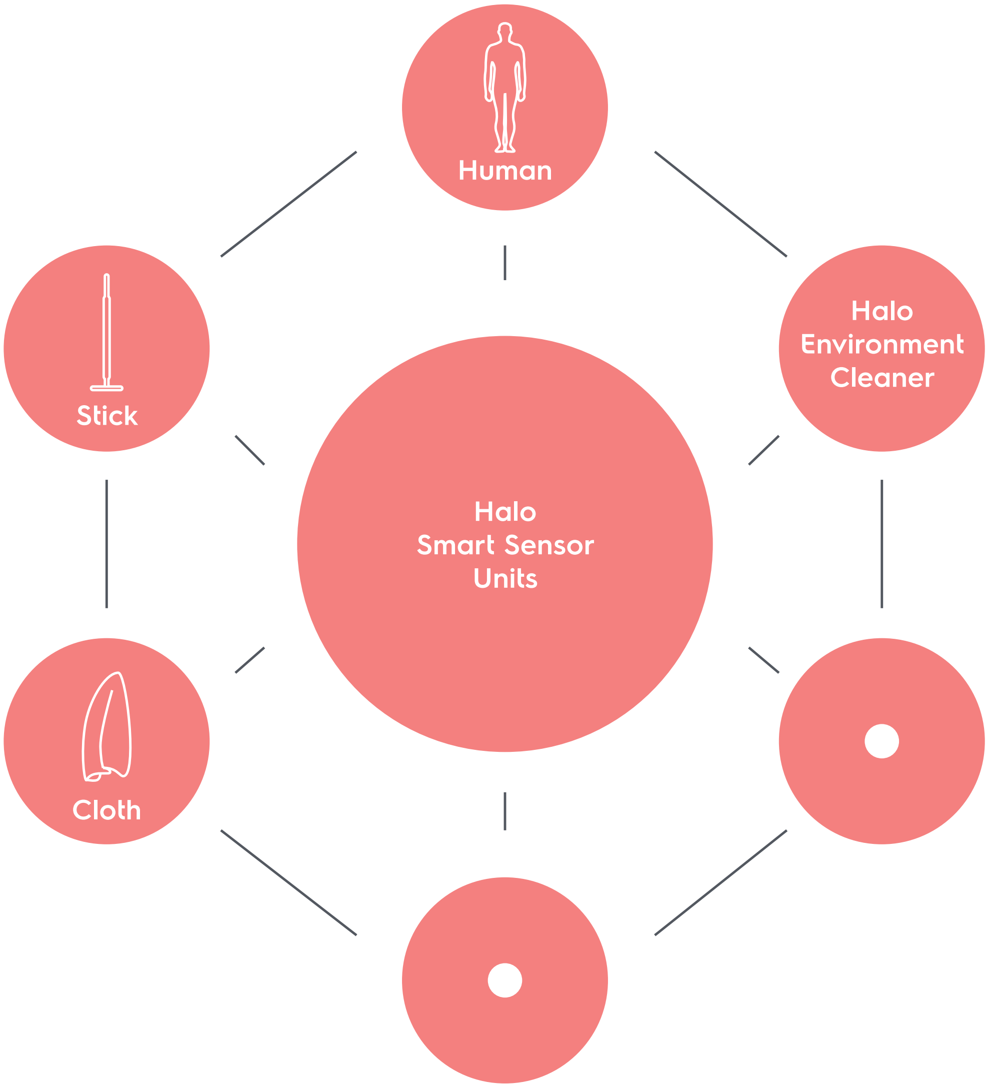
Later that night, Elisabeth have a hard time sleeping because it's so warm inside due to the nice weather they have had for the last couple of days. She calls for Halo "Hey Halo, it's so hot in here!". Halo leaves the charging station with a fresh charge and positions itself next to the bed in the bed room to give Elizabeth a nice breeze of air.

The New Clean Keeping Human-Machine System

Halo is part of a new system that has been referred to as a mesh of devices in this thesis. It includes the new stick and the cloth as cleaning devices, and of course Halo and the Halo sensor units. The mesh of devices that work together to keep the home clean are presented in Figure 75.

Apart from the device mesh, the human is of course also part of the new clean keeping human-machine system. Together with the different types of surfaces, they are all in the air of the home. The system and the interactions within the system are presented as a system model in in Figure 76.

Figure 75
The new mesh of devices that work together. The dots represent other potential clean keeping equipment.



As can be seen from the system model, Halo takes advantage of the fact that dust travels in the air when spreading between all of the components within the system. Thus, by catching the dirt in the air, Halo makes all cleaning more efficient. The size of the arrows furthermore implies that most of the dirt is collected by Halo proactively, while the cloth and stick can be used on easily accessible surfaces.

It is also clear from the model that most of the information goes through the sensor units which creates a controlled and structured operation. Halo brings an easy and simple structure to clean keeping by using the new smart capabilities of the mesh of devices.

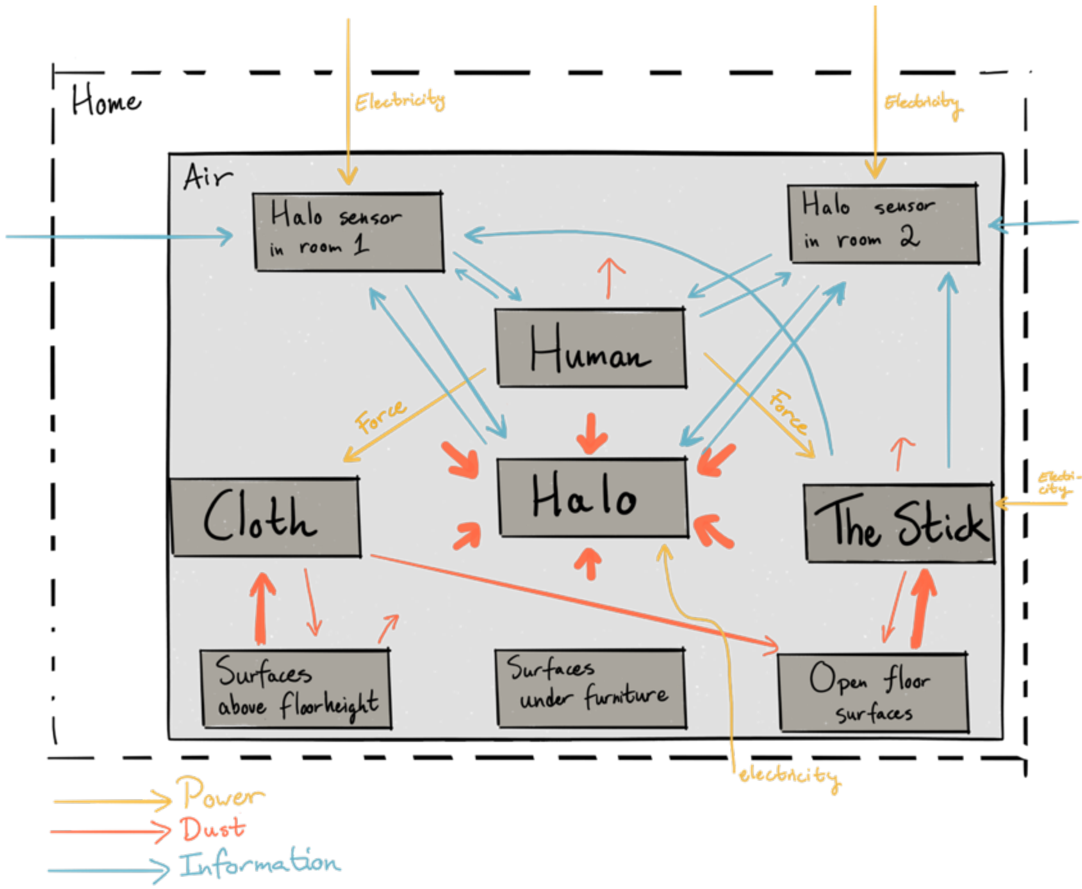


Figure 76
The new clean keeping system model.

Added Value – New Functions

As described in the scenario earlier, Halo has many applications and functions. The main function is to keep the air clean from impurities but what else can it do to create an even better living environment and a better life? An ideation session and consideration of earlier ideas resulted in a couple of functions that were applicable to Halo. The ideas are presented below and further investigation of the effect on architecture and form is presented later in this chapter.

Built-In Fan?

As mentioned earlier, indoor climate is a part of the home environment. The function to act as a fan was exemplified in the scenario and is a great application of the fan that is built into Halo anyway.

Air Circulation?

Indoor air is ventilated to remove smell, humidity, gases and other impurities. In that way cold or hot air is brought in from the outside which requires heating or cooling. The air does of course have to be changed regularly but a lot of the air circulation could be internal. Halo recirculates the air to keep it fresh and free from impurities. Similar solutions can be found in cars for example. Recirculation of the air reduces the need of ventilation and should therefore result in a reduced energy consumption.

Clothing Freshener?

Most people probably recognize the feeling of having clothes that smell from last night's restaurant visit. Clothes spread dust and smell. Halo is therefore also a clothing freshener that removes loose particles and smell from clothes. In that way the home environment is more pleasant all the way right up to the skin.

But this also rises a practical question. What happens when Halo moves around with e.g. a jacket on it? It's not believable to assume that the user always remembers to put the garment away before leaving for work. If Halo moves around trying to clean the air while having a piece of garment on it, the air won't get cleaned. However, a possible solution to this could be a technical one – if Halo *knows* that someone has their garment on it, then it would be possible to program Halo to *not* move around if it won't be able to clean in either way. Such a solution seems applicable. Halo won't be able to move around and clean – which is still an issue.

Smart Charging?

Halo is set on a mission to do various things: it should move around the house when no one is there and clean, it should move to the bedroom when someone has been making the bed, it should come to the kitchen if the user tells Halo to and it should act as clothing freshener. All these functions put a demand on Halo – to constantly be active. Halo will have plenty of time to charge, but at times it will be active to a larger extent. Will the battery last? What happens if the battery dies midway through a cleaning session?

This problem is solved by artificial intelligence. If Halo is aware of its battery status, it could also be able to schedule and map out the needs against its capacities. It could also have a built-in solar panel. And since the system knows if and where it is sunny, it can position itself in the window that lets the most sun light through. Halo could in that way do some of its work in a position that will not drain the batteries.

Reactive Blowing Is Difficult

Several of the functions in the clean keeping system were assigned to the different components at this stage of the project. The proactive blowing function did however need further testing. Is it possible to remove dust from surfaces by blowing from a distance, and if so, from where should the air be blown? It was found that different devices in the system can provide the blown air. An ideation session resulted in a couple of ideas on different possibilities, some of them are presented below:

- **Blowing from floor traveling environment cleaner** – Assigning the blowing function to the floor traveling unit would make most sense because it already has fans built in, it also has the ability to travel around the home to provide blown air everywhere. The unit would have to blow from below or be fairly tall. Further testing was needed to determine the feasibility of blowing from below though.

- **Blowing from ceiling mounted sensor units** – Placing fans in the ceiling mounted units would provide blown air from above and therefore remove dirt from almost any surface. Further testing of that was however necessary. It would make it possible to blow in several rooms and prepare the room before the floor traveling unit arrives. Fans would probably make the ceiling mounted units fairly large however.

- **Additional units** – Concepts presented earlier include ideas where blowing units are placed throughout the home. Such units could provide the blowing function. It would make it possible to reach any surface. This idea was however discarded because it would result in a complex system with a large amount of units. It would also increase the number of visible units, which is undesirable from a user's point of view.

- **Drone** – Drones were also part of the early ideas in the project. A drone could for example cooperate with the floor traveling unit to optimize cleaning by being able to blow almost everywhere. It would however add another obtrusive device to the system and was therefore discarded as an idea.

It was concluded that there are three possible positions of a source of blowing: tall floor traveling unit (horizontal blowing), low height floor traveling unit (blowing from below), ceiling mounted unit (blowing from above). Blowing from different heights, distances and angles was tested to determine whether the fan should be assigned to the floor traveling or ceiling mounted units, or if the function of removing dust from surfaces is feasible at all in this concept. The results from the tests are presented below.

Horizontal Blowing

A floor unit that is as tall as most surfaces in homes would allow it to blow horizontally or slightly angled downwards. Tests on horizontal blowing with a blow dryer showed that some dust is removed already at 4 to 5 meters, but that dust is effectively removed from a surface first at 1.5 to 2.5 meters. Pictures of the results are presented in Figure 77.

Figure 77
Dirt removed by blowing air from different distances, from top to bottom: 4-5 m, 3-4 m, 1.5-2.5 m.

Blowing from Below

A low floor traveling unit (compare to robotic vacuum cleaner) would blow upwards and blow underneath surfaces. For dirt to be removed from top surfaces, it would be required that the blown air “reflects” downwards or attach to top surfaces by an upwards angle (see Figure 78). Air does of course not reflect as light but a test was conducted to see if enough turbulence can be created to spread the moving air. The results clearly showed that air follows and spreads along the bottom of the surface rather than spreading downwards. Another test did however show that air blown from an angle upwards in fact can attach to the top of a surface at certain angles, distances and surfaces. It was concluded that it is not a universal solution.

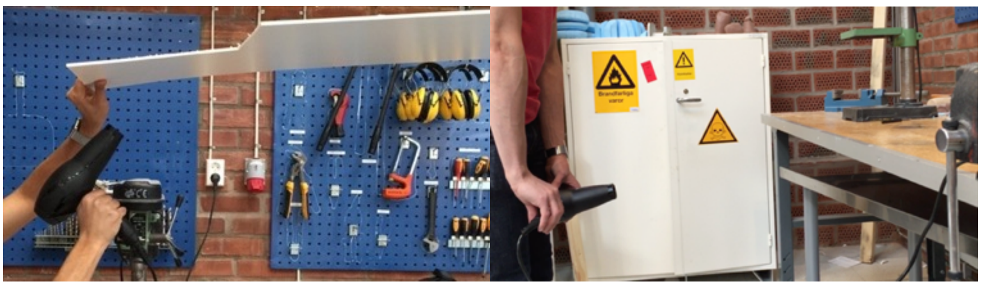


Figure 78
Blowing from below. Left: air does not "reflect". Right: angled blowing can attach to a surface at higher heights.

Blowing from Above

Blowing from above does in theory sound like the most reasonable option. But the distances to different surfaces are sometimes big and vary a lot. Tests showed that a blow dryer effectively removes dirt from a surface just beneath it at ceiling height (approximately 2.5 m). If the surface is not right beneath, but three meters away (horizontally) it barely removes any dirt though (see Figure 79).

Figure 79
The result of blowing from above. Top: blowing perpendicular to the table. Bottom: same test but with a dirty table 3m away (horizontally).

The tests were inconclusive. It was clear that blown air can remove dust from surfaces both in horizontal direction, from below and from above. Horizontal blowing was however found to be the most efficient principle. Blowing from below is not versatile enough and blowing from a stationary point above was found to have a hard time to cover an entire room. Providing horizontally blown air from the floor traveling unit would however require it to be fairly tall since dinner tables are above 70 cm, kitchen counter tops above 90 cm and book shelves are way above that. In the end, the blowing function was assigned to the floor traveling unit only. Halo is set to keep the air moving when there is dirt in the air, rather than actively removing dirt from surfaces. Further tests showed that a blow dryer can create noticeable movement in the air at a distance of six meters which is equivalent to a room size of 12 by 12 meters. Movement in the air was also found to spread to different heights, especially if the source of blowing was rotated during operation. Since Halo focuses on the air it will also affect the living environment on other floors than the one it is traveling on, compared to the robotic vacuum cleaner that requires to be moved between floors. Further investigation of fans is presented later in this chapter.

Horizontal blowing was found to be most efficient.

Function Allocation

All of the top level functions have now been presented. A function allocation between the different components of the system is presented in Table 13 below. The components are represented by the following numbers:

1. Halo floor traveling environment cleaner
2. Halo floor traveling environment cleaner charging station
3. Halo ceiling mounted sensor units
4. New stick
5. Cloth
6. Human

Table 13
Allocation of functions within the system. The functions in bold are the top-level functions.

	1	2	3	4	5	6
Keep home clean						
Prevent cleaning	●					●
Prevent dirt spread	●		●	●		●
Detect dirt in air			●			●
Detect dirt on open floor areas			●			●
Detect dirt on surfaces above floor height			●			●
Detect presence of humans			●			●
Detect movement			●			
Provide navigational help to floor traveling unit	●		●			
Determine general cleanliness			●			●
Prioritize clean keeping			●			●
Optimize clean keeping			●			
Organize clean keeping			●			●
Release dirt from open floor area surfaces	○			●		●
Release dirt from surfaces above floor height	○				●	●
Release dirt from surfaces beneath furniture	○					
Collect dirt from air	●					
Collect dirt from open floor areas	●			●		●
Collect dirt from areas above floor height	●				●	●
Collect dirt from surfaces beneath furniture	●					
Encapsulate dirt	●			●	●	
Store dirt	●			●		
Filter air	●			●		
Determine results of cleaning			●			●
Provide cleaning feedback			●	●		
Dispose dirt						●

	1	2	3	4	5	6
Keep clothes fresh						
Apply dirty clothes to Halo						•
Determine cleanliness of clothes	•					•
Remove excess particles from clothes	•					
Remove smell and other particles from clothes	•					
Retrieve clean clothes from Halo						•
Provide a pleasurable living environment						
Provide blown air	•					
Detect smoke, gas, smells and other particles in air			•			
Collect smoke, gas, smells and other particles from air	•					
Detect users' use of other products in the home			•			
Detect indoor temperature			•			
Provide movement in the air	•					
Other functions						
Provide power		•				
Provide unobtrusive storage charging place	•	•				
Provide automated relocation	•		•			
Provide inter-device communication	•	•	•	•		
Allow for replacement of filters	•			•		
Provide replacement of filters						•

As can be seen from the allocation above, the human is still involved in cleaning. The parts that bring pleasure to cleaning and puts the user in control remain as tasks for the user. It is also clear from the allocation that the user is offloaded from a lot of organizational tasks that the sensor units take care of, and that the environment cleaner is involved in most of the cleaning and clean keeping activities.

C. NEEDED COMPONENTS

A list with examples of components that could be needed was created. As discussed in phase 3, the final system relies on a new stick. The new stick was however not developed further since it is based on an existing product. The components therefore focus on the four parts of Halo: *the floor traveling environment cleaner*, *the charging station* and *the ceiling mounted sensor units*. The components are presented below.

Halo Floor Traveling Environment Cleaner

Ideation on components for the environment cleaner was based on common components in existing air cleaners, ionizers and robotic vacuum cleaners. Many high-end air cleaners for example use a combination of a fan, ionizer + metal plate, HEPA filter and carbon filter to filter most dirt out of the air. Electrolux (2016j) for example describe that functionality with their air cleaner EAP450.

Fan(s)

The environment cleaner should produce an airflow similar to that of a blow dryer of a cooling floor fan. A 2300 W blow dryer proved to be necessary to create movement in the air in an entire room. Floor fans are designed specifically for that purpose, and because of their size, they use less energy and are quieter. Further research showed that some 40 cm diameter floor fans produce an airflow of 600 to 700 L/s and operate on 50 W (Jula, 2016) (Dyson, 2016). It should be noted the existing air cleaners such as the EAP450 has an airflow of only 137.5 L/S.

Ionizer

Similar to the ones used in air cleaners such as EAP450 which fits within 650x285x480 mm.

Charged Metal Plate

Similar to the ones used in air cleaners such as EAP450 which fits within 650x285x480 mm.

Coarse Filter

Similar to the ones used in air cleaners such as EAP450 which has a surface area slightly smaller than the outer dimensions of 650x480 mm.

HEPA Filter

Similar to the ones used in air cleaners such as EAP450 which has a surface area slightly smaller than the outer dimensions of 650x480 mm.

Carbon Filter

Similar to the ones used in air cleaners such as EAP450 which has a surface area slightly smaller than the outer dimensions of 650x480 mm.

Batteries

The batteries would probably have to be slightly larger than the ones used in robotic vacuum cleaners to compensate for the ongoing operation, ionization and powerful fan(s). Research on robotic vacuum cleaner batteries showed that most of them range between 2.5 and 3.5 Ah with a voltage of 14.4 or 18 (Batterilagret, 2016). Such batteries are similar to the batteries used in power tools for example. The volume of such a battery is about 275 cm^3 (mL).

Inductive or Conductive Charging Receiver

Similar to the ones used in robotic vacuum cleaners for example. Inductive charging would require more space due to electronics components but would allow for a more unobtrusive experience that people want to have on display at home.

Charging Indication LEDs

Small LED diodes. Such diodes are insignificant in terms of size and power requirements.

Electric Motors

Similar to the ones used in robotic vacuum cleaners, such as the iRobot Roomba 980 which fits within the dimensions of 350 mm (diameter) x 91 mm (height) (iRobot, 2016).

Wheels or Belts

Two or three wheels/belts are needed to allow for a smooth travel. The size and design of the wheels/belts depend heavily on the design of the unit which is discussed later in this chapter. Bigger wheels will naturally provide a smoother travel and allow the unit the overtake bigger obstacles.

Wi-Fi and Bluetooth Chips

The devices communicate with each other and with the internet using Wi-Fi and Bluetooth similar to those used in laptops or smartphones. Their size is therefore insignificant to the overall design.

Other Electronics Components

The environment cleaner needs other electrical components such as a chipset similar to the ones in smartphones in order to make the environment cleaner function. Smartphones today are more than capable of that task which is why they are a good approximation for the chipset. Halo will also include other electronics components such as cables.

Mechanical Components

Lastly, the environment cleaner needs mechanical components such as axes, bearings and screws to hold everything together. The majority of all mechanical components will be part of the transportation system within the unit.

Halo Charging Station

The charging unit is wall mounted or floor based, and is not as limited in terms of dimensions as the floor traveling environment cleaner unit. Its functions include charging of the floor traveling unit and communication with the other parts of the system. The following components below are therefore needed.

Transformer

A transformer similar to the ones in robotic vacuum cleaner charging stations is needed to bring the power down to the chosen voltage. It could be placed inside or outside the charging station itself.

Inductive or Conductive Charging Transmitter

The opposite of the component used in the floor traveling unit. Probably similar to the ones used in robotic vacuum cleaners.

Wi-Fi and Bluetooth Chips

See “Halo floor traveling environment cleaner” above.

Other Electronics Components

See “Halo floor traveling environment cleaner” above.

Mechanical Components

See “Halo floor traveling environment cleaner” above.

Halo Ceiling Mounted Sensor Units

Ideation on components for the ceiling mounted sensor units were based on smoke detectors, fire alarms, home alarm systems and air cleaners such as the Electrolux's EAP450 described earlier. There is no unit quite like the Halo sensor units on the market, which is why the listed components below are only exemplified with other categories of products. Most of them are components in small products which makes them very suitable for a unit that is similar to a smoke detector. The components were therefore not further specified in this project.

Motion Sensor

Similar to the ones in home alarm systems. Consists of a small sensor on a chip.

Smoke Detection Sensor

Similar to the ones used in smoke detectors.

Gas Detection Sensor

Similar to the ones used in smoke (carbon monoxide) detectors.

Particles Detection Sensor

Similar to the ones used in air cleaners such as the EAP450.

Humidity Sensor

Similar to the ones used in small indoor weather stations.

3D Video Camera, RADAR or LIDAR

A 3D camera similar to the ones used in mobile phones or gaming console accessories such as the Microsoft Kinect would be suitable both in terms of function and size. More advances technology such as RADAR or LIDAR is used as localization and navigation help in self-driving cars would also provide good data, but they are considerably larger.

Thermometer

Simple thermometer or temperature sensor similar to the ones used in digital thermometers.

Wi-Fi and Bluetooth Chips

See "Halo floor traveling environment cleaner" above.

LED Indicator

One or several LED diodes similar to those used in some smoke detectors.

Other Electronics Components

See "Halo floor traveling environment cleaner" above. The ceiling mounted sensor units also include a microphone and speaker similar to those in smartphones or smart smoke detectors.

Mechanical Components

See "Halo floor traveling environment cleaner" above.

D. FORM, COLOR AND MATERIALS

Halo is really two things:

1. **A representation of a gap in the market** – Halo is an example of what a product that keeps people's home clean in a smart way and leaves a lasting impression could be like.

2. **A manifestation of a design that people want to have on display at home** – Most people in the initial user studies were found to want to hide their vacuum cleaners, even the current stick vacuum cleaners that are actually designed to be out in the open and easily accessible. Halo is a visual representation of the results found in phase 3. It is a concept with a completely different expression – one that people hopefully want to put on display.

The form development phase was all about the second purpose described above. It was about designing a product according to the expressions (composed, thorough, unobtrusive, confident, trustworthy, seamless) found in phase 3 and to make sure that Halo is the first cleaning product that people like to have visible in their homes. Being unobtrusive was found to be one of the most important factors for a visible product, and therefore became the starting point of the form development. The results from the form development are presented in the following sections.

An Unobtrusive Form Is Thin and Slim

A sketching session resulted in several ideas on what the main shape of the environment cleaner could be like. It gave a good idea of what the general shape could be and acted like a starting point for the form development and gave it direction. Some of the sketches are presented in Figure 81.

The sketches generated several insights on what factors affect the obtrusiveness of a product or an object. Parallels were also drawn to other products and product categories. The most important factors are presented below:

- **Floor footprint** – It was found that the floor footprint is the main contributor in the case of clean keeping devices, and other devices for that matter. A radiator is for example much less noticeable than a coffee table or a fridge. Minimal footprint is also required to reach into any room.

- **Thinness** – It was concluded that products that are stretched in two dimensions, i.e. considerably smaller in one dimension, are in general unobtrusive. New laptops and tablets, such as many products from Apple, are for example almost unnoticeable both on a table and in the hand of the user.

- **Height** – The sketches furthermore gave the insight that tall objects compete with other pieces of furniture and even humans in terms of real estate. It was concluded that Halo probably shouldn't be considerably taller than wide.

A slim and thin form that is thinner than it is wide and tall was concluded to be a good starting point for the form development. Such a form factor would also allow Halo to almost disappear towards a wall or in-between two pieces of furniture when not being in operation. One of the participants in the study for example said *"I think a flat product is great, it would fit between my couch and the wall. I don't have much place anywhere else!"*. A form that stretches in two dimensions would furthermore maximize the space for filters and therefore increase the clean keeping capability. A circle, rectangle or rounded rectangle with some depth were decided to be feasible ideas for the continued form development. Some examples are presented as two-dimensional sketches in Figure 80. Colors and materials of course affect the obtrusiveness as well; those factors will be discussed later in this section.

A slim and thin form was concluded to be a good starting point.

Evaluations with users were conducted in the continued form development.

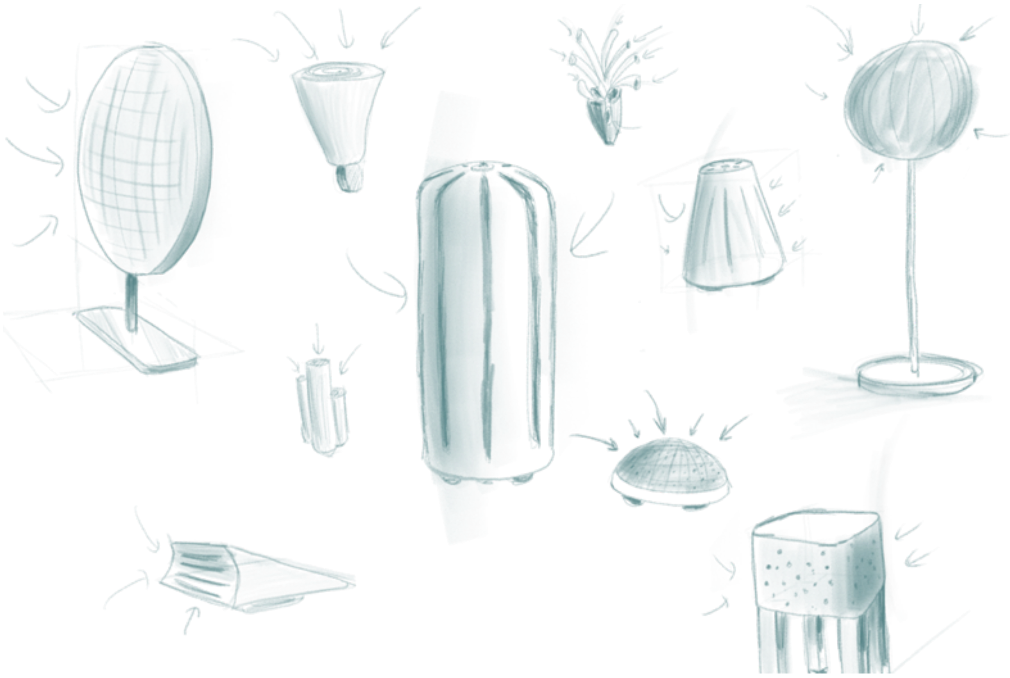


Figure 81
Possible Halo shapes.

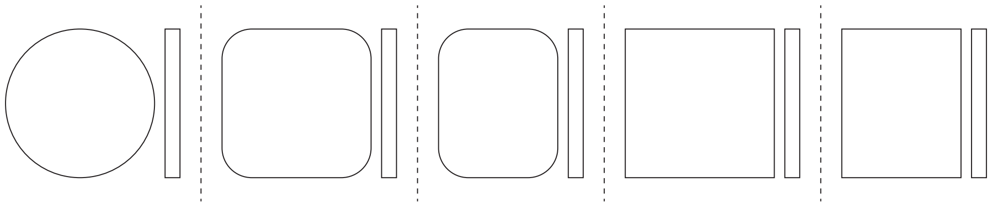


Figure 80
Examples of unobtrusive thin forms. One front view and one side view per form are illustrated.

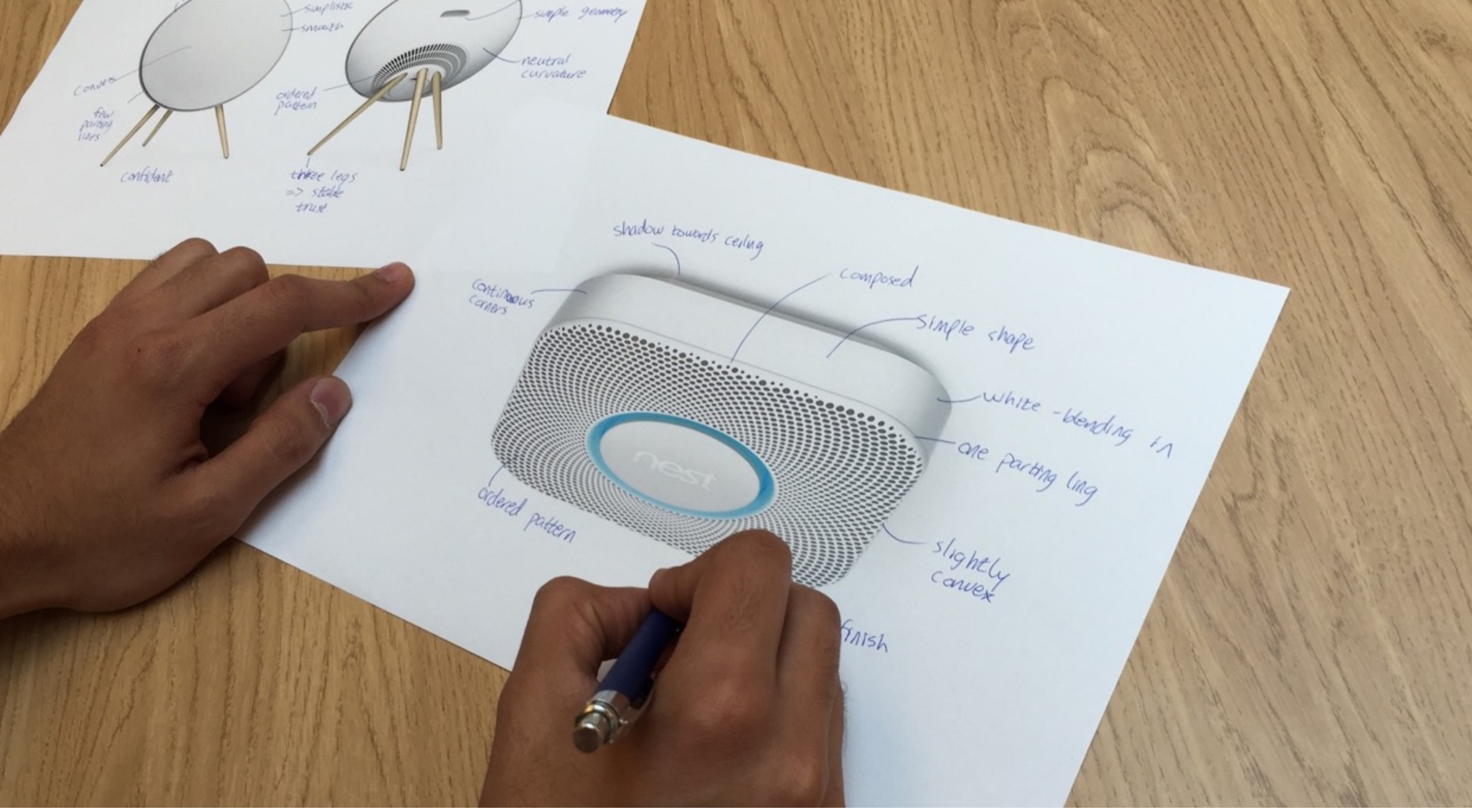


Figure 82
Analysis of Nest Protect and Bang & Olufsen A9.

A Visible Product Should Be Beautifully Crafted – Just Like a Bang & Olufsen Speaker

As mentioned several times, clean keeping products are devices that user's want to hide rather than having visible. Some products have to be visible even if the user want to or not though. Some examples are: smoke detectors, thermostats, heating pumps, air conditioners, home alarm systems, air cleaners, radiators, speakers and TV decoders. All of them have functions that are desirable but that also require them to be out in the open. As it turns out, there are a few companies that have actually succeeded in making such products beautiful and unobtrusive enough to make people like, or even love, them. So what does such a product look like? Two companies that have succeeded across their product lines were found: Nest and Bang & Olufsen. Their products were also found to match the findings about unobtrusive forms in the previous sections. They are presented in the paragraphs below. The specific products that were analyzed are presented in Figure 82 and represented in the expression board in Figure 83.

Nest

Smoke detectors and thermostats are probably some of the most unsexy products in existence. Nest makes both of them. They have made them smart and beautiful. Nest Protect is for example a smart smoke detector that is connected to the user's mobile phone, gives calming voice feedback and acts like a night light (Nest, 2016). All of those factors make it into a product that creates more value to the user, even when not acting as a fire alarm – just as Halo does when not being an environment cleaner. The design is restrained and based on simple geometries. The surface fillets that acts as transitions in the corners give the Nest Protect a composed overall expression. Its color and shape blends well into the interior of most homes, which makes it very unobtrusive.

Figure 83
Nest and Bang & Olufsen were part of the inspiration for the expression board.

Bang & Olufsen

Speakers are definitely more desirable products than smoke detectors, but the users are really mostly interested in the sound they provide. Bang & Olufsen have been able to combine form and function to create objects that are both beautiful and useful for years. Their Beoplay A9, is an incredibly confident yet unobtrusive speaker. Just as Nest Protect brings smoke detectors into the future, A9 brings music listening into the future. Beoplay A9 is a wireless speaker that can be floor standing or wall mounted (Bang & Olufsen, 2016). It is exquisitely crafted as a simple disc with neutral curvatures on the rear and front, which makes it look composed and thorough.

Halo Should Not Look Like a Robot

The sketches and inspiration from Nest and Bang & Olufsen lead onto a path of flat, almost two dimensional designs with limited depth. What would such a form look like when moving? Halo is moving at some times and stationary at others, so should it look stationary or mobile? The answer is both but the contradiction required extra investigation to verify that the chosen form factor path is feasible. The sketches in Figure 84 show several ideas on what the flat form factor could look like when moving, when being stationary and when standing close to a wall. Inspiration was found from other moving products but also from the anatomy of humans. The following conclusions were drawn:

- **Halo should not look like a robot** – Halo must blend well into the interior and therefore not look like an obtrusive, futuristic and technological device such as robot. It was also concluded that it is important for Halo to not look like a robotic vacuum cleaner; to eliminate confusion but also to get rid of unwanted heritage of poor functionality.

- **Halo should focus on looking stationary** – Most of the time Halo is stationary. It is stationary when cleaning the air, freshening clothes, providing air circulation and charging. Most importantly, it is designed to be out of the way from residents and therefore not move in their presence if not wanted. It was therefore concluded that Halo should look stationary and naturally fit into any part of a home.

- **Halo should look movable when moving** – Between its tasks Halo is actually moving. And even if the focus should be on looking stationary, it must look movable when moving, to evoke trust among the users. They must trust that it is more than capable of transporting itself in a safe and secure manner without hurting anyone or damaging anything.

- **Halo should have a low center of mass and close connection to the floor** – As part of looking stable when being both stationary and moving, Halo must visually and physically have a low center of mass. It was especially found that the main form needs to be close to the floor to look trustworthy and stable instead of fragile. One of the study participants for example meant that "a large heavy object on legs at that height makes the product look so fragile".

Make Halo look movable when moving, while beign unobtrusive and elegant when stationary.

It was concluded and decided to proceed with a thin form positioned close to the floor, accompanied with a leg that can fold out to lower the center of mass and spread mass across the floor to make Halo look movable when moving, while being unobtrusive and elegant when stationary.

Figure 84
Ideas on what Halo could look like when moving and being stationary.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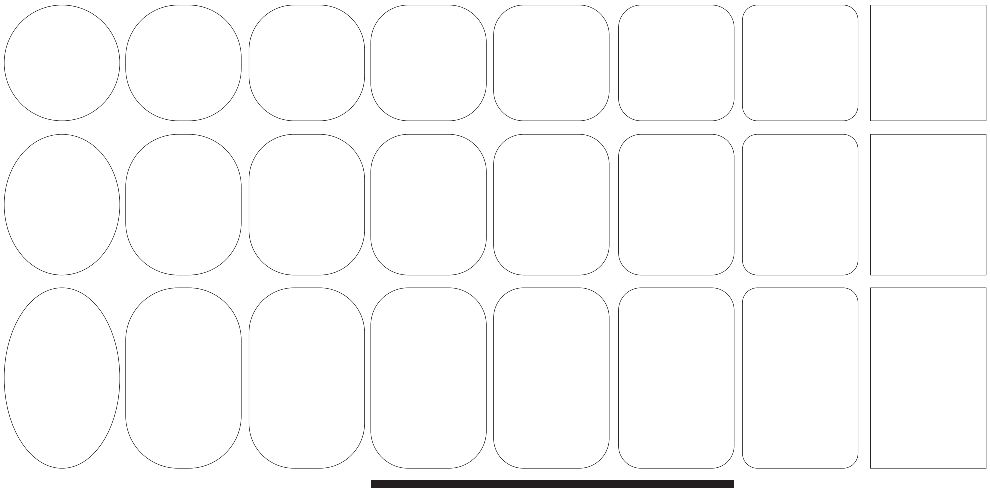
solceller

Halo Is a Composed Rectangle

The ideas, results and inspiration from the previous sections were used to find the final form of Halo. Several variations of the dominant front dimension of Halo were created and evaluated with users. The shapes stretched from a circle to a rectangle with several different radii in-between. They are all presented in Figure 85.

Figure 85
Evaluated shapes for the front dimension. The most liked ones above they black line.



The six interviewees were fairly unanimous in their choice of the favorite shapes. They meant that the rounded rectangles are most composed and also their favorites. A too big radius makes the shape ambivalent, while a smaller radius was perceived as more confident and trustworthy. Circular shapes were in general disliked, one interviewee even meant that it made her think of toys. It was concluded that an elongated rectangular shape with rounded corners was the way forward.

Halo Has a Heavy Base

The side view or cross section of Halo was investigated in a manner similar to the front shape development above. Inspiration was taken from Nest and Bang & Olufsen, and focus was on finding a composed and unobtrusive shape. The result was an enclosure made up of a front and a rear side that consist of composed and neutral curvatures. Several variations of the balance between front and back were created and evaluated with users. The sketches are presented in Figure 86.

The interviewees liked the cross sections that consist of a dominating rear side, minimal middle section and balanced front. They argued that those factors make it look trustworthy and confident. A too obtruding front made the participants think of toys or bellies, they also meant that it results in a visual imbalance and a feeling that it will tip over. Several of the participants wished for a lower center of mass and proposed to move the accentuation of the curvatures downwards. Visual balance was mentioned as an important factor for the overall expression – to make it trustworthy and composed. They also emphasized the effect of the size of the radii on the rear side. They meant that a flat rear fits better towards the wall.

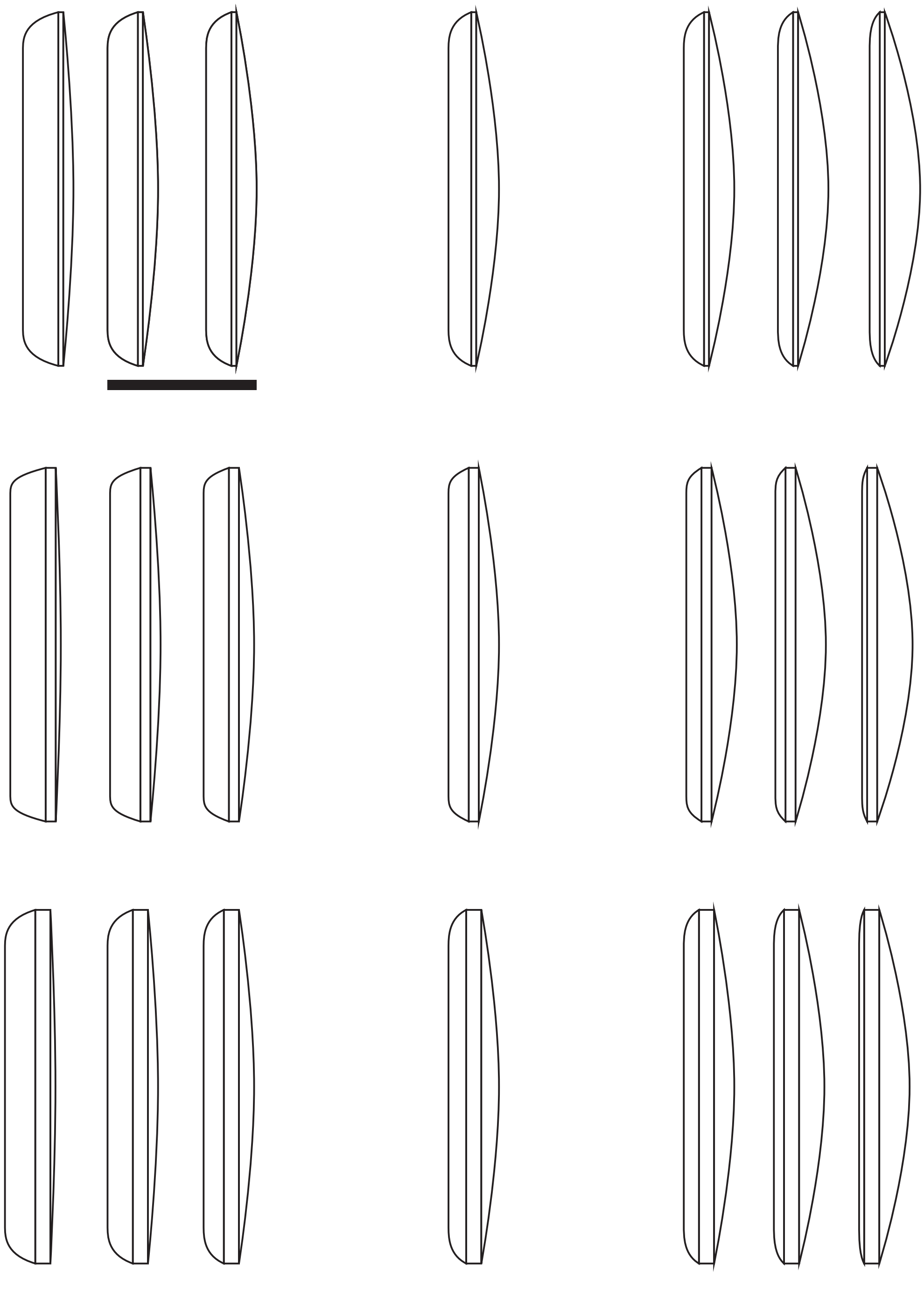


Figure 86
Variations of the cross section of Halo. The most liked ones above the black line.

Several iterations were made and evaluated with the users. Radii, curvature accentuations and visual centers of mass were varied. A tilted cross section with a leg was added to each variation in order to evaluate the stationary, moving and wall mounted expressions at once. Some of the variations that were tested with the users are presented in Figure 87.

The participants clearly liked the ones with a rear side that is accentuated towards the bottom to lower the center of mass. They also preferred the ones that had a less accentuated front because they look more composed.

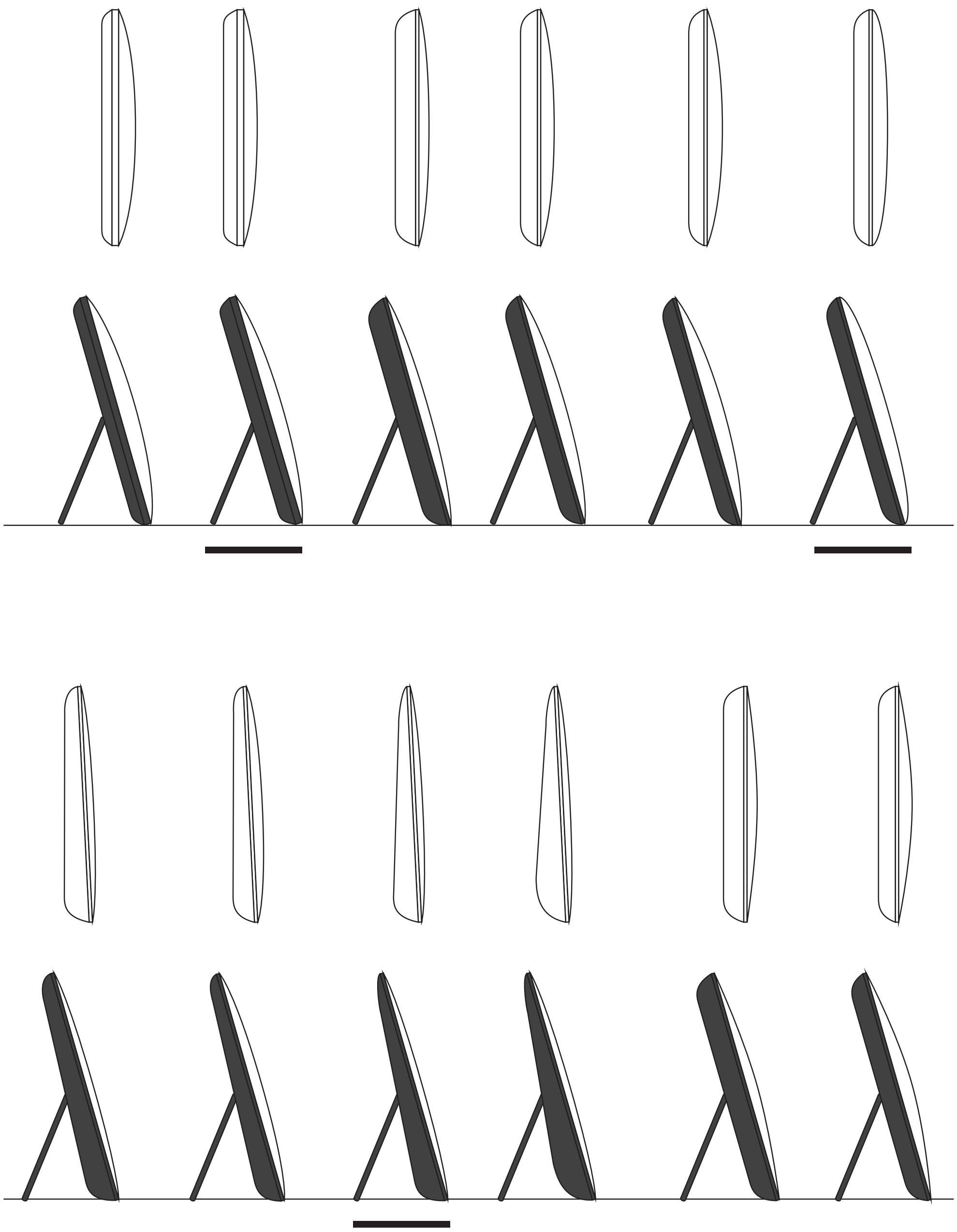


Figure 87
Iterations of the cross sections of Halo. The most liked ones above the black lines.

The three most liked ones (see Figure 88) – also the three that seemed to fit most into the sought expression according to the expression board and expression association web presented in phase 3 – were further evaluated. Two users were interviewed with a semantic scale, based on the wanted expression, as a guide.

Both of the interviewees seemed to agree that number 2 (the one with a low center of mass), is the shape that represents the wanted expression the best. They meant that it is composed, thorough, capable, unobtrusive and trustworthy, but not as confident as the other shapes. Confident was however referred to as being dominant. One of the interviewees for example argued that number 2 is submissive, but in a good way. Number 3 was perceived as far away from the wanted expression. It reminded the interviewees of toys and a blown up belly. Number 1 created a lot of split opinions, which is why no conclusions could be drawn about that particular shape. One of the interviewees meant that it looks more like a tool, compared to number 2 which looks like a piece of art.

A shape with a low center of mass representes the wanted expression the best.

All of the six participants in the form evaluations agreed unanimously that they liked number 2 the best. Number 2 was therefore used as a foundation for the continued form development, and transition to three dimensional form.

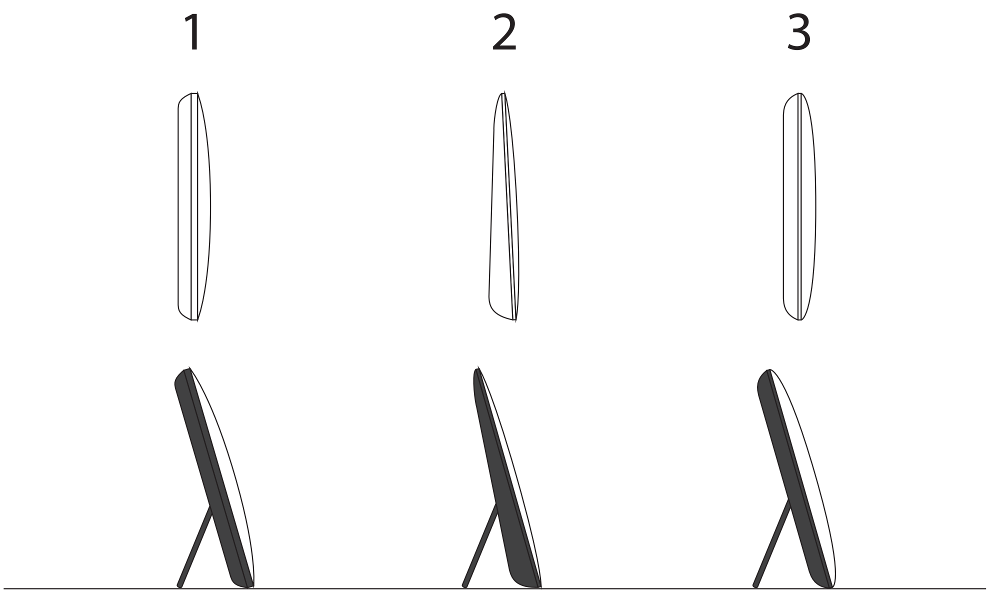


Figure 88
The most liked cross sections of Halo.

Like a Tailored Shirt

The next step was to define the dimensions and proportions of Halo. Several factors were taken into consideration during the process. The main focus was on the different functions of Halo, available space inside homes and relation to other products within the home. The drawing in Figure 89 acted as a guide throughout the process.

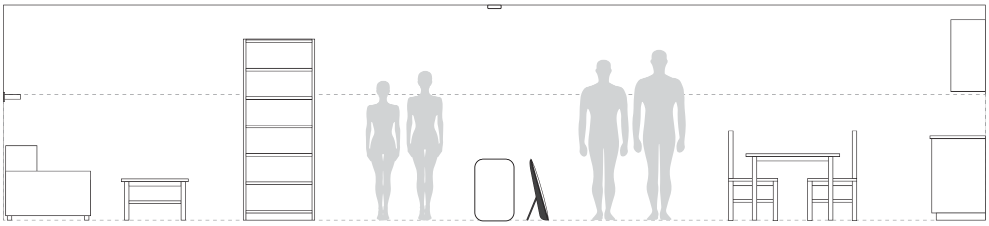


Figure 89
Halo in relation to other objects and humans.

The front dimensions of Halo were at first inspired by other products:

- Air cleaner Electrolux EAP450: 480 mm (width), 650 mm (height)
- Speaker Bang & Olufsen Beoplay A9: 701 mm (diameter)
- General coat-hanger 430 mm (width)
- Floor standing fan: 400 mm (diameter)
- General dinner table: 730mm (height)

Since the Bang & Olufsen speaker was an inspiration throughout the project and since it represents the wanted expression well, the first tests were based on its 701 mm diameter. The size of a fan was used as the smallest possible dimension. A first test was made by measuring different dimensions in an apartment. The dimensions 500x500 mm, 600x600 mm and 650x650mm are visualized in Figure 90.

600 mm was found to be a visually pleasing and reasonable dimension. A foam board mockup was created to represent a product with a width of 600 mm and a height of 800 mm. It was immediately clear that such a large product is way too large and obtrusive. All of the interviewees agreed and the development continued.

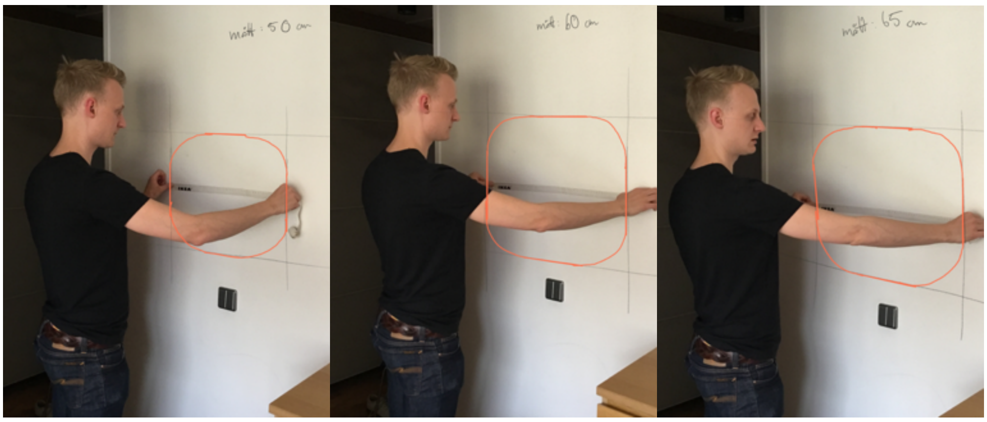


Figure 90
Different dimensions on a wall, from the left: 500x500 mm, 600x600 mm and 650x650mm.

It was decided that the total area of the filters within Halo should be the same or more than in an air cleaner such as the EAP450 to guarantee an effective clean keeping functionality. The outer dimensions also heavily affect the clothing freshening functionality. The idea was that it should be possible to hang a coat, shirt, t-shirt or other pieces of clothing over the top of Halo. It was therefore concluded that the dimensions of a coat-hanger should act as guidance. Three new foam board models were created. All of them had a width of 450 mm but varied in height from 600 to 800 mm (see Figure 91). 450 mm was in fact found to be the perfect width for a shirt or a coat hanger as can be seen in Figure 92.

Evaluation of the different dimensions with the six users clearly showed that people in general want the device to be as small as possible. They also meant that they liked the proportions of the taller ones better. Most of them preferred the 650 mm tall one but one of them clearly preferred the 700 mm tall one. To keep Halo unobtrusive while optimizing its capabilities, it was decided to keep the height as tall as possible but still beneath dinner table height. The final dimensions of Halo are therefore 450x700 mm. The depth was decided based on the earlier form development and set to 100 mm. Those dimensions were also found to make it possible for Halo to travel through several parts of a home, such as door frames and the space between a couch and a coffee table.

Figure 91
Varying dimensions, from the left: 600x800 mm, 450x800 mm, 450x650 mm and 450x600 mm

Figure 92
450 mm is the perfect width for hanging clothes.

Halo Goes Gray and Polymeric

Halo needs to fit into any home and therefore any interior and taste. Every home includes a different combination of colors, forms and materials. Before the final three dimensional form could be created, the direction of colors and materials had to be chosen. Inspiration was found from the expression board and it was concluded that grayscales should be used to design such a visible product as Halo. Cool shades of gray, i.e. with a slight blue tint, were chosen because of their freshness and because some white or light gray materials tend to go yellowish over time. The rear of Halo was chosen to be gray with quite a lot of whiteness to it to meet the shadows on a wall and blend well into the environment. The front was decided to be white with a slight gray tint to blend into the white walls of the simplistic modern home of Filip and Elisabeth.

Aluminum and plastic materials were considered because of their lightness, durability and surface properties. Aluminum was discarded for cost reasons though. A durable polymeric material that ages with dignity was sought. ABS plastic was chosen as an example because of its durability and possibilities of excellent surface finishes. Plastic also makes Halo blend in and not take too much attention as a piece of art.

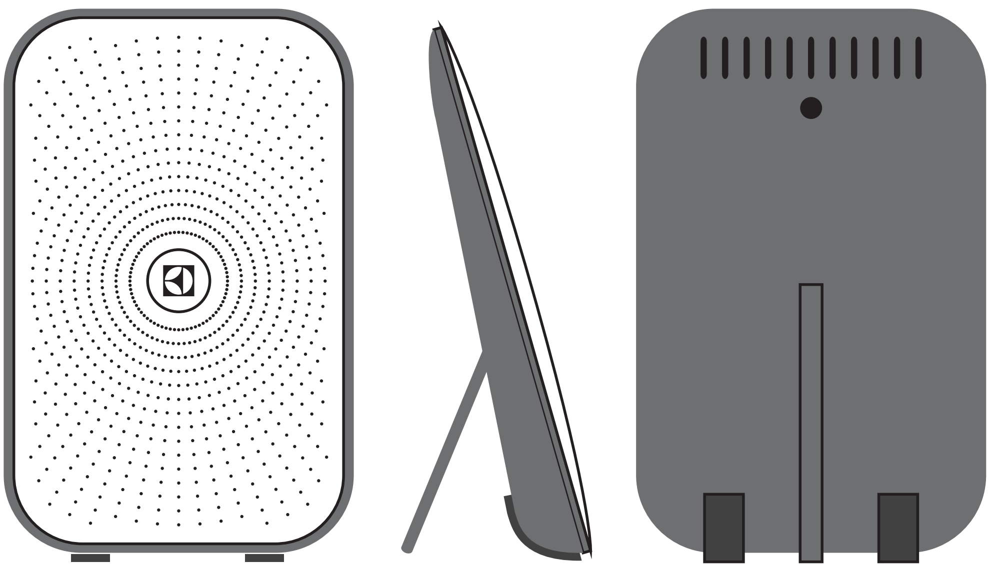
Design of the Last Bits and Pieces

The overall form of the floor traveling environment cleaner of Halo was decided at this stage of the project. A few factors remained to be decided. Sketching and ideation resulted in a couple of ideas on how to finalize the form of Halo. The following decisions were made:

Air Inlet and Outlet

The front of Halo was chosen to be the air inlet. That allows the filters behind to take advantage of the full surface area of the front. It also makes it incredibly easy to clean. The inlet was designed as holes in a circular pattern. An early sketch is presented in Figure 93. The holes were designed to be big enough to let dust, smells and other particles through. The outlet was created as slots running along the top of the rear side to let the air out in a desirable direction with a powerful airflow. Air is only let out through the top to reduce the risk of moving dust from the floor to surfaces above floor height.

Figure 93
An early view of Halo floor traveling environment cleaner



Transportation

It was decided to use two transportation belts on the main unit in combination with a wheel on the foldable leg. The three supporting points give Halo stability, and ability to rotate and navigate freely. The transportation belts allow for an unobtrusive expression that follows the form of the main unit and makes it possible to climb carpets and door steps. The belts and the leg allow Halo to move almost everywhere in the home, but they do not allow Halo to walk the stairs, which could be seen as an issue since all floors are in need of cleaning. One of the main issues with robotic vacuum cleaners is that they cannot walk the stairs, and thus, are needed to be moved manually by the user to the next floor. However, is the inability to walk the stairs really a big issue for Halo? The main difference between robotic vacuum cleaners and Halo is that Halo cleans the *air*. On the account of human activities in the home, the air is moved around the home during a period of the day. Thus, Halo is able to clean the air that once has been on the other floor. The downside may probably be that tables, shelves, decorations, etc. on the other floor won't become clean as effectively as the surfaces on the floor on which Halo is present. Two Halos is an effective solution, but also a more expensive solution for the customer.

Three supporters give Halo stability, and ability to rotate and navigate freely.

Maintenance Access and Inside Structure of Components

The rear was designed as one body which gives it an unobtrusive, thorough and seamless expression. The parting line was placed between the front and the rear where the colors change as well. The front is magnetically attached to the rear shell, which makes the inside easily accessible. Just inside the front are the layers of filters and behind them fans, electronics, motors and batteries. A cut out circle with the Electrolux logo acts as a handle from the front.

Charging

The Halo floor traveling unit charges itself automatically by returning to the charging station when it's done cleaning. The wall mounted charging station was designed flat to disappear almost completely when Halo is on charging. It allows the user to comfortably hang their clothes for freshening when Halo is on charge. By being wall mounted, the charging station does not occupy any floor space at all. It is white to blend into white walls and fit on any wall. Inductive charging was chosen as method of charging to create a seamless expression.

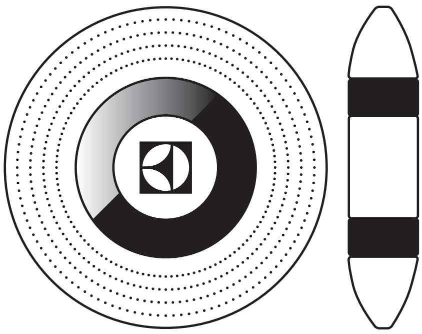
Attachment to the Charging Station

The wall mounted charging station consists of two overlapping plates; one fixed to the wall, and one sliding vertically towards the floor. The outer plate slides down to the height of Halo floor traveling environment cleaner in order to retrieve, or release, the environment cleaner. It attaches to a concavity on the rear of the environment cleaner and moves it up or down.

Sensor Units

The sensor units were made to be companions to the floor traveling unit. They were therefore based on that unit and inspired by the Nest Protect and the Beoplay A9. The sensor units were designed as circular pods with three layers of different functionalities (see Figure 94). The outer circle is for sensors such as smoke and dust detectors. The center circle is covered by glass and reserved for visual sensors such as the motion sensor and the 3D camera. The rest of the electronics and the LEDs are placed in the inner circle.

Figure 94
An early view of Halo ceiling mounted sensor unit.



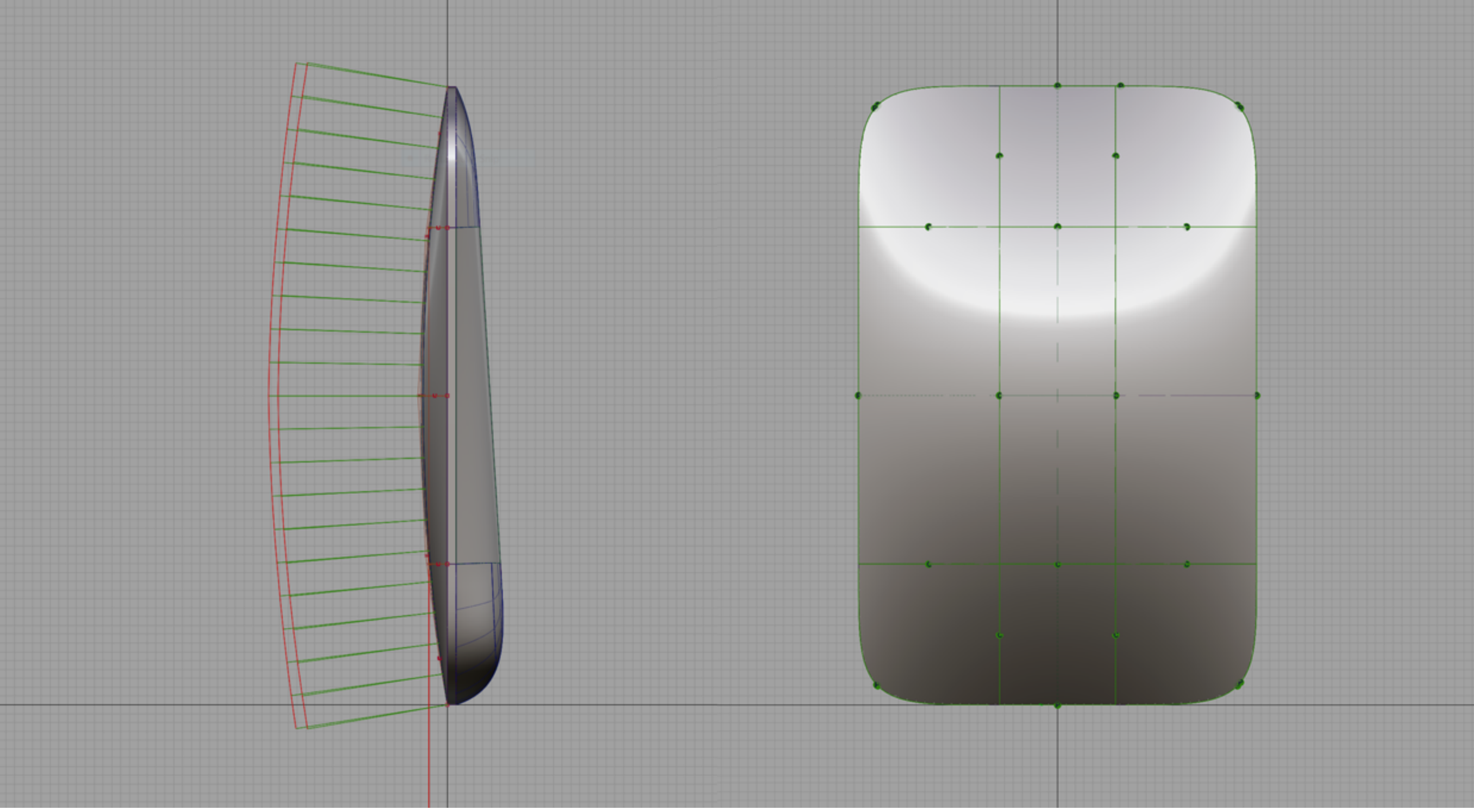


Figure 95
Perfect curvatures and surface continuities create beautiful reflection.

Finalization

The rest of the form development and design was made in CAID software. Some of the most important factors and expression properties, such as thoroughness, were created at this stage. The choice of material, color and general shape was used to develop a thorough, trustworthy and confident final expression. Most of that work was in creating perfect curvatures and surface continuities. The exquisite curvatures and surface continuities create the perfect travel of light and reflections visible in Figure 95. Those properties contribute heavily to the expression of quality and thoroughness. A matte surface finish of the ABS plastic was chosen to create a smother travel of light and an even more crafted expression. The final renderings are presented in the following sections.

E. INTERACTING WITH HALO

Halo is designed to require minimal interaction, but for some purposes the user will interact with the system. And it was made incredibly simple. Focus was on creating an interface that is like no interface at all. The activities that require interaction are described in the following sections.

Filter Cleaning or Replacement

Filter access was made extremely simple by using a magnetically attached front. It easily snaps of and the user reaches the layers of filters. Since Halo is wall hung when on charge, it is furthermore on a comfortable height. The filters can be replaced in seconds or just put on the floor for a quick cleaning with the new stick.

Feedback to the User

Since the Halo system is completely automated, it doesn't really need to communicate with the user unless something is failing. It does however give the user positive and encouraging feedback by voice messages from the sensor units. In that way, the user gets it anywhere in the home, but is not disturbed by several new notifications on their smartphone for example.

The User Wants Halo to Come or Disappear

Of course there are situations when the user wants Halo to clean, blow some cold air or freshen their clothes in the bed room, but also situations when they want Halo to stay away because they are treating the surface of the wooden floor. In those situations, the user can just catch Halo's attention by saying "Hey Halo!" and tell it what they want. They can even ask Halo if they need to clean tomorrow or what the indoor temperature is. And the best thing is that the functionality is always available due to the sensor units that are distributed throughout the home.

Catch Halo's attention by saying "Hey Halo!".

F. SAY HELLO TO GLORIOUS HALO

The insights and understandings of people, clean keeping and dirt resulted in a vision of specialized devices working together in an intelligent mesh. The specialized devices include a revamped stick vacuum cleaner (as explained in phase 3) and also Halo. Halo is a futuristic product concept that serves as an *example* to the authors' view of effortless cleaning – a smart environment cleaner that revolutionizes clean keeping as it fills a gap in the market by being a product focusing on proactive cleaning and the sustainment of a clean household environment. Halo also manifests the authors' values – products should be beautiful and useful.

Halo consists of two types of units: the *Environment Cleaner* and the *Smart Sensor Unit* (see Figure 96).

Figure 96
Halo Environment Cleaner and Halo Smart Sensor Units.

Halo Environment Cleaner

The Environment Cleaner, or "EC" in short, is the body of Halo. It is a battery-operated, autonomous clean keeper of indoor climate – dust, odors, smoke, pollen and other particles in the air are filtered (with a coarse filter, a HEPA filter and a carbon filter) by the EC. Halo draws air in from the front (see Figure 97) and forces it through the filters before letting it out it through outlets on the back (see Figure 98). The front is magnetically attached (see Figure 99) which, together with the handy unlock grip in the center, makes filter maintenance easy as pie. Battery and filter statuses are presented by LED indicators on the top side of the EC, as shown in Figure 100.

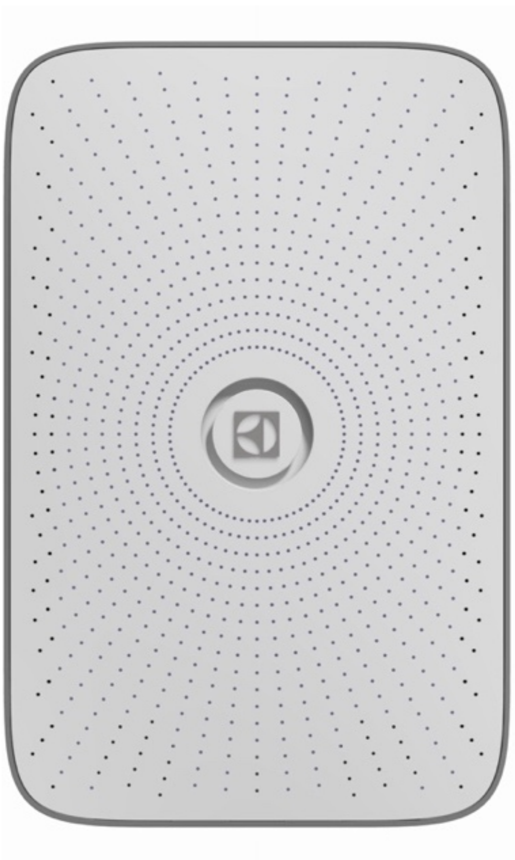


Figure 97
Halo Environment Cleaner – front view.

Figure 98
Halo Environment Cleaner – rear view.

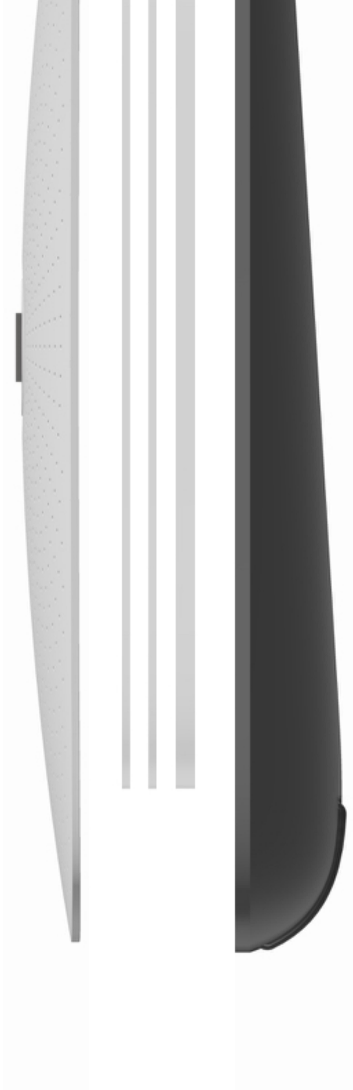


Figure 99
Halo Environment
Cleaner – side view.

Figure 100
LED indicators present
battery and filter
statuses.

Unstoppable

The unit acts upon orders from the smart sensor units and moves around on the floor in order to retain a clean environment everywhere. It moves with the help of two motorized belts and a supportive, wheeled leg that together create a three-point support, which stabilizes the EC. Halo EC is able to tilt and lower its center of mass (see Figure 101) thanks to the flexibility of its supportive leg, enabling it to overcome thresholds and to move around different rooms and types of floor. Also, the ability to tilt in different angles is a protective measure if indoor pets accidentally (or consciously) nudge it.

Figure 101
The flexible supportive leg allows Halo to go almost anywhere.

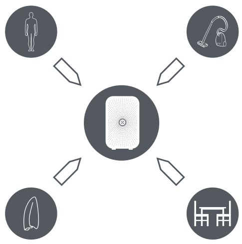


Figure 102
Dirt is taken care of before it lands on surfaces thanks to Halo.

Lasting Impression

Surfaces and textiles usually get dirty due to the airborne dirt. However, as Halo reactively keeps the air clean, Halo also proactively keeps those surfaces clean. Dirt from humans, furniture and other clean keeping devices emitted into the air is taken care of by Halo before landing on surfaces (see Figure 102). Dusting surfaces becomes a much less frequent activity as Halo retains a fresh living environment, leaving a *lasting impression* after each cleaning session that the user is involved in.

Unobtrusive in Its Function

The general cleaning of air is operated when the residents are not at home in order for it to be truly unobtrusive and to not disturb the residents with the sounds it could possibly make (e.g. from fans). Consequently, the user will most of the time not see Halo EC in action. On the other hand, it's very simple to see it in action by communicating with the sensor unit.

Does One Thing Great

Halo moves around the home, which makes it similar to robotic vacuum cleaners. One could ask "*why not combine these products?*". The authors of the thesis have deliberately refrained from developing a robotic air and vacuum cleaner device. Research in the earlier phases of the project strongly indicated that multi-purpose products make trade-offs in user experience. Halo does not pick up dirt from the floor, and there are three reasons for that, all connected to user experience:

1. A product that offers the best experience is a product that does one thing the best. Halo should do what it does best – keeping the air clean.

2. The efficiency of Halo lies in its ability to quickly move to the spot where it should be. A combined Halo vacuum cleaner would need to cover every square centimeter of the floor in order to be a great robotic vacuum cleaner, which clearly conflicts with the efficiency requirement.

3. Halo is great at cleaning the air since its design allows it to cover the air. The design of robotic vacuum cleaners makes them able to cover the floor. A combination of these two, radically different products in terms of design would most likely result in a trade-off in user experience as optimization within air clean keeping and floor clean keeping would be nearly impossible without designing a product that does not inflict with the product semiotics or the principles of clean keeping devices (easy, simple, capable, best experience).

As previously stated in the report, the future of cleaning is a mesh of specialized devices that includes a revamped stick vacuum cleaner for cleaning of open floor areas. However, this does not mean that there's no room for the robotic vacuum cleaner. Depending on how the robotic vacuum cleaner will evolve in the coming 10 years, they may have a more or less significant role in the mesh. They could for example navigate with the help of the sensor units.

A combination would most likely result in a trade-off in user experience.

Halo Smart Sensor Units

Halo Environment Cleaner cleans where it's needed, when it's needed. The Halo Smart Sensor Units (see Figure 103) are the brains of Halo and make the smart cleaning possible. They are ceiling mounted readers and analyzers of the home environment – one in each room.

Layers of Sensors

The circular "layers" of the sensor unit have different functions. Dust, smoke, pollen, etc. are sensed by Halo by the particle sensors behind the white, perforated surface. Optical sensors, such as motion sensor and sensors comparable to Kinect/3D video cameras, are placed behind the black, transparent surface. These optical sensors register movement and items in the room. One step closer to the center is the "layer" with a LED indicator. The purpose of the indicator is described later in this section. In the very middle of the Smart Sensor Unit, required electronics related to the functions of Halo (including Internet) are positioned

The Brain

The Smart Sensor Units are the intelligence in the mesh of devices. They command the Halo EC to move to the source of the dirt – when someone has been making the bed, when someone's been cooking or when someone's been cleaning (and thus made the air polluted with dust and particles). The Smart Sensor Units help the environment cleaner to navigate through the home, making navigation perfect.

Figure 103
Halo Smart Sensor Unit – front view.

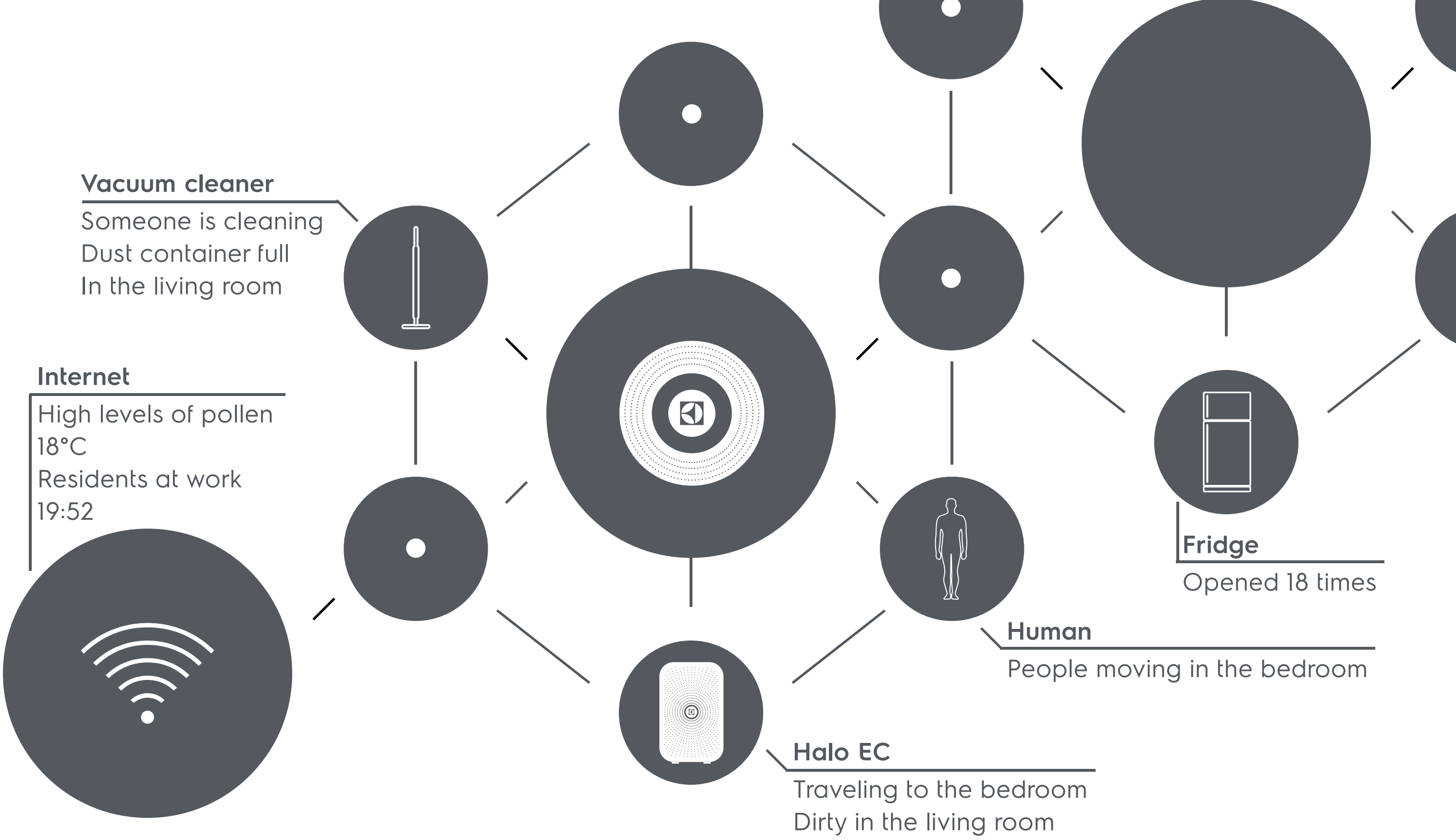


Figure 104
Halo Smart Sensor Units are the spider in the web of connected devices.

Technology Made Relevant

The Smart Sensor Units do not only implement connectivity in the smart home – they make connectivity useful and relevant. They are connected to e.g. the stick vacuum cleaner, to the Internet, to Halo EC and other products in the mesh in order to make cleaning as efficient and effective as possible (see Figure 104). By communicating with other meshes of devices in the home, they could even gain information about the fridge for example. The Smart Sensor Units could know how many times the fridge has been opened, and thus estimate how dirty it is in the kitchen. The sensor unit's own sensors read information regarding human activity in the home, so that they know where it's the dirtiest and where the air has been in movement.

Cleaning Made Effective. And Efficient.

In short, each and every sensor unit in the home reads, analyzes and concludes what's needed to be done in order to operate an effective and efficient clean keeping that is optimized for the user:

- **The living room is dirty and no one is home** – send Halo in there! A real-time scanning of the living room by the sensor unit shows that there's currently no motion in the room, strengthening the fact that the residents are at work (the sensor unit was hinted about the residents' absence by synchronizing their calendars). Furthermore, the sensor unit in the living room knows, from earlier recorded data, that there's been a lot of movement in the living room recently and that no one's been using the vacuum cleaner in there for a while. Thus, the Halo Smart Sensor Units conclude that it's time to clean the living room, and order the Halo Environment Cleaner to move over there and clean the air from dirt.

- **Elisabeth is making the bed** – send Halo in there! It's the time of the day when Elisabeth usually makes the bed, and a real-time scanning shows that there's movement in the area of the bedroom where the bed is. The number of particles has drastically increased. The Halo Smart Sensor Units conclude that the air in the bedroom needs to be cleaned from dust in order to prevent the whole apartment from becoming dusty, and thus order the Halo EC to move over there and clean.

- **Filip is cooking meatballs** – send Halo in there! The sensor unit in the kitchen detects an increased number of particles in the kitchen air and concludes that the particles are odors from food. Information from the oven also tells that the source of the odors is likely to be from cooking. The Halo Smart Sensor Units know that cleaning the air from food odors would make Filip happier, and thus tell the Halo EC to move over there.

- **Elisabeth is vacuuming in the bedroom** – send Halo in there! The Halo Smart Sensor Units are connected to the vacuum cleaner and know that it's currently turned on. There's movement in the bedroom and an increased amount of particles in the air. The Halo Smart Sensor Units now know that some dust has possibly been emitted from the vacuum cleaner into the air in the bedroom, and tell the Halo EC to clean the air over there.

- **Filip and Elisabeth are watching Netflix in the living room** – don't send Halo in there! The Halo Smart Sensor Units are connected to the TV and thus know that the residents are watching Netflix. There's motion in the living room, but very little. Halo EC won't disturb by going there.

- **There is a fire** – the Smart Sensor Units replace the smoke alarm.

- **Someone likes their toast burnt** – the Smart Sensor Units can tell the difference between a burnt toast and a fire based on information about temperature, smoke particles and carbon monoxide particles. In addition, the toaster itself is connected to the mesh of devices and informs Halo about current activity.

Integrity

Of course, Halo cares about integrity. All data is stored locally on a secure chip, so that no personal data is shared with other devices without the user's personal consent.

No Interface Is the Best Interface

The user communicates with Halo by talking to the Smart Sensor Units. The voice control never requires the user to physically touch the Halo EC, making Halo accessible to people with physical and visual impairments. Halo was designed with Design for All in mind, as cleaning by norm is a physically strenuous task. Even though the idea of an app was dismissed earlier in this chapter, an app specialized for people with auditory impairment would make Halo accessible for everyone.

Halo was designed with Design for All in mind, as cleaning by norm is a strenuous task.

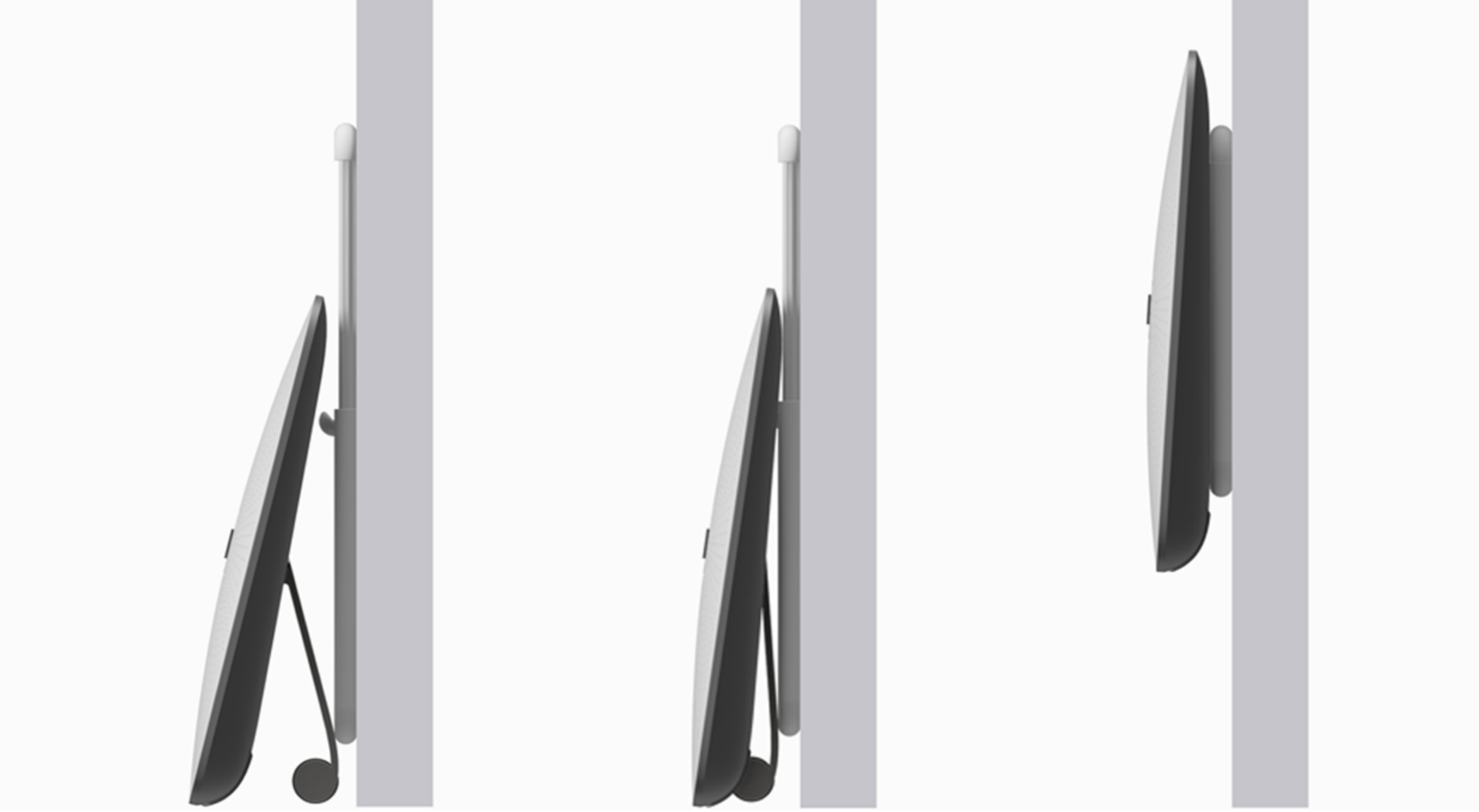


Figure 105
Halo Environment Cleaner and its supportive leg fold together when docked to the charging station.

Added Values

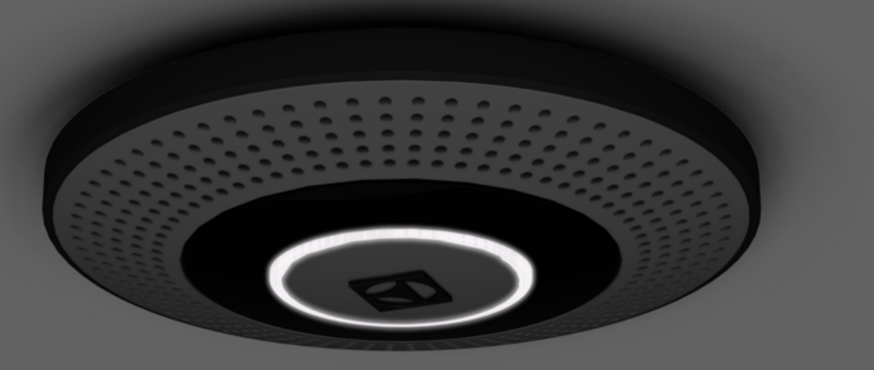
The authors' research in this project showed that *added values* are important. Since Halo is a device that is constantly visible in the home environment, it should always have a purpose.

Halo is always there for the user. The simple interface requires the user to only say "Hey Halo!" followed by a question or an order to make it do something that they want. It could for example be "Hey Halo! Come here and give me a breeze" and Halo EC will become a fan that blows filtered, clean air. During this event, the user is faced with the carefully designed rear side of the Halo EC. Even though it differs from its front side, it still conveys a similar, unobtrusive expression.

In the morning, the user can tell Halo to start the coffee maker while being in the shower. The user can even ask Halo about the temperature outside. But the user can also tell Halo "Hey Halo, get out of here!" if it by all means would be disturbing. Over time, Halo will learn when not to disturb the user.

As previously stated, the Halo EC does not require any physical interaction. This statement also applies to the charging of Halo. Thanks to inductivity integrated in the wall-mounted charging station, the Halo Smart Sensor Unit and the flexibility of the supportive leg, the Halo EC is able to put itself on the wall without the user noticing it as shown in Figure 105.

Figure 106
Halo Smart Sensor Units can become night lights when needed.



When being on its charging station, Halo EC becomes an excellent clothing freshener. The user can hang their coat over the Halo EC and it will automatically start cleaning the garment. The Halo EC maintains a good indoor quality for a longer period, as it sets air into circulation. That also reduces the need of ventilation, which creates a more sustainable living environment.

The circular LED indicator on the Halo Smart Sensor Unit lights up in the dark (see Figure 106), becoming a night light when the user needs to go to the bathroom during the night.

G. EVALUATION OF HALO

The evaluation of the concept Halo consisted of several analyses: a physical ergonomics assessment, a check-off with the design principles, a semiotic analysis, a user experience analysis and a realizability analysis.

Practically Zero RULA/REBA Score

Halo in itself does not pose any physical activities, which means that it's an ergonomically sustainable product. This fact is strengthened by the fact that, with Halo in the home, clean keeping is made less often and during a short time, referring to *all* surfaces.

Looking at the whole clean keeping context, the revamped stick vacuum cleaner is meant to help the user to mainly clean keep open floor areas, thus clean keeping on open areas will be the most usual activity. This activity was assessed to be a 5 on REBA, which shows that the usual activity is not that dangerous compared to vacuum cleaning beneath furniture (assessed as the maximum risk level of 12), which was an activity that had to be done way more often without Halo in the context.

Halo – Easy, Simple, Capable and the Best Experience

The clean keeping device principles found from phase 2 explain that a new clean keeping device should be far better than the canister and the cloth within four aspects: *ease, simplicity, capability* and *experience*. Below follows a review of Halo with regard to those principles.

Halo is **easy** within several aspects:

- *Use* – Halo requires a pre-installation, but after that, it is free to go and keep the house clean – of course, without disturbing the user.
- *Maintenance* – Halo only requires cleaning of its filters, which can be done by e.g. water in the shower or a quick swipe with the stick vacuum cleaner.
- *Interaction* – Halo does not require a use manual, as it is fully independent. If the user wants to give Halo a specific task, e.g. to come to the kitchen and clean, the user only needs to say *"Hey Halo!"* followed by the task of interest *"Come and clean the air in the kitchen from smells!"*.
- *Physical ergonomics* – Halo does not require any physical interaction.
- *Temporal demand* – is practically zero as it does not demand the user to do anything, and thus, does not put any time pressure.

Halo is **simple** from one very important aspect:

- *Minimal interface* – Halo focuses on doing what it does best: to clean the home environment. The user doesn't need to do anything. Advanced analyses and optimizations are done by Halo's sensor unit in order to maintain cleanliness in the home, but from the user's perspective, "it just gets clean" without them doing anything.

Halo is **capable** within several aspects:

- *Better living environment in the long run* – this is the focus of Halo, rather than "remove the dirt on surfaces right there and right now".

- *Effectiveness* – drastically increased compared to today's air cleaners. Halo moves to where it's dirty. Thus, the air gets cleaned from dirt before ending up on surfaces.

- *Efficiency* – increased compared to today's air cleaners as the fan is also more powerful, which in turn, makes Halo more effective.

- *Biomimicry* – wind is the core of how nature cleans itself. Halo makes sure the air in the home is constantly in motion, maintaining a good air climate.

- *Independency* – one of Halo's core values. With the sensors, Halo is capable to keep the home environment clean on its own. The independency of Halo is unique.

- *Shorter cleaning sessions* – by keeping the air clean, surfaces get dirty much slower. The user cleans less often, and when cleaning, it isn't as dirty as it would've been without Halo

Halo offers the **best experience** within several aspects:

- *Easy, simple and capable* – as concluded from above bullet points.

- *Lasting impression* – the cleanliness after the user has been cleaning the house is maintained for a longer time. There is no dust in the air that lands on newly dusted surfaces, leaving a positive impression that lasts longer.

- *Convenient* – changing filters on Halo is easy, which is very appreciated as the results of the user studies from phase 1 clearly stressed the fact that people dislike maintenance.

- *Pleasurable* – since Halo makes the user and other people in the household visually perceive the cleanliness (no dust on surfaces) and olfactory wise perceive the cleanliness (no non-pleasurable odors left in the air), people can really see and feel the cleanliness in the home, removing displeasures that was earlier problematic.

You Would Love to Have It on Display

The semiotic evaluation included an analysis of the product expression of Halo. Does Halo follow the expression association web formulated in phase 3? Below follows an analysis of Halo's product expression.

Halo Is Thorough

The exquisite surface continuities and curvatures reflect its environment beautifully and prevents from non-continuous reflections, which would make it look fragile and plasticky. The number of parting lines are very few and the surface transitions are made with distinct and clear functional reasons behind them (e.g. the grip on the front side), making the product convey a precise and thus thorough expression. Also, a thorough *impression* is seen in its functions, as Halo takes care of *everything* in the air (rather than dust only). It truly deserves its right to exist by maintaining a healthy environment.

Halo Is Unobtrusive

Halo blends into people's modern homes as the carefully chosen neutral colors leave room for the user's self-expression. The elements of Halo are few and ordered – the surface of the front side and its air inlets are symmetrically distributed in two dimensions and the components on the rear side are few and placed, from a user point of view, in a purposeful, simple and intuitive way. The overall simplicity in its shape and thin design furthermore conveys an unobtrusive expression that leaves a respectful impression in the eyes of the beholder. In addition, the sensor unit is programmed so that the Halo environment cleaner doesn't disturb the residents when they're home. It's not there when you don't want it to, which further strengthens the unobtrusiveness of Halo.

Halo Is Confident

Bold contrasts between the front and rear in both colors and surface finishes (from a white satin finish to a dark gray matte finish), and a well-defined sharp outer shape express confidence in a way that makes people believe in the product. The contrasts between the front and rear create a natural parting line, which furthermore leaves an honest impression. Confidence also lies in its honesty about its functions. The whole front is an area of air inlets, which expresses its function – to take care of the air. The shape of the outlet was designed radically differently compared to the inlet (rectangular instead of circular), as its function is the direct opposite – to deliver fresh, clean air.

Halo Is Trustworthy

The thorough combination between the exquisite surface continuities and the satin finish results in a trustworthy expression as these elements in harmony form a product that is long-lasting and rigid in its expression instead of weak and dishonest. It creates trust in its functions by having inlets covering the whole front. The shape of the rear side has a visually heavier area in the bottom than in the top, which further adds on to the expression of trustworthiness – a visual balance in proportions and weight is met. Halo is designed to be honest in terms of function as well – the supportive leg is not hidden as its design clearly tells what it does.

Halo Is Seamless

The rear side is made as a single part which creates one, natural and purposeful parting line against the detachable front. The seamless impression is perceived in function as well: the incredibly simple voice assistant and the smart units make sure the experience between Halo, the stick vacuum cleaner and other devices in the mesh of specialized devices is consistent and purposeful.

Halo Brings Pleasure

Pleasure in relation to products is a significant part of the user experience. Is the future of clean keeping pleasurable? In what ways? To answer those questions, a theoretical user experience analysis was conducted with Jordan's Four Pleasure model as a foundation. The pros and cons of the authors' vision of future clean keeping, with focus on Halo, are discussed below.

Ideo-Pleasure

People's tastes, aspiration and values in relation to the authors' vision of future cleaning deals with the acceptance of the vision.

Pros

Halo makes cleaning easier, faster and less frequent, which reduces the displeasure of cleaning. Halo helps people to reach their aspiration of having a clean home as often as possible. By cleaning the air from particles, surfaces are kept clean. People also like to be in control, and since the sensor unit obeys to the user's orders, they can always feel that they can take control of Halo whenever they want to.

Halo helps people to reach their aspiration of having a clean home as often as possible.

Halo was designed as a beautiful interior product that people would want to have, even without its functions. Inspiration from renown companies such as Bang & Olufsen and Nest resulted in a product that embodies the thoughtful, unobtrusive and thorough Scandinavian design – a preference of what good design is. The trend shows that people search for a simplistic but personal home, and Halo is a product that truly embraces those aspects, and thus, reflects some of the aspirations that people may have. Halo has yet to be described as a sustainable product, partly due to the lack of knowledge about its components and manufacturing. Great potential is however seen, as the simplistic nature of Halo doesn't include extra functions that does not take advantage of already existing components.

Halo and the vision of future cleaning were developed with the belief that a multi-device clean keeping experience (which can be seen today) cannot be the best until each of the devices in the mesh focuses on doing what they're best at. For example, the stick vacuum cleaner should only be designed to clean open floor areas. Thus, people with the moral belief that "the whole is greater than the sum of its parts" will most likely agree with the vision of future cleaning.

Cons

Halo could be perceived as a magical tool that fully gets rid of cleaning. This could create a displeasure since cleaning will still remain as surfaces will eventually get dirty. What Halo does is to maintain a clean air environment, which naturally means that dust in the air is taken care of. But higher-density particles will not be taken care of by Halo. The cloth or the stick vacuum cleaner, or a robotic vacuum cleaner for that matter, should be preferred in those cases.

Socio-Pleasure

Products connect people and Halo is no exception of that.

Pros

Keeping the home clean with Halo is an effective way to keep surfaces clean from dust during a longer time. A socio-pleasure connected to this is the fact that people generally want their homes to look and to be clean in front of their friends, guest and family members. A compliment from a friend about the cleanliness of the user's apartment creates pleasure connected to Halo. And also, the friends will feel comfortable staying in a home that is clean, both on surfaces and in the air. Seeing Halo hanging on the wall will eventually become a sign – if someone owns a Halo, the person is very likely to have a clean home and lives in a healthy environment.

Investment in health by owning a Halo.

Halo could become a status symbol, which is pleasurable for some people. A person owning a Halo does not only put sensible attention to the aesthetics of the interior, they also invest in their health by owning an environment cleaner. A person owning a Halo would likely to be perceived as self-conscious and smart by their relatives, making the owner proud of themselves for buying Halo.

Another socio-pleasure is the endless possibilities with voice control and a connected home. For example, when no one in the residence have the possibility to start the coffee maker in the morning (one could be showering while the significant other happens to be oversleeping), Halo can start the coffee maker by just a "Hey Halo, start the coffee maker!"-command. The person that showered won't be left without coffee and become grumpy, and the other person won't get blamed.

The feeling of having a friend may surface.

One attendant during the thesis presentation of this master thesis highlighted an interesting aspect of self-going products, connected to socio-pleasure. The seemingly "alive" feature of Halo could elicit a relationship between the user and Halo that resembles the relationship between a human and its pet. As an example, a relative of the thesis presentation attendee sometimes speaks to its robotic vacuum cleaner. Since it looks like it loses its way most of the time, the user watches over it and sometimes exclaims "oh, you shouldn't go there, there's nothing to grab over there!". The feeling of having a pet-like thing in the home lowers the feeling of being alone. The feeling of having a friend at all times may surface. The psychology behind this is complex and could result in displeasure, but it's an interesting aspect related to user experience that could be taken into account in the further development.

Cons

Today, speaking to a ceiling-mounted device in the presence of other people could be an awkward thing to do. However, the acceptance of voice steering has radically increased the past half-a-decade as various voice assistance services has become quite popular and widespread. Halo is believed to be mature for the market in a decade – by then, the general level of voice assistant services has most probably vastly increased to the level of being truly useful.

The pride that people usually feel after a cleaning session decreases in frequency as Halo makes cleaning less frequent (by keeping the general level of cleanliness high over a longer period of time). On the other hand, less cleaning sessions also prevent occasions in which others may become disturbed by the cleaning activity.

Psycho-Pleasure

Halo was designed so that people can describe it by the magical words “it just works!”.

User tells by their own wording what they want Halo to do.

Pros

Halo’s autonomous and simplistic nature doesn’t require any app or buttons. The smartness lies in the intelligence of the sensor unit and how it optimizes cleaning in favor of the user, without requiring anything from the user. The seemingly non-existing interface prevents a lot of use errors that could occur with a product as technical as Halo. It’s very intuitive as the user can simply tell by their own wording what they want Halo to do, or not to do.

Cons

The voice steering interface is not obvious until the user knows about it and what to say in order to activate it (“Hey Halo!”). An introductory guidance is needed, during the installation of Halo for example, in order to understand what it can do and how it works.

Physio-Pleasure

There are several physio-pleasures connected to Halo.

Pros

Halo was designed to convey a product expression that makes it visually pleasurable and thus desirable to have on display at home. Displeasure related to its active presence (e.g. noisy sound) is prevented by programming it to move around the house while residents are not at home. Halo creates pleasure in keeping the air clean from dirt, but this pleasure is not immediately noticeable – the user probably notices the difference after a while of having Halo in use. On the other hand, a more immediate pleasure lies in the function of cleaning the air from odors, which could be very appreciated in some cases.

The vision of future cleaning includes the stick vacuum cleaner. The physio-pleasure connected to vacuuming (e.g. hearing gravel running through the vacuum cleaner) is enhanced as vacuuming will include less dust (thanks to Halo) and more of the dirt category bits and pieces.

Cons

To clean a dirty surface with a cloth has been proved to have a pleasurable effect since the difference between dirty and clean is immediately perceived. Halo does not generate such immediate pleasures since its usefulness becomes apparent after a certain amount of period. The user will need to clean surfaces from dust and dirt every now and then, so the physio-pleasure is still there, but in a decreased frequency. Noisy fan can create a displeasure, but is prevented to the extent of not disturbing the user until the user themselves tells Halo to do something else than it was originally programmed to do.

No immediate pleasure since its usefulness becomes apparent after a certain amount of time.

Realizability – Halo Is Real

How realizable is a commercialization of Halo? Important aspects of this analysis are the manufacturing possibilities, cost estimation and market analysis.

Components Will Become Smaller

All of the components of Halo (listed earlier in this chapter) are components that are available today and used in various consumer products. The challenge could be to fit them all into Halo, as it is a thin product. The components that are available today will most probably *not* fit into the body of Halo. However, it was concluded that the form design of Halo is of great importance. The form design is the result of many iterations that led to an expression that makes Halo into an accepted product. It is unobtrusive, and yet beautiful according to the interviewees. To claim that components will decrease in size and increase in efficiency is reasonable when looking at the technological advancement made during the past 5 years – smartphones have for example almost become computers. Halo is a futuristic concept and thus designed to house the components of the future.

A Priceworthy Cleaning Assistant

How much could Halo cost? Looking at similar products in the stores, it could be concluded that Halo can be approximated as a mix of an air cleaner, a robotic vacuum cleaner and a smart ceiling-mounted device:

- Air cleaners vary between 1000 SEK to 7000 SEK (Pricerunner, 2016a), depending on brand and quality. Electrolux *EAP450* has been used earlier as an example of air cleaner comparable to Halo's capabilities. It is sold for 3995 SEK (Electrolux Home, 2016).

- Robotic vacuum cleaners vary between 1000 SEK and 10000 SEK (Pricerunner, 2016b). Miele *Scout RX1* is sold for 6890 SEK (Miele, 2016), which has been named as one of the best in its category (M3, 2015).

- Smoke detector Nest *Protect Smoke + CO alarm* is sold for $99 (Nest, 2016), which approximately is 800 SEK (with current exchange rate 8 SEK/USD). Nest's device is the most comparable product to Halo's ceiling mounted unit today.

Compared to house keeping services, Halo is rather priceworthy.

According to above references, a Halo floor unit and Halo ceiling unit could cost up to 10000 SEK altogether. As Halo can become pleasurable by becoming a status symbol for some people, it could also become displeasurable for others as the analysis shows that Halo could become a rather expensive product compared to other cleaning tools. However, Halo is the pioneer in its product category as it is unique – it fills a gap in the market of automated home environment clean keeping. Comparing with housekeeping services, Halo is rather priceworthy as it is a one-time cost and keeps surfaces clean from dirt. In order make Halo more accessible, Electrolux could launch a subscription service that provides people with clean homes instead of products specifically. Halo could be part of such service.

Integrity Matters

An issue that has to be solved if Halo was to be realized is the integrity, safety and security of the users. It showed to be a worry among users, which is understandable. Specific information from the ceiling mounted sensor units of Halo would however never have to leave the system. Similar problems have been solved before. Apple has for example solved the problem of storing sensitive data, such as fingerprints and credit cards, by introducing a secure element that is completely separate from the main operating system (Apple, 2016b).

H. CONCLUSIONS

The following conclusions were drawn from phase 5, *Say Hello to Halo!:*

- Halo is a manifestation of what's missing today – a correct prioritization of clean keeping that can maintain a lasting impression. Most of the dirt is airborne, and should be taken care of before landing on interior surfaces.

- Halo, a revamped stick vacuum cleaner and the cloth is an example of how a mesh of clean keeping devices can work together to create a good clean keeping experience – both while cleaning is made and the lasting impression of cleanliness afterwards.

- By constantly clean keeping the air from dust, particles and odors, the home is kept clean longer. With Halo, dust won't stack up on shelves and beneath couches. Cleaning sessions will become less strenuous due to the higher level of overall cleanliness.

- Pleasure in cleaning is increased by making the result of the user's effort – the feeling of cleanliness – last longer.

- A minimal interface connotes reduced constraints in the user's everyday life, leaving room for their self-expression.

- *Best experience* is a trait that partly comes as a result of *easiness*, *simplicity* and good *capabilities*.

10.

DISCUSSION

This chapter includes a discussion regarding the project, the process, the phases (1-5) and the future of clean keeping.

A. THE PROJECT

The results are discussed in relation to the background, purpose and goal of the project in this section.

The Background to the Project

The background to the project was mainly that people don't like cleaning and that cleaning devices don't support that fact. Does Halo?

People Don't Like Cleaning

Throughout the project it was proven time and time again that there is most definitely room for new products in the clean keeping system. Products that create vastly better user experiences and fit into the modern lifestyles of people today. The project started with the assumption that almost no one likes cleaning, which was proven several times throughout the project. It was also found that there are some pleasures in cleaning, like the satisfaction from feeling the difference in cleanliness. The displeasure that comes from time demand and effort is however much greater. The focus on less user involvement is therefore the most natural path for development of clean keeping products. It also fits perfectly into people's modern lifestyles. Halo and the new stick are designed for quick interactions to support those lifestyles.

Focus on Dirt

The starting point of the project was the discovery of dirt and the travel of dirt. That focus proved to be key to the level of innovation in the end. Dirt is the actual problem, not cleaning per se. The focus on the travel of dirt is at the heart of Halo as well as the new stick. It made it possible to design new ways for dirt to travel and therefore new ways to capture dirt. It could of course be discussed if dirt is the main problem, or if it actually is the fact that materials and objects produce dirt at all. That is an interesting thought but was considered out of the scope of this project.

The Future of the Vacuum Cleaner

In the beginning of this project vacuum cleaners were criticized for being a source of time demand and effort. Sticks and robotics were presented as too weak and unable to reach everywhere. And yet, the project resulted in a concept that includes a stick vacuum cleaner. It was found that each vacuum cleaner has problems in the setup of today. But those problems are related to the design of the products, the system and the activities within the system. By breaking the clean keeping system into pieces and rebuilding it from the ground up, it was possible to find a new future for the vacuum cleaner. A future where it is specialized on open floor areas and where the total clean keeping functionality comes from a mesh of devices. The same formula is therefore important to any clean keeping device. New clean keeping devices within the clean keeping system must be specialized and purposeful. They must be the very best at a specific cleaning activity – in other words, be easier, simpler, more capable and create a better experience than any other clean keeping device. And there are several areas that such a product could focus on, because the future of cleanliness is not in clean surfaces only, but in a better and more comfortable living environment. Some devices will focus on proactive clean keeping at the source and travel of dirt, while others will focus on reactive cleaning at the destination surfaces to take care of the entire spectrum and enhance the entire living environment.

The Use of Several Devices Create Disruption

The mesh of devices is a concept that depends on several devices to keep the home clean. Perhaps even more devices than in the current system, depending on the final design of the mesh. Initially, several devices and activities sere seen as sources of disruption and distraction. The automated nature of Halo does however remove many of the disruptions since the user is less involved. Furthermore, the new devices need to work together and create a completely seamless experience for the user. The future is a mesh of devices that are designed together.

That type of cooperation will also be crucial to the future of robots. For robots to create an unobtrusive experience they must work together and be almost unnoticeable. The mesh of devices is also the key to make robots smarter and therefore more trustworthy. The smart sensor units are at the core of making that happen and making sure that the user is presented with a seamless experience across several clean keeping devices.

The Purpose and Goal of the Project

The purpose and goal was to show a vision that creates a better experience. Was to goal reached? Does Halo create a better experience?

Increasing Pleasure and Decreasing Displeasure

The main purpose of this project was to create a clean keeping experience that is way better than today. Part of that purpose was to decrease the displeasure and increase the pleasure from clean keeping. The focus of Halo is to reduce and hopefully eliminate most of the displeasure related to clean keeping. It doesn’t necessarily increase the pleasure during cleaning, but it enhances the pleasure that comes from the results of cleaning. A home that looks, feels and smells clean – is clean. The total experience over time should therefore be considerably more pleasurable and less displeasurable.

Improving the Entire Clean Keeping Situation

The goal was to present a vision of the future that considers the entire clean keeping situation. Several parts of clean keeping were discovered and investigated in the project, and even if focus was on vacuum cleaners initially, the end result is not a floor care device. While Halo itself doesn’t consider the entire clean keeping situation, it does clearly show a path and a foundation that will eventually make every part of clean keeping more pleasurable.

Real in Five to Ten Years

Halo is, as set in the boundaries of this project, realizable within five to ten years. The long timeframe made it possible to completely redefine the clean keeping system and present a vision of the future. It did however also limit the amount of possible solutions. An even longer timeframe would have made it possible to consider people’s homes or even eliminate clean keeping entirely. The extended future of clean keeping is discussed further later in this chapter.

The Focus on The Swedish Market

By limiting the project to the Swedish market it was possible to design a focused and truly purposeful device. The types of dirt, climate and architecture in Sweden shaped big parts of Halo. In the end though, it could be discussed whether Halo is a product for the Swedish market only. The concept behind it, i.e. a truly intelligent environment cleaner that works together with other devices in a mesh, is applicable to any market. It might even be more useful in countries with high concentrations of air pollutions. Users in other countries might also value a clean and comfortable living environment even higher than Swedes from the beginning. Implementation in other countries would however require a physical redesign of Halo. Homes in some countries might for example be much smaller, which reduces the need of the robotic functionality. A stationary environment cleaner might be more applicable in those cases.

Limited Focus on Maintenance

Maintenance in terms of bag replacements proved to be one of the major talking points in relation to vacuum cleaners. A full bag makes the vacuum cleaner less effective, and replacing it is somewhat cumbersome and disgusting. Those aspects were not considered further because of the scope of the project. It could of course be discussed whether focus on those issues would have changed the result. Focus was however on making the entire experience more pleasurable for the user, and since Halo redefines the entire cleaning system it has every opportunity to redefine recycling and disposal of dirt as well. Those aspects should be considered when designing the interaction of Halo.

B. THE PROCESS

The process of this project was based on Bligård's product development model ACD^3. The explorative nature of the project did however result in five distinctive phases that are hard to relate to the specific design levels of ACD^3. The model acted as a template and a guide throughout the project to make sure that progress was made and that all necessary parameters were defined in a logical order. The use of phases instead of strictly following existing processes is discussed in this section.

The Focus on Effect and Use

ACD^3 was the most suitable method for this project, for two reasons. It clearly encompasses the iterative nature of an explorative project. It also includes the *effect* and *use* design levels that allow for new innovative solutions that are independent of the solutions of today. The effect, and especially the use design, proved to be very important to the end result. Halo exists because there was a new way to design the use of clean keeping products that create more capable products and that reduce the user involvement.

The focus on effect and use meant that the project didn't complete all of the traditional parts of product development. The problem with traditional product development processes is that they, in many cases, are linear and that they assume that the end result will be a physical product that is an incremental change of a predecessor. Such a process might include user studies, analyses, concept generation, evaluations and further concept development. But this project was different and focused on finding a vision of the future, which is why such processes were found to be inapplicable. Most of the parts were however included in the project, in a different order.

Following Existing Processes Could Hurt the Result

It could be discussed if the result would be different if the project would have followed ACD^3 or another process to the letter. Following ACD^3 would mean going through all of the design levels in their thought order briefly several times. That could have resulted in a concept that was further developed in terms of interaction and architecture. It would, on the other hand, most certainly have reduced the level of innovation in terms of effect and use design. Following a traditional process could also have brought the project further down the product development road. User studies investigating people cleaning, finding problems and solving the problems in product concepts would for example have generated feasible concepts much earlier in the process. Those steps were however parts of phase 1, 2 and 3 so it is reasonable to believe that the end result would have been a trivial improvement of the vacuum cleaner. A more visionary concept was sought.

The Key Was to Start Over

The real key to the result of the project was to start over after phase 3. To realize that the vacuum cleaner is and will be good enough. That is why phase 4 and 5 were about looking for the real intended effect and use, all over again. It meant that several new concepts were found and that a vision of the future could be created instead of using the other half of the project to develop a product that, in some sense, already exists.

In summary, phase 1, 2 and 3 can be seen as phases of need finding that resulted in an understanding of the intended effect. They included user studies, analyses, concept generation and evaluation. Phase 2 and 3 touched on architecture and interaction to explore the possibilities of improving existing vacuum cleaners but resulted in the conclusion that a new use is needed. Phase 4 was about exploring new ways to use and design clean keeping products, while phase 5 was about in detail specifying the found gap in the market in terms of intended effect and use. Phase 5 also included architecture and interaction design in order to visualize the found gap. So the five phases brought the project to its goal by exploring architecture and interaction, but by emphasizing on effect and use. Developing the concept further would have been unnecessary and unwise. Halo will need to go through the entire product development process again to go from vision to life changing product.

C. THE PHASES

The approach and result of phase 1 to 5 are discussed in this section.

Phase 1

Phase 1 set the foundation of the project. The methods used in phase 1 and their significance for the thesis are discussed below.

Top-Level Thinking

Phase 1 was in general a phase of data collection and understanding. The focus was on creating a broad picture of, not only vacuum cleaning, but cleaning in general and how that fit into people's lifestyles. The broad nature of the studies could have led to lack of depth in some areas. But interviews, surveys, observations, tests, research, etc. produced data from several angles, including several aspects, which gave a multi-facetted picture of cleaning. A broad top-level picture was furthermore considered as important for the following phases. The top-level thinking proved to be key to design new ways to keep homes clean later in the project.

The System Model

The system model was primarily based on data and insights from brainstorming sessions. Some components of the system could have been missed using such an approach. All aspects were however brought up and confirmed by the interviews. The combination of brainstorming and interviews gave a broad understanding of both all existing components but also their commonality.

The Significance of the Online Survey

The online survey included many open-ended questions. Questions of that nature can been tiring and thus result in unreliable and incomplete answers. The majority of all answers were however complete and the order in which the questions were presented was randomized between participants in order to balance out any effects of tiredness. For that reason, the survey contributed considerably to the results and many of the understandings in later phases. Without a doubt, people's verbalization of the expressions of different pieces of clean keeping equipment created the foundation that was necessary in order to conclude that the stick vacuum cleaner actually has potential to become a great product. The results were furthermore both confirmed and complemented by the interviews.

In-Depth Interviews

Most of the objective and qualitative data in phase 1 was collected during the interviews. It could be discussed whether using nine participants was enough to produce valid and reliable data. However, answers in many of the discussed subjects saturated quickly. The online survey and Electrolux's own survey could furthermore prove the findings valid for a wider audience. In that way, the interviews also added understanding and explanation to the data from the surveys. It could also be questioned if an unstructured approach to the interviews would have generated other results. People don't tend to speak about experiences and emotions naturally in interviews though, especially not in an area of very little interest to so many people. The structured approach was therefore useful to elicit emotions.

A Switch of Target Group – Did It Affect the Validity of the Study?

The initial user studies involved nine in-depth interviews with a sample set of adults in various ages living in various types of households. Later in the project, the target group was narrowed down to young adults in apartments. However, the data collected from the initial user studies still ruled as guidance when designing for the target group of choice, even though the data originated from people mostly not connected to the target group. The question is: did that affect the validity of the thesis result? Throughout the project, six people participated in each evaluation of ideas or form designs. The six participants were the same individuals with similar backgrounds – industrial design engineering students. In-depth interviews with those individuals were never done, however, congruency with the original nine interviewees was often encountered. The students spoke about very similar problems as the interviewees of the initial study. The sample set of the initial study spoke more extensively about cleaning than the students, probably due to their high degree of experience. Furthermore, since the students were the ones that ideas, concepts and form designs were evaluated with, it's safe to assume that the sample set of the initial studies did not distort the final results. On the contrary, the wide sample set most probably influenced the result of the thesis to include experiences and insights that would probably not been elicited from the young adults.

Continuing on the topic of validity, the evaluations made throughout the project (with the six industrial design engineering students) is also a topic of interest. How did the choice of participants affect the results? The design students differ from other people in some aspects – they have higher educational background and do probably have a more selective taste in product design than most of their contemporaries. Furthermore, when comparing the design students to the persona, there are significant differences in economic circumstances and accommodation. Those aspects might have influenced the evaluation process, as the result could've been different if the sample set matched the persona. However, having design students as participants probably made it easier to document user's thoughts, since they are trained to express and verbalize their thoughts. The designer's intent was also a part of the evaluation in order to make sure that the sample set did not move the project into a track that was not accordant to the user data and insights. Despite the small amount of participants, the design students were in many cases unified in their opinions, increasing the reliability of the evaluations.

An Appropriate User Experience Study

User experience was the main focus of the entire project. It was incorporated in interviews, observations, quick tests and in the analysis of every part of the studies. Extensive user experience tests and real context observations could have resulted in more and other results related to the good and bad experiences of the cleaning equipment used today. Such user tests would however focus too much on the solutions and products of today instead of the broader picture of cleaning and were therefore considered, not only unnecessary, but inappropriate.

A Function Analysis That Doesn't Narrow the Solution Space

Using function analysis to analyze current vacuum cleaners was necessary to understand and complement functions that are related to user values. Such a bottom-up analysis could have resulted in a reduced design space that is dependent on current solutions. Needs in terms of capabilities were therefore also collected using the top-down approach that meant starting from dirt. That approach created the important difference between cleaning and clean keeping.

Design for All – Helpful, But Adaptable in Later Phases

Understanding user characteristics is key when designing such universal products as clean keeping products. Every aspect of *design for all* was therefore considered and discussed in phase 1. Further tests, interviews and observations with a more diverse sample set would be required to understand all effects of every characteristic. Such deep knowledge was however considered as more important in the later phases of design, for example on the interaction level. A general understanding of the diversity was found to be sufficient in a project as explorative as this.

Persona and Trends – Understanding the Future

The trend analyses were based on general knowledge and opinions in combination with picture research and did therefore include a lot of assumptions and predictions from the authors of this report. Those predictions were however backed up by professional analyses, data and theories, which increased the validity. It was also concluded that *designing for the future* means *designing the future*, which is why such predictions had to be made. For the same reason, the lifestyles and homes of future users had to be anticipated. One specific user group, persona and apartment was chosen to represent the future users. That decision excluded many users from the design work. It did however bring focus to the project, which made it easier to design a product that fulfills its function to its fullest. It was also found that most of the problems in cleaning are common between users. To make something really great the past has to be understood and then left behind.

Phase 2

The approach and methods used in phase 2 are discussed below.

Top-Level Design Work Requires Top-Level Thinking

The *clean keeping device principles* were important guidelines throughout the entire project. They were used as categorization, design inspiration and evaluation, which is why their validity is key. It could be questioned whether the principles are overly simplistic to be valid. It was however found during the project that it is impractical to consider huge amounts of problem areas this early in a development process. Sticking to problem areas would furthermore lead to a focus on problems instead of solutions. The top-level approach to design a new device required top-level principles. It should also be noted that the definitions behind each principle were considered carefully in every step.

Principles Developed from User's Thoughts

The cleaning products of today were analyzed in relation to the clean keeping device principles, but only by interpreting user's thoughts based on answers from the online survey, interviews and tests. A second survey that specifically investigated product's fulfillment of the principles could have resulted in a more valid result. The analysis was considered valid since the principles were developed from the very same answers though.

A Focused Exploration of Technical Principles

Ideations on technical principles resulted in many ideas that are unused in clean keeping today. It could be questioned whether it would be fruitful to explore those technical principles further by testing and prototyping and not only discard them due to realizability problems in terms of manufacturability, safety and cost. The used technical principles, blowing and suction, were however tested extensively later in the project as they were theoretically evaluated as the most feasible technical principles for clean keeping from dust, particles, and bits and pieces. The project may have reached an another level of innovation if the focus was turned into finding a new technical principle to remove dirt. However, to validate a new technical principle for clean keeping would most probably require extensive studies and thus become a project of its own.

Gaining Knowledge from the Industry

Most decisions and evaluations in phase 2 were based on the Electrolux workshop. It could be discussed if an evaluation with independent users would be necessary. Evaluation of the ideas was however only a coarse screening at this stage of the project. Many of the ideas were actually kept to the following phases, either as concepts or inspiration to new concepts. It should also be taken into consideration that the participants of the workshop have vast experience of clean keeping products and the business in general. The workshop acted as a milestone in the project where the authors and Electrolux together chose the continued path.

A Fair Product Comparison

The extensive vacuum cleaner tests were very helpful for mapping out the pros and cons of the different clean keeping devices on different surfaces in the use. The clean keeping devices of choice for the test (Electrolux Ergorapido and Electrolux One) were picked out as representatives of their respective product category (stick vacuum cleaners and canisters). Neither of those products are high-end, nor the cheapest on the market. Since there are both “better” and “worse” ones on the market, the choice of devices for the tests was considered acceptable. The devices represent their respective product category well.

The validity of the tests with two vacuum cleaners and a cloth can be further discussed as the test consisted of only one participant. One user can impossibly represent all users. However, it was noted that the opinions of the participant very well corresponded to the opinions of the interviewees in the user study in phase 1. Furthermore, the participant of the test was one of the authors of this thesis, which can be seen as a strength since the analysis of the participant’s thoughts could be performed without leaving room for any interpretation.

Product Comparisons Conducted to a Suitable Extent

The tests were not conducted in the context of actual use – a home environment – which led to a gap in the tests that included the evaluation of vacuum cleaner’s capabilities on different *carpets*. It is however believed that the inclusion of carpeted floors would not have changed the opinions on vacuuming of hard floors. The general satisfaction of floor vacuuming may probably have decreased to a lower level due to the increased resistance from the floor nozzle when vacuuming carpets, which makes vacuuming more strenuous. However, this would probably not have had a great effect on the general analysis and comparison between vacuum cleaners and the cloth, since the vacuum cleaner is still best for open floor areas.

Phase 3

The approach and methods used in phase 3 are discussed below.

An Objective View of Vacuum Cleaner Capabilities

Sticks were compared to canisters and the regulations of the European Commission. Actual tests and measurements of different sticks and canisters would probably provide more reliable, valid and comparable results. Such tests would also provide actual numbers that could be compared to what is perceived as clean. It could also be questioned whether canisters' performance correspond to people's standards in terms of cleanliness or just perceived effectiveness. The comparisons did however give a hint on how well sticks perform – data that doesn't exist because sticks are not regulated by the European Commission.

No In-Depth Studies of Possible Incremental Improvements

The issues of the stick were concluded to be solvable based on several suggestions on solutions. Those solutions would have to be tested further and evaluated with users to get definite answers on whether they are good solutions or not. Similar solutions exist on the market and they were all concluded to tackle problems found in the user studies though. That level of realizability was enough at this stage of the project.

Qualitative Data Collection of Semantic Issues

The semantics of sticks were evaluated by semiotic evaluation by the authors, and by quick interviews and analyses of the initial user studies. Further studies, such as semantic rating scales, would probably give more quantitative results that could be used to determine the biggest semantic issues. Qualitative data was considered as more important, since an understanding of the issues was developed.

Validity of the Semantic Expression

It could be questioned whether the developed expression is correct for stick vacuum cleaners or not. Prototyping and evaluations would be needed to verify the semantic expressions completely. Such evaluations were made later in the project when a detailed concept was chosen. The expression was however based on products that has proven to stand the test of time. It was also developed specifically to avoid the issues of current sticks. Further tests of prototypes would tell if the new expression introduces new issues.

A Strategic Decision

The stick was concluded to be a good product, but it was also concluded that it needs improvements. A revamped stick vacuum cleaner was imagined as a part of the mesh of clean keeping devices, but not further developed. This choice was strategic: focusing on developing a new device, including its semantics, would reflect not only the found user needs, but also the authors' perspective on how an on-display clean keeping device can be designed to express the desired expressions (such as unobtrusiveness). The thesis is the foundation for how an on-display clean keeping product, like the stick, should be developed.

Phase 4

The approach and methods used in phase 4 are discussed below.

Applicability of Ergonomic Assessments on User Experience

The strive in phase 4 was to generate concepts that are easier, simpler, more capable and provide better experiences than today in the areas that are hard to clean. Poor ergonomics was found the be a main reason to why it is cumbersome to clean beneath furniture and on surfaces with decorations. The RULA and REBA analyses were performed on the most extreme cases of cleaning. One could wonder how frequent those activities are, and thus, discuss whether an ergonomic assessment was needed. They are however the activities that contribute to displeasure in cleaning. The displeasure is also the reason why those areas may not be cleaned as often in the first case. In that sense, the ergonomics analyses were not carried out specifically to find ergonomics problems but rather to find reasons for displeasure.

Lessons Learned from the Ideation Workshop

The workshop was carried out to see if there were any unexplored areas. It resulted in a tremendous amount of ideas, which required a fair amount of analysis. Many ideas were similar to the ones already found and others were inappropriate. It was noticeable during the workshop that it was too long, both the sessions and the total workshop, which resulted in a decreased focus. A shorter and more efficient workshop would probably have generated the same, or more focused, results.

Tests Worthwhile Despite Limitations

The tests of technical principles and concepts were carried out in a workshop. Such an environment does not represent a common home in terms of furniture, surfaces, surface finishes, kinds of dirt, dimensions, etc. The specific testing area was however designed to resemble a home environment as much as possible. The huge variety of different surface finishes also contributed to a versatility of the tests and the results. Saw dust was considered as a good enough approximation of dirt in the first test, which is of course questionable. Dust from a real vacuum cleaner dust container was however used to confirm the findings from the first test in the second one. The tests were also limited to the number of settings of the blow dryer for example. The blow dryer was very effective – in many cases too effective for the purpose. It could for example confirm that blowing is a feasible principle for dirt removal, but the high airflow velocity made the tests that required synchronization between blowing and suction difficult. Those tests would have to be conducted in an even more controlled manner. However, the shortcomings of the tests should not have influenced the development process in a negative way. Purify was found to be the best concept, even given the presumption that blowing and suction would work perfectly in Weasel and SUR.

Breaking a Convergent Product Development Trend

With the tremendous amount of ideas generated in phase 2, one could wonder whether it was necessary to switch into a divergent approach in phase 4 and further explore the solution space by e.g. conducting another workshop. It's impossible to predict the outcome of the project if the project process instead converged additionally and focused on the already sketched ideas from phase 2. However, it's safe to claim that they were all considered, and together with the results from the workshops and tests studies, they created all of the three concepts in phase 4. Furthermore, the deep insights gained throughout the project would most likely not have been found if the amount of ideas had been limited.

Evaluation of Concepts Through Tests

Tests showed that blown air can remove a satisfying amount of dust from several surface types. Tests on blowing from those distances that would be required of Purify were however not performed. At this stage it was concluded that it is feasible that Purify would be able to release dirt on some surfaces using blowing. But most importantly, it would be able to keep the air moving and therefore keep the dust in the air until it is collected.

The Importance of the Intelligent Mesh of Connected Devices

One could also argue that Purify wouldn't be of any help to some people since it's not compatible with other kinds of dirt than particles. The strength of the concept is however in a system together with the stick. The new stick will make it considerably easier to take care of gravel on open floor areas and most of the dirt on other surfaces is dust, which Purify will help taking care of. People will still have to clean, but it will be easier, simpler and more pleasurable. Above all, it will be less frequent.

It could furthermore be discussed if Purify already exists and why current solutions haven't become commercially successful. The brilliance of Purify is not in the robotic vacuum cleaner itself though, it is together with the other smart devices in the system, which is completely unheard of in the clean keeping business. The system is what will create cleaner homes and better experiences and therefore make the product successful.

Phase 5

The approach and methods used in phase 5 are discussed below.

Optimizing Blowing

Dust proved to be quite unpredictable in the way it travels. What's known is that it travels around in the air, and at some point, rests on an exposed surface. However, the dust needs to be in the air (and thus in motion) in order to get collected by an environment cleaner. A lot of tests related to blowing were made throughout the project, and was proved that blowing will keep dust in the air. Still, additional tests need to be done that include a blowing power that is a better approximation to that of an environment cleaner (like Halo) in order to evaluate the actual effectiveness of the technical principle.

Optimizing the Dust Intake

The mobile design of the final concept Halo is based on the belief that dust needs to be taken care of right where it is, which seems logical. But further investigation is needed on whether a moving environment cleaner really is significantly more effective than a stationary environment cleaner (i.e. regular air cleaners). The difference may lie in the fact that a mobile environment cleaner is able to prevent the dust from landing on surfaces (and thus keeps e.g. shelves cleaner) since it's closer to the dirt. This thought leads to yet another question: does the dust fall slow enough to catch it before it lands? Or is the blowing induced from an environment cleaner enough to keep the dust in the air? Again, further investigation is needed, but what's still true is that the final concept Halo, together with an intelligent central system that can prioritize clean keeping, makes the home into a more comfortable environment to live in.

Optimizing the Result of Air Cleaning

Continuing on the subject of effectivity, the topic of surface clean keeping is of interest. How much less will the user actually need to clean on surfaces above floor height when having an environment cleaner like Halo in their home? If the blowing is sufficient and correctly directed, the user will notice a difference in cleanliness. Again, further tests and investigation are needed in order to perfect those parameters. Furthermore, as discussed above, if Halo is able to catch the dust before it falls, the surfaces will get cleaner. At this stage, it's impossible to speculate in specific clean keeping improvements in terms of numbers, but it's reasonable to claim that surfaces above floor height *will* get cleaner as the dust in the air is taken care of.

The Focus on Form

The process behind developing Halo could be discussed. Was it wise to design the form/shape before the architecture? The authors' experiences tell that a product has to be beautiful both on the outside and on the inside in order to express an exquisite thoroughness and care in the product. For example, user studies showed that people do not trust stick vacuum cleaners. They look plasticky and ineffective. Stick vacuum cleaners were probably thrown into the market too early to leave a good impression, which led to the bad public impression of sticks. Even though the sticks are becoming as powerful as canisters, they still "look weak" and are thus not seen as a replacement to canisters. Thus, it was a natural decision to focus on the semantics of Halo rather than the architecture in order to manifest an example of what a tech product that is supposed to be on-display needs to express.

Future Household Needs

The trend analyses showed that households will become smaller, which raises the question whether a mobile environment cleaner is necessary. Is there a need of robots? Households are becoming smaller, but the process is slow. A significant change is most probably not seen until decades into the future. Since Halo is intended to reach the market in five to ten years, making it stationary wouldn't be a reasonable choice with regard to its position in time. A stationary environment cleaner would fit better within its own era in the future.

Theoretically made User Experience Evaluation

Another topic of discussion is whether the evaluation of user experience was sufficient. The main idea of the final concept Halo was indirectly evaluated with users when Purify was evaluated, but Halo differs in many other aspects too.

The evaluation of Halo towards Jordan's Four Pleasures was made theoretically. As described in the theory chapter, pleasure is a user experience that is experienced in the *moment* between the user and the product. The true user experience cannot be foreseen to 100 % until the users are actually using the product. Thus, when speaking about experience per se, a theoretical evaluation is not sufficient enough to be considered as a valid and rigid user experience analysis.

Further interviews with users could be a part of the evaluation of Halo – with those who know what Halo is (but do not use it) and especially with those that actually use Halo. Of course, an evaluation with those types of users has not been possible in this project since Halo is a concept. Functional mock-ups for example would be a good starting point. Building mock-ups early in the development process is a cheap way to tackle user experience issues.

Nevertheless, the theories that were taken into consideration when designing Halo are from renown researchers within the area of user experience. The theoretical evaluation that points towards a clean keeping system offering a better user experience than what the cleaning of today does is a good sign.

A Thesis Covering the Big Picture

The scope of the project included creating a good user experience when cleaning. By developing the concept with users' thoughts and insights in mind, the project naturally converged into attempting to remove displeasure and increase pleasure in cleaning. People like the clean feeling afterwards, and thus, the mesh of intelligent devices is set to create a "lasting impression" by maintaining a clean home environment longer. Adding value to the product, exemplified by Halo being able to clean the air and clothes from unwanted odors, should theoretically induce positive emotions. However, the thesis of this project does not present a direct solution to all the found user experience problems. Many of the problems are solved through incremental product development, but some are trickier to solve – such as clean keeping below furniture. On the other hand, the thesis (Halo, the revamped stick and the intelligent mesh of devices) do assume the following: if the air is constantly kept clean from dust, surfaces including those below furniture should hypothetically also be kept clean from dust. Such assumption is not irrational, but should be examined by further tests.

However, the questions are: does the *overall* experience really become better with Halo? Are the positive experiences with Halo sufficient to make the whole cleaning experience better? If less frequent cleaning actrivities (such as window cleaning) is disregarded from the discussion, it can be seen that, theoretically, the whole cleaning experience has become better. The revamped stick is powerful, lightweight and good-looking, making floor cleaning into a better experience. However, there are still downsides. Surfaces beneath furniture are still in need of cleaning every now and then. But Halo's final goal is to make sure that the home becomes clean from dirt, at all times. This would make dusting, which is cumbersome, into a non-existing task. The cloth would still be needed when cleaning the interior from dirt other than dust, which still, could be improved experience-wise.

From Product Design to Service Design

The selling price of Halo was also presented in the evaluation – around 10000 SEK. That is a number that was based on how much a Nest smoke detector, a high-quality air purifier and a high-quality robotic vacuum cleaner cost altogether in stores. The selling price could of course differ radically, but it's reasonable to claim that Halo is much more expensive than a cloth and a vacuum cleaner. The follow-up question is: *does the selling price make it unreasonable*? Looking at the trend, technology used within robotic products will decrease in price as robots are becoming more common, both in the industry and in society. This could make Halo less expensive to produce, and thus, less expensive to buy. The goal of Halo is that the user eventually won't need to clean at all, which makes the price tag more acceptable. Another idea to commercialize Halo is for Electrolux to offer a *comfortable living environment* rather than a product per se. Such a *service* would include Halo and the revamped stick. The customer would only need to pay a monthly fee, which would include installation and maintenance of both Halo and the stick. The service would also make Electrolux products, in the end of their life cycle, end up in the hand of Electrolux. The products wouldn't end up in landfill and would instead be recycled into their last bits. In a future where shortage of materials is possible, a service would be a good solution.

The Alleged Gap in the Market

During the project, it was found that robotic air cleaners exist, but they have been commercially unsuccessful. The reasons to why they haven't been successful has already been explained, but the question still remains: is there really a gap in the market? There may be a reason as to why companies like Electrolux haven't been trying to dive into this market. Looking at Halo, several speculations can be made. The market may not have matured enough as the user's still haven't explicitly stated their need of a robotic air cleaner. Another speculation is that it is expensive – it was stated earlier that Halo could cost around 10000 SEK, which is on par with a very expensive robotic vacuum cleaner. A third, more believable guess is that the technology is not ready yet – the ceiling mounted unit needs rigorous programming and an advanced artificial intelligence. As the project was focused on developing the future of clean keeping, it is evident that the result may not be suitable for the market of today. Nevertheless, semantics and value aspects were too important to not regard as one of the main reasons to the failure of robotic air cleaners. Halo is a completely different product.

Artificial Intelligence is Key

Looking at the big picture, Halo and the revamped stick together with other devices in an intelligent mesh, should be evaluated. Considering today's technology, the weak spot of the concept is probably the artificial intelligence – how well will it understand the user? As artificial intelligence is an area in rapid development, such problems are considered to be solved in the near future.

A Solution Space Worth Exploring

The approach of the project included ideations throughout the project instead of forcing all ideation into one phase. Purify, Weasel and SUR were three different concepts that tackled different aspects of clean keeping. When Purify was chosen, it was further developed as presented in phase 5. This leads to the question: are there other ways than Purify and Halo to clean keep the air free from dust, particles, odors etc.? Purify was only one *suggestion* of how to keep air, and thus surfaces clean from dust. Additional ideation sessions could've been conducted in order to explore the solution space of this specific task. Nevertheless, the scope of the project was to provide a vision of the future of clean keeping, and Halo is certainly a visualization of that.

D. THE FUTURE OF CLEAN KEEPING

One of the key findings in the project is that people in general dislike cleaning. There are of course parts of cleaning that are pleasurable compared to even more displeasurable parts, for example auditory feedback when dirt runs through the pipe of the vacuum cleaner compared to the physical demand that is related to most cleaning activities. But there is most certainly more pleasure in doing other things in life than cleaning. On top of that, the level of automation is increasing all around us, which makes it natural to believe that users will be less and less involved in clean keeping in the future. It could be questioned whether there will be a counter-reaction to automation as it increases, but it is reasonable to believe that users will be more prone to put their energy into other manual activities that are more pleasurable than cleaning, for example exercising or cooking. So in a long term perspective, full automation or dirt prevention are the only natural destinations for clean keeping. Halo is a step on the way to full automation that considerably decreases the need of user involvement, and therefore also decreases the displeasure related to cleaning.

As automation increases, clean keeping will become more frequent and regular, or even constant. That will result in homes that are cleaner than today in general. For that development to proceed, clean keeping will shift focus from surfaces to the living environment and the health of the residents. Companies like Electrolux might for example sell healthy and comfortable living environments instead of clean keeping devices in the future. The pleasure will be in living in a clean, comfortable and healthy living environment that allows the users to do other things that they like. Halo is the first clean keeping concept that proves that such a change is possible, which opens up for other entirely new clean keeping products as well.

So what will it actually be like to live with a device like Halo and other devices within the mesh? What are the real benefits and what will bother users? Those aspects, and the long term future of clean keeping are discussed in the following sections.

What Will It Be Like to Live with Halo and a Mesh of Devices?

Since Halo is a step on the way to fully automated clean keeping, users will still have to clean, but a lot less than before. Of course, it can be questioned to what extent Halo will reduce user involvement. More tests and user studies are needed to investigate that. Halo will however at least reduce the need of cleaning by 50 % based on the air cleaners of today, it will also provide a much better living environment – without disturbing the residents. So users will spend less time cleaning, and therefore be able to do more and other things in life. So the main result of having a Halo is a considerable reduction of displeasure that in turn allows for pleasure.

Halo came from the conclusion that vacuum cleaners are and will be good enough for floor cleaning even in the future. The stick was found to be the easiest, simplest, most capable device for that purpose. That conclusion was however based on the fact that robotic vacuum cleaners suffer from navigation and capability problems. Since Halo offers drastically better ways to navigate due to the smart sensor units, a lot of the issues with robotics might be solved as well. Further studies including Halo and a new robotic vacuum cleaner would be needed to confirm that, but together they have the opportunity to turn cleaning into something almost fully automated and magical.

Less time spent is one of the benefits with Halo. But Halo also add other values to the lives of people. It will enhance people's lives by providing helpful services such as clothing freshening and fan functionality. Such functionalities should increase the quality of life.

Halo relies heavily on the smart sensor units. They make the system smart and make sure that everything works without the user even noticing. They have the capability to learn from all parts of the home, understand and predict. In that way, Halo also shows the way for home automation in the future. It is a highly expandable foundation, on top of which completely new devices can be built. It might for example pave the way for smart successful robotic vacuum cleaners and ovens that understand the food you put into them. That is why Halo has every opportunity to change people's homes and lives forever.

What New Problems and Disturbing Factors Are Introduced?

Introducing a new way to keep homes clean might of course introduce new problems that don't exist in the current system. It is reasonable to believe that people start bothering about new things when the most displeasurable things of today disappear.

Sound and noise were some of the most prominent disturbing factors found in the user studies, and should therefore be carefully considered when developing new clean keeping devices. Halo will probably generate some amount of noise when cleaning the air from various particles, and also when acting as a fan and clothing freshener. Due to the automated and continuous nature of Halo, it will also operate over lengthier periods of time compared to vacuum cleaners for example. That might become a disturbing factor in the future. Halo does however have the capability to clean when no one is near, or even home, which reduces the disturbance considerably. At some points, however, Halo will need to operate when the user is near. When acting as a fan is the most obvious example, but also when the user asks Halo to come clean in a specific area, or when Halo is unable to take care of all clean keeping because there is always someone home. Further studies regarding acceptance for sound are needed to investigate those cases. However, it is reasonable to believe that users are more prone to accept the sound if they get something out of it, such as a colder environment due to the fan. Furthermore, Halo doesn't reasonably produce more sound than any other floor standing fan.

The artificial intelligence that Halo is based on gives it an almost magical feeling. It is probably the thing that users will come in contact with the most. It makes clean keeping automated and prioritized, and it is also the way in which users and Halo communicate with each other. Some users might have trouble trusting artificial intelligence and therefore distrust the clean keeping capabilities as well. Such distrust would probably be due to earlier experiences of artificial intelligence. As technology evolves, that distrust should disappear. A similar distrust and irritation might occur if the artificial intelligence is not working properly, and therefore introduce more problems than help. That is the exact case of the current robotic vacuum cleaners, but since Halo relies on information from a wide variety of sources, it is reasonable to believe that it will be able to make more intelligent decisions. A completely opposite problem is that the magical feeling of Halo might result in over-trust. People might perceive Halo as the magical helper, that will take care of everything, and become disappointed when they realize that it doesn't. People should however experience the benefits of having Halo after a period of time as the living environment improves and the results of cleaning last longer.

With the help of other devices, however, the total mesh of devices will naturally become the magical help that everyone is looking for, eventually.

Another factor found in the user studies is control. People like to be in control. With Halo, users will have less control of clean keeping in general, but also of Halo itself. That shouldn't be a problem however – Halo was in fact designed to relieve the burden of staying in control from the users. The ability to, at any time, communicate with Halo put the user in immediate control, and the automated feedback on cleaning and cleanliness makes it easier for the user to understand the clean keeping situation without even thinking about it.

People with pets and kids in their homes will probably benefit the most from living with Halo. There were for example comments from users throughout the project about kids and pets bringing dirt into and around the home constantly. A fair amount of that dirt is gravel and fur, which Halo doesn't take care of, but the increased movement will most definitely spread a lot of particles into the air. Robotic units like Halo and robotic vacuum cleaners could however evoke quite a lot of interest among kids and pets. They might be afraid of or like the robotic devices. Further studies are needed to investigate the interaction between kips and pets, and Halo. Such devices must for example be designed to withstand the weight of a dog playing with it. Halo was designed to be as unobtrusive as possible, but also to be able to slide down to lower the center of mass and therefore handle a pet playing with it.

What Comes After Halo?

Halo is a huge step forward for clean keeping. It clearly shows a new way to think about cleaning and clean keeping. But it is one part of a system on the way to full automation. So what are the problems to solve next?

The ultimate goal of clean keeping is to eliminate any kind of user involvement, to provide users with clean and comfortable living environments, without them even thinking about it. One way to reach that goal is with further automation. Halo, a robotic vacuum cleaner and some other specialized automated devices could together provide a seamless, unnoticeable clean keeping experience. As has been mentioned earlier in the report, those devices must be designed in tandem, especially if they're robotic. Halo shows a glimpse of the future, and it is important to understand and define that future before heading into it.

Halo also shows a glimpse of what is possible with home automation and artificial intelligence when used properly. That makes it interesting to think about what home automation will bring to clean keeping and other parts of the home in the future. Next up will probably be further development of home automation and smart homes where different meshes of devices benefit from each other. Not only Halo and clean keeping will benefit from the information from the smart sensor units. The fridge, freezer and the oven might for example work together to optimize cooking and predict, or even suggest, what the user should eat for dinner. It could of course be discussed whether people will want, believe or trust in home automation, and therefore if it is the future at all. Automation is however increasing all around us, from our smartphones to our cars. It helps people and makes it possible to spend time doing more pleasurable things, which is why it is reasonable to believe that it will continue to develop and grow into our lives to make our lives and lifestyles healthier and more pleasurable.

This project was set out to create a new way that is realizable within five to ten years. Throughout the project, several ideas had to be discarded due to that timeline. It was found that many of the ideas focused on the home and the interior of the home instead of clean keeping per se. The design of homes might very well affect the future of clean keeping in the long term. Together with products like Halo the design of homes could change the world of clean keeping. Materials that don't spread any dirt, and materials that capture dirt, already exist, which already makes it possible to design cleaner homes. Designing clean keeping into homes will take concepts like Halo to the next level, making it even more unobtrusive. Such proactive approaches that prevent dirt in the first place are most certainly the future of clean keeping, together with and also after Halo

11.

GENERAL CONCLUSIONS

The main conclusions of the thesis – Halo and the mesh of specialized devices – are presented here.

Halo is a vision of the future. It demonstrates that it is possible to create a more comfortable living environment, while improving the clean keeping experience. It represents a gap in the market and a new way to think about clean keeping. It is beautiful and useful and it is the future. Say hello to Halo!

- There is a gap in the market of clean keeping devices. Smart, robotic environment clean keeping devices are parts of the future of clean keeping.

- The clean keeping system must be reimagined and rebuilt from the ground up, with new devices and activities, to create better experiences.

- A mesh of specialized devices is the core of the vision of the future. Each clean keeping device must be specialized on a specific task, i.e. be easier, simpler, more capable and provide a better experience than any other device within the mesh. Seamless and unobtrusive interfaces will be key for the mesh to be accepted.

- The mesh of devices is key to make robots smarter and therefore more trustworthy. It is the source of perfect navigation.

- The smartness is not in apps but in listening, analyzing, understanding and learning from the living environment and the users. That data will be used to provide a prioritized, organized and optimized clean keeping, that will ultimately eliminate the need of user-involvement.

- Clean keeping must in general be easier. The user has to be able to accomplish more with less – i.e. clean one area and get another one for free.

- The future of clean keeping includes a clean and comfortable living environment – not only clean surfaces.

- Clean keeping should leave a lasting impression.

- Products that are visible in the home need to have a purpose at all times to succeed, i.e. provide the user with value, by acting as a clothing freshener for example.

- The expression of a clean keeping device that is visible in the home needs to be composed – i.e. thorough, unobtrusive, confident, trustworthy and seamless. Especially important is unobtrusiveness, the device must leave room for self-expression throughout of the home.

12.

RECOMMENDATIONS FOR FURTHER DEVELOPMENT

Halo is a vision of the future: a representation of a gap in the market and a manifestation of an expression that people want to have visible in their homes. It shows that clean keeping can be radically different from today and that clean keeping devices can provide users with values beyond cleaning. Most of all, it demonstrates that a smart robotic environment cleaner is a natural part of clean keeping in the future of robotic devices. Halo is however only one example of what the functionality and design of such a device could be like.

The goal of this project was to find a gap in the market. By doing so, a new effect goal was found: *to design an optimized smart environment cleaner that meets all of the goals and requirements that Halo does*. Further development should therefore iterate the entire development process with the new effect goal as a starting point. That means designing a device, or a system of devices, that considers the entire living environment and that analyzes the environment to provide a prioritized, seamless and pleasurable experience that lasts longer. The development should go through the *effect* and *use* design levels before touching architecture and interaction. The desired *effect* must for example be redefined in terms of targeted users and contexts. User studies on what types of users and homes that can benefit from a smart environment cleaner should be conducted in order to ensure a targeted development of a product that actually fits into the modern lifestyles of future users.

The most important work that remains is on the *use* design level. Halo is *one* part of a mesh of devices that creates a system. In order to design the devices within the system, all of the devices must be defined. Possibilities of other complementing products should be investigated. Products that take care of other types of dirt and areas for example. The functions needed to keep a home clean must for example be allocated between the devices. In this project, it was concluded that the stick vacuum cleaner is a natural part of the future of cleaning, but robotic vacuum cleaners will of course be a part of that future as well. Several use scenarios and system models must therefore be created. Focus could be on defining use cases that are based on both semi-automated and fully automated systems. The relation between Halo and a new robotic vacuum cleaner should be defined in order to find fully automated solutions that eliminate the need of any user involved cleaning. The communication, transportation and navigation functions of the two different devices should be further investigated to find optimized solutions where the devices help and strengthen each other's capabilities.

Several iterations and evaluations of analyses, ideas and concepts were made throughout the project. Evaluations of the actual function and form of the final concept are however needed. When the *use* is defined, further development of Halo should therefore continue by building prototypes. Functional prototypes and mockups with the real visual appearance. The functionalities of keeping air moving, collecting particles, keeping different parts of the home clean from dirt, mobility and clothing freshening should be verified. Tests of functionalities should be conducted in home environments to verify the findings from this project. The expression of Halo should also be evaluated with a larger amount of users to make sure that people want to have it visible and that it will fit into a large variety of homes.

With functional prototypes it will also be possible to conduct extensive studies regarding how Halo contributes to the user experience of clean keeping. Users should use Halo over extended periods of time to understand how such a product could change their lives and lifestyles. Interviews based on experiences, pleasures and emotions, similar to the ones in phase 1, should be conducted to make comparisons.

In the continued development, several iterations of the architecture and interaction are required to further design and develop Halo. Components need to be further specified and packed into the design of the outer shell. And the shell must be adjusted to house all of the needed components. It is however important to use the found form of Halo as a starting point and make sure that it keeps its unobtrusive expression.

As mentioned earlier, Halo relies on the fact that there are several other specialized clean keeping products in the mesh of devices. If the stick is to be part of that mesh, it needs to be further developed according to the expression and simplifications described in phase 3.

Finally, other ways to fill the gap in the market should be explored. Halo is one example. In what other ways can the clean keeping system be redefined with a mesh of specialized devices that prioritize clean keeping to leave a lasting impression?

13.

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14.

APPENDIX

APPENDIX 1 – SURVEY QUESTIONS AND RESPONSES

Edit this form

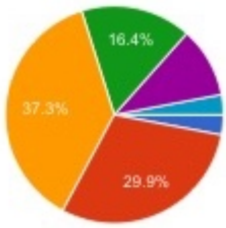
67 responses

View all responses   Publish analytics

Summary

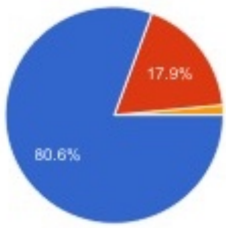
Personal information

How old are you?



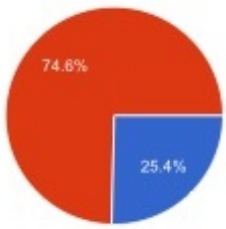
Below 18	2	3%
18-24	20	29.9%
25-34	25	37.3%
35-44	11	16.4%
45-54	7	10.4%
55-64	2	3%
65+	0	0%

What type of housing do you live in?



Apartment	54	80.6%
House	12	17.9%
Shared	1	1.5%
Other	0	0%

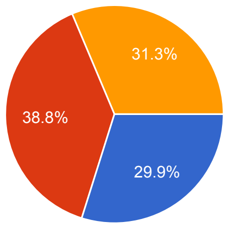
Are there any stairs INSIDE your house/apartment?



Yes	17	25.4%
No	50	74.6%

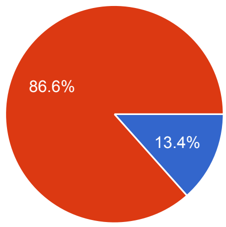
How many people live in your home? (including yourself)

1	20	29.9%



2	**26**	38.8%
3+	**21**	31.3%

Do you have any pets?



Yes	**9**	13.4%
No	**58**	86.6%

Cleaning equipment in general

Please name five or more properties that you think cleaning tools (for example vacuum cleaners) should have

Easy to store/prepare, nimble, effective, quiet, flexible

Fast, power, silence, ease, helpfulness

Small, quiet, effective, agile, low friction to the floor

Remove dirt Not be noisy Not leave a smell after use Not leave marks on what I am cleaning Leave the thing I'm cleaning in a better state than before use Don't take up much space while storing (I have a small flat)

Easy/nimble to store Suction power Long cord Nimble to move around Reach underneath furniture - easy to adapt to the furniture Easy to change the bag

Easy to use Lightweight Nimble (smidig) Trustworthy (actually working) Easy to store

Easy to use, light, possibilities to hide it, good suction, possibilities to clean tight spaces

Simple to use, hygienic, silent, slim, reliable

Inte vara för tung, snygg, tyst, platt (kunna nå in under låga möbler), enkel (få funktioner)

silent, compact, hygenic, ergonomic, inobtrusive

effective, convenient, flexible, aesthetically pleasing, safe

Fast Not too noisy Re-usable Robust Easy to use

Quiet, Fresh, Effective, Quick, Agile

Light weight, silent, flexible, long range, 'large' container

-fully automatic (robot) -can be emptied in wastepaperbin (no vacuum cleaner bags) -rechargeble batteries -silent simple, effective, multi-use, reusable, last long

Effective Quiet Small Flexible Easy to clean

lättmanövrerade, väga lite, lätta att förstå hur de ska användas, göra rent snabbt, enkla att använda

Flexibility, versatility, power, effectiveness, silent

I not sure how I can answer it

Not heavy, absorbation (uppsugningsförmåga), lasing (hållbar) and nonharming (ickeskadlig mot ex väggar, möbler)

Easy to use, mobile, silent, powerful, robust

Ergonomic, Silent, Easy to service, Durable, Small

quiet, easy to store, effective, efficient, ergonomic

Wheels or being transportable, Easy to use (roll/drag/carry etc.), Light, Easy to access, Small (so it is easy to store)

Good at cleaning, easy to handle, environmental friendly, easy to store, not too noisy

good nozzle (head) long cord 2 accessorie (brush and small pipe) good suction power good brush between head and floor

Add-on brush for pets, battery instead of a chord, some sort of brush and spray function so you can skip swabbing

Smoothly following my instructions Give great result ín one go Accessable and ready to use Intuitive maintainance Compact and easy to store

don't get stuck on door frames and walls when i drag them, distinguish between dirt and 'valuable' objects, be recyclable, be ergonomically correct, easy-peasy handling where I need it (e.g. adjust volume where my hands are anyway)

intuitive to use, ease to carry, silent, flexible (allow to clean different surfaces, etc.), powerful (good sucking power)

Power, not too heavy, versatile, rugged, easy to store

Easy to handle (intuitive), Easy to maintain (bag change etc), Premium feel in the parts (no cheap plastic feel with "loose" parts), good suction, flexibility in where to vacuum (on and above floor), good storage capacity (minimize the footprint in storage, not too many loose parts),

reach any corner, clean at once (doesn't let anything behind - solve at the first time), be silent, be self cleaning

Easy to move around while using, easy to carry, minimum maintenance, sturdy construction, good sucking/cleaning power

Powerfull, silent, flexible, precise, beautifull

Good dust collecting performance, work well on different surfaces (hardwood/plastic/ceramic/carpet), silent, compact, durable

clean, cozy, non-loud, nice, robust, friendly,happy,cleanable, possible to use in your own way, easy to take with, not to loud sound, cleaning good in many ways

Status of filters and bags. Long cable. Easy to exchange filter/bags

Easely stored, dust catcher, flexibility for different surfaces, high mobility, easy maintenance/cleaning

Take away the dust, a vacuum cleaner should be quiet, handy to use wherever you are, small,

Mobile, effective, durable, ergonomic, adaptive

EASY TO MOVE, LIGHT, CUSTOMIZABLE, INTUITIVE, PLAYFUL

Cleaning the air (ie Hepa Filter) Long small/thin nozzle for those impossible places, like inbetween radiators etc Would prefer without cord, maybe chargable Takes little space when not used Removal of Pethairs easily, at the moment their is no good solution

performance, low noise, no cord, big dust filling capacity, easy to use

strong, clean, smooth, light (weight), quiet

Good suction power, good design, compact size, long chord or no chord and extra Tools for sofas etc.

low noise, good cleaning capability, not too Heavy, not too big, easy to handle

a special nozzle for carpets, a soft brush nozzle for furnitures, a nozzle for sofa/bed, a holding clip for the hose, a nozzle cleaner

Performance, Silent, Mobility, Weightlessness, Reachability, Storage ability

Compact, silent, non-obtrusive, simple, effective

lightness, easy to drag, able to clean corners, easy to change bag, slim (for storage)

easy to use, good performance, light, easy to store, nicely designed

Functionality (do what it is promising), light, nimble, stable, no cord

be lightweight, realtively quiet, soft wheels (not damage floor, interior), powerful; (manage "heavy" material), manage wet material, look good

Easy to use, effective, silent, easy to store, possible to use on many types of surfaces

Head/brush not getting stuck in a carpet (too powerful) Brush has to be down when cleaning hard surfaces Not stumbling on the tube/vacuum cleaner Has to have good suction power

Efficient in cleaning, "fool proof"; easy to operate, hassle-free to store, require low effort, provide highly satisfying results

Efficient, clean, silent, stowable, easy to handle

Quiet, easy to move around, low weight, compact, be able to reach under and behind things

Silent, long cord, adjustable power, adjustable height, nice look

low noise, easy to store, low energy consumption, simple and Clean appearance, easy to remove dust collected, standard bags if a bagged version

Silent, effective, low energy consuming, smart storage, easy to use.

High Suction Power, Low Noise, Easy to Use, Versatile (Clean different areas), Solid quality feeling when vacuuming.

soft bumpers, pet hair nozzle, robust handles, easy to move, low noise

efficient convenient odourless silent lowprofile

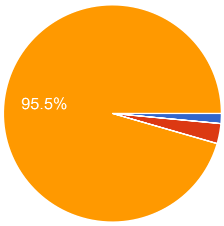
Different levels of suction, different mouthpieces, ability to change height of handle, easy to move around and into corners and small spaces, clean without me having to do anything

Experience of vacuum cleaners

[Image]

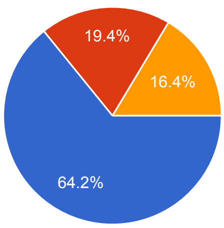
Experience

CANISTER: Do you have any experience of canister vacuum cleaners? (i.e. have you used one?)



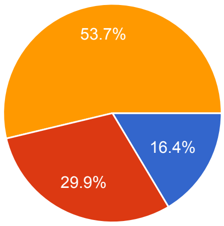
Never	**1**	1.5%
One or a few times	**2**	3%
Several times	**64**	95.5%

UPRIGHT: Do you have any experience of upright vacuum cleaners? (i.e. have you used one?)



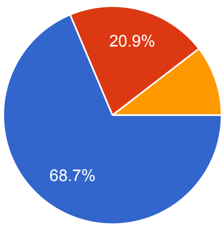
Never	**43**	64.2%
One or a few times	**13**	19.4%
Several times	**11**	16.4%

CORDLESS: Do you have any experience of cordless vacuum cleaners? (i.e. have you used one?)



Never	**11**	16.4%
One or a few times	**20**	29.9%
Several times	**36**	53.7%

ROBOTIC: Do you have any experience of robotic vacuum cleaners? (i.e. have you used one?)



Never	**46**	68.7%
One or a few times	**14**	20.9%
Several times	**7**	10.4%

Opinion on vacuum cleaners

[Image]

Opinions

CANISTER: Please name five or more words that come to mind when you think of canister vacuum cleaners

Standard

clumsy, powerful, noisy, versatile, boring

Noise, big, bulky, powerful, clean

Effective, boring, everyday, dirt, hard-working

Lightweight, bulky, cumbersome nozzle, intuitive (moving around), effective

Cumbersome, hard to reach everywhere, sand, clunky, storage

Clumsy, short reach, heavy, unstable, filter (cumbersome change)

Slow, work, sweat, tangled cord, clumsy

Reliable, hygienic, cord-troubles, space-wasting, clean

tung, otymplig, svår att förvara, projekt att ta fram och jobba med.

standard, noisy, tangle, smelly, effective

nice, effective, robust,

Usual Good Hard to store Noisy Takes up a lot of space

Heavy, Ugly, Full, Impractical, Powerful

Reliable, back pain, noisy, switching power outlet, power

full dammsugarpåse, dålig "sugstyrka", sladd i vägen

effective, wellknown, traditional,

Traditional Effective Clumpsy Cheap

klumpig, kommer åt på många ställen, stor,

I don't know how I should answer it

High quality, Good suction, Heavy and in the way

A "real" vacuum cleaner.

Bulky, hard to store, strong, normal, ugly

bulky, noisy, effective, cord, frustration

Heavy, "otymplig", "trassel", big, hard to store

Animal, smelly, cord, bag, colours

Easy to clean with, lightweight, too long tube, small and petite, functional

unsanitized

Bulky storage Many parts Dragging behind Good result Cord length is limiting flow

bulky, stupid, never goes where i want it too, easy to replace dirt bags, cumbersome but a feeling of a job well done, bad back afterwards

doesn't follow you properly (keeps hitting everything around), noisy, difficult to carry, needs cable

Powerful, main cleaner, heavy, in depth cleaning, heavy duty

flexible,powerful, Classic, durable, hose

noisy, effective

inconvenient, noisy,

Small, light, powerfull, beautifull, flexible

Versatile, heavy, noisy, bulky, ugly

classic, robust, good, correct, as it should be, clean, strong, durable, ergonomic

Booring, loud, warm, flexible, long reach

Stor, tar upp de mesta damm, lätt att använda, tar mycket plats, tung, kan låta mycket

Regular, reliable, heavy, noisy

POWERFUL, DIFFICULT TO MOVE

The best one so far, hate the cord

traditional, heavy, effective, boring, smell

normal, precision, strong, best result

bulky, old fashion, low Tech, chord is to short, enoying step to take it out

bulky, noisy, hard to take out

known, familiar, easy to use, hard to store

heavy, jammed, chunk, pieces, hard to storage

Falling over, flexible

lightness, it can clean under furniture, it can be stored in cupboard

traditional, bulky, bags

Effective, clumsy, does its job, wiggly, cord in the way

heavy

traditional, good reaching, easy to use, big and hard to store in a good way, standard

Lump hanging on the tube, cord falling off, replacing bags, different bags, tube falling off main unit (is attached to the bag, dragging in the hinge), telescope pipe getting stuck

Awkward to handle and operate, cord and body is restricting, difficult to store, carry and handle. Cleans quite efficiently.

Standard, big, clunky, cord is too short

Flexible, loud, reachable, heavy, drag

Flexible, ergonomic, powerful, bulky, colorful

easy to store, ergonomic, nimble, modern, fast

Deep cleaning, effective

High suction Power, Versatile cleaning, Heavy to use, Take a lot of storage space, Good cleaning result.

small, easy to use, silent, low, sweet

efficient silent clean bagged filtration

normal, boring, reliable, safe, good

UPRIGHT: Please name five or more words that come to mind when you think of upright vacuum cleaners

powerful, clumsy, hard to handle, cord, america

Big, powerful, noisy, America, dirty

Old fashioned, housewife, female oppression, ineffective, ugly.

Hotels Heavy/trög att flytta Noisy Ugly Cleaning person

Not reaching under furniture, clumsy, nimble, poor ergonomics, how to change bag?

Clumsy, heavy, industrial, not reaching everywhere (under furniture), easy to understand (maintenance)

Traditional, compact, light, easy to manoveur, noisy

Outdated, relic, space-efficient, America!, loud

bra för heltäckningsmattor.

heavy, clumsy, old fashioned, the 50s, nostalgic

clunky, ugly, effective, robust

Outdated Unmodern Noisy Ugly In efficient

Easy, Small,

heavy, old fashion, clumsy, loud, brown

omodern, -

weight

Clumpsy Hard to use under furniture

svårt att komma åt överallt, tung,

Comfortable

I don't have nothing in my mind

US, heavy, old School and slim

Mobile

Hotel, classic, USA, easy to store, old

noisy, heavy, big, bulky, wrong

boring, dusty, heavy, clumsy, "jobbig"

American, cartoons, old-fashioned, 50s, housewife

good, not for an entire apartment, clumsy, easier to fetch, good nozzle

bad sucktion

Heavy Bulky Hotel cleaners Uggly USA

bulky, how do you empty it?, 1950ties housewife, can't go under furniture

bulky, old-style, noisy, difficult to clean, ergonomic

old fashion, UK, cumbersome

-

ugly

american, heavy, convenient maybe?

Light, sexy, powerfull, strong, flexible

Old fashioned, bulky, difficult to reach under furniture, ugly

ugly, strange, not enough space for dust, wrong, unergonomic, not reaching things far away in small places

Old style

Hoover, bulky, large, impractical, office

Klumpig, tar mycket plats, ser inte så fin ut, har en sladd

Weak, ineffective, toyish

DIFFICULT TO STOCK, TRANSFER AND MANEUVER

Works well only when carpetted floor..like in America or UK

bulky, heavy, cumbersome, effective, big nozzle

Have nothing to say really

modern, slim design, high-Tech, low suction power, short battery life

no

old fashion, bulky, big, hard to store

handy, heavy, bold, trick, unreachabilty

Powerful

heavy, difficulties to clean under furniture, it takes long time before emptying the bag

american, ugly, big, heavy

Need to change bags more often?, smaller dust bag?, is it powerful enough?, more nimble than a canister

heavy

inconvenient, big, bulky, loud, hard to handle, heavy

Carrying all dirt (everything is resting on the head), cord bothersome

Heavy, noisy, not efficient at cleaning. Easy to store since it has no cord.

Like what you see in movies, must be heavy

Old school, unflexible, stable, broad, streight,

Ugly, difficult to maneuver, heavy, loud, awkward

Heavy, noisy, old fashioned, carpet, hard to store

Big and bulky, USA

Large Size, Carpets, Brush in Nozzle, Heavy, Limited reach.

big, heavy, ugly, storage, loud

heavy inconvenient deep clean noisy obtrusive

heavy, stairproblems, old, otymplig, big

CORDLESS: Please name five or more words that come to mind when you think of cordless vacuum cleaners

weak, neat, easy, charging, inflexible

Weak, 'smidig', easy, charge, noise

Ineffective, dishonest, nimble, not clean, American housewife

Nimble, low-capacity, crumbs, professional context, style in use

Nimble, easy to store, easy to move around, function (how does it work?), cool

Nimble, practical, ineffective, charging station, easy storage, clean, simple/easy

Modern, not completely trustful, charging, malfunctioning battery, swift

Space-efficient, multi-functionality, simple, time-consuming, practical

dålig sugförmåga, liten, enkel, måste tömmas ofta.

weak, plastic, caravan, tv-shop, ineffective

x

flexible, nice, not reliable, not effective, neat

Efficient Modern Easy to store Not the best vaccuming powers Silent

Five words are far to many on all of these..

electrolux, colorful, low-battery life, small container, weak

centraldammsugare, praktisk

useless, unefficient, "leaks" content after sucking it up

Uneffective Easy to move around Sleek Expensive

smidig, väger lite, får inte plats med så mycket smuts

Flexibel, easy to take out

I don't know how I should answer it

Light, easy, little suction and modern

Easy to use

dissatisfactory, underpowered, ugly, plastic, easy to use

handy, sleek, small, uneffective, modern

easy to store, flexible, not so powerful or useful (måste säkert byta påse ofta?)

Battery, poor cleaning, colours, wall-hanging

Good for small areas, no need of bag, no cord is good, not for an entire apartment, can see when you need to empty it

they look like they are fast, but they are really clumsy and slow to roll

Freedom Instant spot cleaning Easy use Good enough on a Daily basis rest can be outsourced Kids like using it

right at hand, quick, not enough power, kids can use it too

ergonomic, versatile, noisy, not powerful enough, battery doesn't last enough

versatile, freedom, limited power, battery life, only limited task

availability, easy, Quick, modern, storage

Beautiful, usefull, low Power, not effective

breaks easily, convenient

Powerfull, long lasting, precise, light

Tv-shop, bad fit for common use case, degrading battery

weak, no space for dust, will not bear enough enery, unergonomic to use, breakable,

Freedom

Shelves, mobile homes, boats, small, charger

Lång, kan vara svårt att dammsuga under en soffa, måste laddas ofta, smidig när man vill dammsuga upp något fort

Old, hard to manouver.

QUICK ACTION, RELIABLE, FAST BUT NOT SO POWERFUL

Little suction power, does not work in our house, i sold mine after a few months.

easy, quick, spot cleaning, handy, tool

weak, worthless, flexible, light

no experience

too weak, easy access, colourful

easy to use, easy to store, practical, handy

weak, baterry, handy, quick, light

Ineffective

it needs to be cleaned every time , it can't be stored in a cupboard because it needs to be attach to a socket all the time, lightness,

easy, quick, small, bagless

Battery lasting?, less effective, no cord, easy to handle, nimble

convenient, limited battery

easy to use, for smaller households/needs, silent, weak, easy to store

Not powerful enough, low suction power

Quick, convenient, easy, very good for in-between upkeep but not main cleaner.

quick, loud, not as efficient, convenient

Easy, light, crumbles, kitchen, ineffektive, unflexible, easy, time effective, quick

Weak, frequent use, colorful, slim, stiff

noisy, weak, batteries(why have battereies where there is high quality energy in the wall socket?!!!!), small

quick clean, not 100% clean

Easy to use, low weight, at hand, limted performance, filter maintence.

week, pretty, useless, easy access, cool

convenient noisy messy modern good value

easy, smidig, versatile, light, good

ROBOTIC: Please name five or more words that come to mind when you think of robotic vacuum cleaners

modern, unnecessary, scary, charging, weak

Fun, not trusting, automatic, simple, complex

Ineffective, cute, creepy, needy, fragile

Robotic lawn mower, hyped, low effectiveness, noise, clumsy

Happy/joy, nimble, time saving, fresh home, needy

Practical, fun, new, unpractical/inflexible (can't clean skirting), East/simpel, more maintenance (less storage)

Automatic, quick, smooth, not completely trustful, modern

Lazy, automatic, simple, time-saver, space-efficient , quiet

liten, gullig, gör jobbet själv. Som en liten familjemedlem/husdjur.

stupid, useless, stuck on carpet, novelty, potential

cool, ineffective, energy consuming, annoying

Future Not good enough Expensive Efficient Compact

Wall Bouncers, Dog Opponents, Toe Eater

future, non-reliable, lazy, small, expensive

praktisk, skön, dyr

effortless, automatic

Expensive Comfortable Modern

smidig, läskig, enkel, praktisk

Time-saving

I don't know how I should answer it

Small, miss spots, bad suction and modern

Not for my household

Future, ineffective, Wall-E, confused, pet

funny, cool, easy, pets, nice

posh, self-going, futuristic, expensive, lazy

Animal, corners, advertisements, always on?

don't believe in them, can't reach corners, low suction power, doesn't do its job, cannot cover the entire apartment properly

expensive

Cleaning partner Time saver Not smart enough Get under where you don't Good for small rooms

has a name, works when Im doing other things, no worries, it gets stuck on socks

gets lost too easy, noisy, leave some areas uncleaned, reduces the workload

getting stuck, not so trustworthy, expensive, gimmick

new, modern, convenient, helpful, future, timesaving

silent,

easy, inaccurate, expensive

Powerfull, Smart, beautifull, silent invisibile

Expensive, convenient, wasteful, low flexibility, not sufficient for all needs

automated, non-controllable, destroying stuff, modern, ugly

Every day cleaning to keep a basic level. Not excluding weekly cleaning.

Mostly impractical, huge surfaces, tangled, threshold, cats riding them

Smart, no cord, handy, energy efficient, you can do other things meanwhile

Non adaptable, futuristic

INTERESTING BUT NOT RELIABLE

i have never used them, but i doubt they would to the job in our home...

auotomatic, smart, small, pet, helper

easy, flexible, timesaver, smart, strong

no experience

tresholds

future, efortless, time saving, pet, ambient intelligent jammed, handy, handsfree, tech, unnoticed

Inflexible

Doesn't clean corners, it can be programmed

innovative, future, technology, autonomous

Fantastic, cannot reach everywhere, good if they are doing the same job, have to vacuum skirting anyway, complement needed

comfortable, limited, convenient

Lazy, unnecessary cleaning when it's not dirty, difficult in the beginning with removing obstacles(trösklar etc.), easy once get started, high tech, silent

Dangerous (fatal), can stumble on it, smart if it can clean when you're not home, can it reach everywhere, only floor (no surfaces, furniture, stairs)

Hassle free, expensive, doubtful whether it actually does a good job. Like the idea of domestic robot.

silent, getting stuck, won't work if you have kids

Easy, nonreachable, lazy, time, save, technology

Why round? (can it reach edges?), small, cute, weak, silent

fun, easy, intelligent, modern, compact

Inefective, lots of prework needed for good result

Advanced, Noisy, Get stucked, Reach under, Limited to Floor cleaning

lazy, easy, fun, pet, corners!

gimmicky expensive inefficient slow modern

Simple, lazy, cool, cornerproblems, easy

APPENDIX 2 – INTERVIEW GUIDE

Lifestyle
Age
Gender
Allergies?
Work hours and days
Household: single, cohabitants, family, etc.
Home: apartment, house, stories, number of rooms
Hobbies/spare time: when, how often?
What does a regular weekday look like?
What does a regular weekend look like?
Pets in the household?

Dirt
What is the first thing you think about when I say dirt? What emotions?
What do count as dirt? Why?
From where do you think the dirt in your home come from?
What is required for it to count as dirty at home according to you?
How do you feel when it's not clean at home? Why?
What type of dirt bothers you the most? Where? Why?

Cleaning in general
What is the first thing you think about when I say cleaning? What emotions?
Do you like cleaning? Why/not?
Do you have any good/positive memories of cleaning or activities around cleaning? Emotions? Why?
What does you cleaning routines look like?
Who is cleaning in your home? For the most time? Why?
Do you buy cleaning services? Why/not?
Are you affected by others cleaning around you? In what ways? Why?
What do you do before/after cleaning?
What activities are part of your cleaning sessions? (e.g. vacuuming, dusting, etc.)
Where do you clean? More often in some areas?
What do you clean often? What do you clean less often?
When do you clean? Time? Day? In relation to other activities?
How often do you clean?
How long is a regular cleaning session?
Do you feel that you have the time for that?
What pieces of equipment/tools/detergents/etc. do you use when cleaning?
Which piece of equipment do you use the most?
Which piece of equipment is your favorite?
If allergies. Has that affected cleaning? How?
What is easiest to clean?
What is most difficult/cumbersome to clean?
What is most boring to clean?
What is most fun to clean?
How do you feel after cleaning?

Vacuum cleaners
What is the first thing you think about when you think of your vacuum cleaner? Emotions? Associations?
What is the first thing you think about when I say vacuuming? What emotions?
Do you have any good/positive memories associated with the vacuum cleaner? Emotions? Why?
Do you have a strategy when vacuuming to make sure that every area is covered? What?
How many vacuum cleaners do you have?
What type of vacuum cleaner do you have? (canister, central, robotic, upright, etc.)
What brand is your vacuum cleaner?
What model is you vacuum cleaner? Why did you choose that one?
For how long have you had your vacuum cleaner?
How much are you willing to pay for a vacuum cleaner?
What properties are important for a vacuum cleaner to have?
What is you vacuum cleaner used for except floor cleaning?
Are you satisfied with your vacuum cleaner?
How would you describe the sound of your vacuum cleaner?
How effective do you find your vacuum cleaner to be? Why?
What do you feel when using your vacuum cleaner?
What do you think about your vacuum cleaner?
What is you vacuum cleaner best for?
What is less good about your vacuum cleaner?
Is there anything about you vacuum cleaner that bother you? What? Why?
How often do you replace the bag of your vacuum cleaner? How? What do you think? Emotions?

Kansei inspired scales (1=low, 7=high)
Visual impression:
Tactile impression:
Auditory impression:

Excited:
Interested:
Enthusiastic:
Happy:
Relaxed:
Bored:
Sad:
Guilty:
Lonely:
Frustrated:
Anxious:
Disgusted:
Angry:
Afraid:

Easy to use:
Functions I need:
Designed in a logical manner:

APPENDIX 3 – LIST OF DIRT TYPES

TYPE	CATEGORY	SIZE	STATE OF MATTER	ORIGIN	SPREAD RATE	WEIGHT	LONG OR SHORT TERM ACCUMULATION	OTHER	FREQUENCY
Dust	Particles	Small	Dry	Clothes Secretion Humans	High	Light	Long-term	Airborne	Common
Dust bunnies	Fibers	Small Medium	Dry	Clothes Secretion Humans	Medium	Light	Long-term	Airborne	Common
Gravel (grus)	Bits	Medium	Dry	Outdoors	Low	Medium	Long-term		Common
Sand	Bits	Small	Dry Wet	Outdoors Playground Hobby indoors	Low Medium	Medium	Long-term (origin: outdoors Short-term (origin: hobby indoors)		Common
Mud/soil	Goo (sticky) Liquid	Small Medium	Wet Dry	Indoor plants Outdoors	Medium	Light Medium	Short-term Long-term		Fairly common
Clay	Goo (sticky)	Small Medium Large	Wet Dry	Hobby indoors Outdoors	Low	Medium	Short-term (origin: hobby indoors) Long-term (origin: outdoors)		Fairly common
Lime (kalk)	Stains	Small	Dry Wet	Bathroom water Rain Kitchen	Low	Light	Short-term		Common
Spider web	Fibers	Medium Large	Dry	Spiders	Low	Light	Long-term		Common
Insects/bugs	Bits	Small Medium	Dry	Outdoors	Low	Light	Long-term		Common
Fat	Grease	Small Medium	Wet	Food Liquids	Low	Light	Long-term Short-term		Common
Poop, pee, vomit and other body fluids	Liquids Bits Grease Goo (sticky)	Small-medium	Dry Wet	Human	Low Medium	Light Medium	Short-term		Common
Nails	Bits	Small	Dry	Human	Low	Light	Short-term		Common
Mite	Particles	Small	N/A	Bed Dust	Low	Light	Long-term		Common
Paper(writing)	Bits	Small Medium Large	Dry	Living room Work	Medium	Light	Short-term	Small (and medium bits) are airborne	Fairly common
Paper (wiping)	Bits Particles Fibers	Small Medium	Dry Wet	Bathroom Kitchen wiping towel	Low Medium	Light	Long-term	Airborne (medium bits less than others)	Common
Glass	Bits	Small Medium Large	Dry	Dishes Mirror Window Interior decoration	High	Medium Heavy	Short-term	Heavy in density	Uncommon
Porcelain	Bits	Small Medium Large	Dry	Dishes Interior decoration	High	3	Short-term	Heavy in density	Uncommon

Skin care products	Grease	Small Medium	Wet		Low	Light	Short-term Long-term		Fairly common
Bacteria	Bacteria	Very small	Dry Wet	Foods Humans Outside	High	Light	Long	Both airborne and sticks to surfaces	Common
Hair	Fibers	Medium Large	Dry Wet	Humans	High	Light	Long		Common
Powder	Particles	Small	Dry	Outside Foods Hair products	High	Light	Short Long	Problem for vacuum cleaner filters/ engines?	Fairly common
Plants – leaf etc.	Bits	Medium Large	Dry Wet	Outside Plants	Low	Medium	Short Long		Fairly common
Pollen	Particles	Small	Dry	Outside	High	Light	Long	Problem for allergists	Common
Lint (ludd från textilier)	Fibers	Small Medium	Dry	Textiles	High	Light	Long	Problem for allergists	Common
Fur	Fibers	Medium Large	Dry Wet	Pets	High	Light	Long	Problem for allergists	Common
Crumbs	Bits	Small Medium	Dry	Food Food containers	Low Medium	Medium	Short		Common
Jam	Goo (sticky)	Medium Large	Wet Dry	Food Food containers	Low	Medium	Short	Attracts bugs	Uncommon
Meat	Bits Goo (sticky) Grease	Medium Large	Wet Dry	Food containers Cooking	Low	Medium Heavy	Short	Smell over time	Fairly common
Pasta	Bits	Large	Dry Wet	Food containers	Low	Medium	Short		Fairly common
Cereals	Bits	Medium Large	Dry	Food containers	Low Medium	Medium	Short		Fairly common
Juice	Liquid Goo (sticky) Stains	N/A	Wet Dry	Foods Food containers	Low	Medium	Short	Reaching into crevices Attracting bugs	Uncommon
Water	Liquid	N/A	Wet	Sinks Food containers Outside	Low	Medium	Short	Reaching into crevices	Common
Milk	Liquid Goo (sticky) Stains	N/A	Wet Dry	Foods Food containers	Low	Medium	Short	Reaching into crevices Smell over time	Uncommon
Rice	Bits	Medium	Dry	Food containers	Low	Medium	Short	Reaching into crevices	Fairly common
Flour	Particles	Small	Dry	Food containers	High	Light	Short	Airborne Reaching into crevices	Uncommon
Sugar	Bits	Small	Dry	Food containers	Low	Light	Short	Reaching into crevices	Fairly common
Grains	Bits	Medium Large	Dry	Food containers Outside	Medium	Light Medium	Short	Can be airborne Reaching into crevices	Uncommon

APPENDIX 4 – DIRT CATEGORIES

CATEGORY	SIZE	STATE	ORIGIN	SPREAD RATE	SPREAD AREA	WEIGHT	LONG OR SHORT TERM ACCUMULATION	FREQUENCY	OTHER
Particles	Small	Dry	Humans Textiles *(carpets, curtains, furniture, clothes etc.)* Outdoors Plants Foods Hair products Construction dust	High	Big	Light	Long	Common	Airborne. Allergenic.
Fibers	Medium Large	Dry Wet	Humans Bugs Textiles *(carpets, curtains, furniture, clothes etc.)* Pets Plants	Medium High	Big	Light	Long	Common	Airborne. Allergenic.
Bits	Small Medium Large	Dry	Outdoors Children's toys Plants Humans Dinnerware Chinaware Glass Foods Construction dust	Low Medium	Small Medium	Medium Heavy	Long Short	Common	Reaching into crevices.
Goo (sticky)	N/A	Wet	Plants Outdoors Toys Humans Foods Pets	Low	Small	N/A	Short (Long)	Fairly common	Reaching into crevices. Can turn into stain.
Liquid	N/A	Wet	Human Foods Sink Outdoors Pets	Low	Small Medium	N/A	Short	Common Fairly common Uncommon	Reaching into crevices. Can turn into goo (sticky) or stain.
Stains	N/A	Dry	Water Outdoors Foods Humans Liquids	Low	N/A	N/A	Long Short	Common Fairly common	Hard to remove (generally)
Grease	N/A	Wet	Foods Skin care products Humans	Low Medium High	Medium Big	N/A	Short Long	Common	Could smell.
Bacteria	Very small	Dry Wet	Foods Humans Outdoors Pets	High	Big	Light	Long	Common	Airborne. Sticks to surfaces.

APPENDIX 5 – DIRT COMPATIBILITY

EQUIPMENT	PARTICLES	FIBERS	BITS	GOO	LIQUID	STAINS	GREASE	BACTERIA	SUM •=1, (•)=0,5
Vacuum Cleaner (canisters, bagless, backpack, semi-professional, central, uprights)	•	•	•						**3**
Vacuum Cleaner (water)	•	•	•		•				**4**
Vacuum Cleaner (steamer)	•	•	•	•	•	•		(•)	**6,5**
Vacuum Cleaner (stick)	•	•	(•)						**2,5**
Vacuum Cleaner (handheld)	•	•	(•)						**2,5**
Vacuum Cleaner (stationary)	•	•	•						**3**
Vacuum Cleaner (robotic)	•	•	(•)						**2,5**
Broom	(•)	•	•						**2,5**
Dustpan	(•)	•	•						**2,5**
Hand feather duster	•	(•)							**1,5**
Microfiber floor duster	•	•	(•)						**2,5**
Mop	•	•	(•)	•	•	•	•	(•)	**7**
Towel	•	•	(•)		•				**3,5**
Window scraper	•				•				**2**
Cloth/rag	•	•	(•)	•	•	•	•	(•)	**7**
Detergents				•		•	•	•	**4**
Sponge	•			•	•	•	•	(•)	**5,5**
Water	•	•		•	•	•	(•)	(•)	**6**
Dish-brush	•			•		•	•	(•)	**4,5**
Toilet brush	•			•		•		(•)	**3,5**
Paper	•	•	(•)	•	•	(•)	(•)	(•)	**6**
Canned Air – Duster	•	•							**2**
SUM •=1, (•)=0,5	**20**	**16,5**	**10**	**9**	**9**	**8,5**	**6**	**5**	

APPENDIX 6 – VACUUM CLEANERS' COMPATIBILITY WITH DIFFERENT SURFACES

	CANISTER	CORDLESS	UPRIGHT	ROBOTIC
		Most rooms		
Floor	•	•	•	•
Walls	•	•	•	
Ceiling	•	•	•	
Windows	•	•	•	
Furniture	•	•	•	
Skirting	•	•	•	
Cornice	•	•	•	
Corners	•	•	•	
Surface	•	•	•	•
Inside cabinets	•	•	•	
Shelves	•	•	•	
Door steps	•	•	•	
Carpets	•	•	•	
Curtains	•	•	•	
Light fixture	•	•	•	
Decorations	•	•	•	
Plants				
Doorframes	•	•	•	
		Kitchen & Bathroom		
Sink				
Oven				
Stove	•	•	•	
Hob	•	•	•	
Kitchen fan	•	•	•	
Fridge				
Freezer				
Shower	•	•	•	•
Basin	•	•	•	
Toilet	•	•	•	
Mirror				
Bathtub	•	•	•	
Bathroom floor	•	•	•	•
		Other		
Electronics	•	•	•	
Bed	•	•	•	
Stairs	•	•	•	
SUM	**28**	**28**	**28**	**4**

APPENDIX 7 – FUNCTION ANALYSIS

Canisters

(QUESTION) WHY...	(POSSIBLE REASON/ANSWER) BECAUSE...	FUNCTION (VERB + NOUN)
...is there a big handle on the stick/pipe?	...to be able to grip the stick in a way that makes vacuuming ergonomically easier.	*Allow ergonomic cleaning while standing.*
...is there a stick/pipe?	...to be able to control the head of the vacuum cleaner.	*Allow control of the cleaning.*
	...to be able to transport dirt from the vacuumed surface.	*Facilitate transportation of dirt from surfaces.*
	...to be able to vacuum surfaces from a distance.	*Allow cleaning from distance of maximum ~1 meter from the user.*
	...to store the dirt	*Transport dirt to storing*
Tube	Transport dirt	*Transport dirt to storing*
	Allow to pull the main unit with the help of the big handle or metal pipe	*Facilitate transposition of the product.*
Brush on head	Free the dirt from the carpet	*Facilitate removal of dirt from surfaces.*
	Protect wooden floor from scratches	*Prevent scratches on sensitive surfaces.*
Buttons/remote control on pipe	Easy control of pulling out/in the brush	*Ease brush activation/deactivation*
	Easy activation of automatic suction power adjustment	*Ease automatic suction power adjustment activation/deactivation*
	Easy manual regulation of suction power	*Ease manual regulation of suction power.*
	Easy shutdown	*Ease product shut down.*
Metal pipe	Facilitate control of the head	*Facilitate control of the product.*
Telescopic pipe	Allow the user to adjust the reach of the vacuum cleaner.	*Enable adjustment of the reach between the user and the surface*
Button on telescope	Allow the user to manually adjust the reach of the vacuum cleaner	*Allow manual adjustment of the reach between the user and the surface*
Wheels on head	Facilitate control of the head	*Facilitate maneuvering of the product.*
On/off button on main unit	Allow shutdown	*Allow shutdown.*
Cord button on main unit	Allow automatic gathering of the cord	*Allow cord gathering control*
Wheels on main unit	Allow vacuum cleaner to move easily when dragged	*Facilitate maneuvering of the product.*
Specifically three wheels on main unit	Facilitate for the user to move the main unit	*Facilitate maneuvering of the product.*

Slot on the rear and bottom side of main unit	Allow the user to fasten the metal pipe on the unit in a upright position	*Allow upright fastening of the metal pipe*
Handle on the main unit	Offering the user to lift the main unit or to drag it more ergonomically	*Offer lifting/dragging of the product ergonomically*
Display on the main unit: big number	Present the user the current suction power	*Present suction power*
Display on the main unit: pictures of different surfaces	Facilitate the choice of suction power	*Facilitate suction power adjustment*
Display on the main unit: "S-BAG"	Indicating the user to change the dust bag.	*Provide feedback when dust bag is full.*
Display on the main unit: "AUTO"	Tells the user when the vacuum cleaner is on a auto mode, regulating the suction power automatically	*Provide feedback when activating/deactivating automated suction power regulation*
Display on the main unit: "FILTER"	Indicating the user to change the filter	*Provide feedback when filter is too dirty.*
Many slots on the upside of the main unit	Allow the air to pass out	*Allow air to pass out of the product.*
Push button on the front of the main unit	Allow user to open the vacuum cleaner's cover and change the dust bag and filter	*Allow opening up the cover of the main unit in an ergonomic way*
Cover on the upside of the main unit	Allow user to reach the dust bag and filter	*Allow exchange of the dust bag/filter*
	Protects the dust bag and filter from falling off, getting dirty etc.	*Protect the dust bag/filter.*
Rotatable hose between the main unit and tube	Facilitates for the user when walking around the unit vacuum cleaning	*Prevent twisting of the tube.*
Indicators on the head: "LO MED HI X-HI" with	Informs the user about the cleaning heights for carpets by indicating the brush height	*Provide feedback about the current brush height.*
Indicator on the head: "CHECK BRUSH ROLL"	Warns the user that they need to check the status of the brush rolls.	*Provide feedback when brushes need to be checked.*
"HEIGHT ADJUST" button on head	Allows user to adjust the brush height	*Allow brush height adjustment*
"HANDLE RELEASE" button on head	The user can release the metal pipe from its parking position	*Allow release of metal pipe from its parking position*
"FILTER" button on the back of the main unit	To be able to open up the cover to the filter pocket.	*Allow release of back cover*
		Facilitate the changing of the back filter.
Electrolux logo		*Provide brand acknowledgement*
"UltraOne"		*Facilitate product line identity*
Orange slots on the upside of main unit		*Facilitate product line identity*

		Indicate interaction
Orange split line between the cover and the push button opening up the cover		*Indicate available interaction under the cover*
"S-bag" logo		*Provide information about the dust bag that should be used*
Plastic cover on main unit	Plastic is easy to clean with a cloth	*Facilitate cleaning of the product surface.*
		Facilitates lifting and dragging of the product
Rubber handles	Rubber is easy and comfortable to grip	*Provide grip in an ergonomic way*
Gray-metallic tube color		
Air valve on the handle of the metal pipe	Allows the user to regulate the air intake manually when temporarily needed	*Allow suction power regulation temporarily.*
Gray air valve	Provides color contrast since the handle its placed on is black	*Facilitate finding of the air valve.*
Rough surface on air valve	Makes it easier for the user to slide the air valve just the right amount they want.	*Provide grip*
		Increase friction.
Lock on the metal pipe	Gripping the lock and pressing it unlocks the telescopic pipes, making it able to change the length of the pipe	*Allow extension of the telescopic pipes*
		Provide locking of the telescopic pipes in desired length.
Plastic handle on the metal pipe		*Facilitate cleaning*
Black handle on the metal pipe		*Provide visual contrast between the handle and other available operations*
Rubber on wheels		*Facilitate maneuvering of the product.*
		Prevent scratches on sensitive floor
		Prevent scratches on the wheels
		Provide contact with floor in a steady manner
Lock buttons on the hose between the tube and the main unit	To prevent the tube to separate from the main unit	*Prevent separation of the main unit from the flexible tube*
Light gray lock buttons on the hose between the tube and the main unit	Facilitate the user to find the area that are interact-able	*Provide visual contrast between the button of interaction and surrounding materials and interactions*
Nozzle of the head	To provide holder for the metal pipe	*Provide fastening of the metal pipe on the head.*
Black nozzle of the head		*Provides relation between the big handle and the head*
		Provide feedback of the nozzle being interactable given that other interactable PARTS (not e.g. buttons) are black as well

Collar on the neck of the head nozzle	Provides surface to press on while removing the metal pipe from the head nozzle	*Provide support when removing the metal pipe from the head nozzle*
		Provide grip support when inserting the metal pipe into the head nozzle
Electrolux logo on the head		*Provide brand acknowledgement*
		Provide relation between head and the main unit
Star shape on all wheels	Similar form factors connect the different components with each other	*Provide relation between head and the main unit*
Glass part of the main unit handle		*Provide support for the handle*
Distinct parting lines		*Provide feedback of the cover being removable*
Cord		*Provide electricity*
Cord holder		*Provide cord storage*
Bag		*Store dirt*
Filter		*Prevent polluted air from being released by the product*
Rotational handle on main unit		*Facilitate ergonomic moving of the product*
Main unit		*Create suction*
		Transport dirt to storing
		Enable mobile cleaning
Main unit and handle separate?		*Off lift weight from user by letting the floor lift many of the necessary components*
		Enable flexible cleaning by reaching narrow spaces
3-in-1 nozzle		*Facilitate cleaning of other surfaces than floors as in bookshelves, tight spaces and furniture*
Seal the bag ability		*Prevent dirt from being released into the air when changing the old bag to a new one.*
Bag made of paper		*Enable air to blow through*
		Enable decrease in environmental impact
		Enable cheaper production
Wheels being big		*Facilitate transportation of product on different kind of surfaces*

Uprights

(QUESTION) WHY...	(POSSIBLE REASON/ANSWER) BECAUSE...	FUNCTION (VERB + NOUN)
Air valve outlet		*Provide manual regulation of suction power*
Handle		*Provide grip in an ergonomic way*
Orange highlight on handle		*Provide feedback regarding handle's functionality*
Handle in black and glossy plastic		*Prevent grease from hands being visualized from afar.*
Push button releasing handle from the metal pipe		*Enable detailed cleaning in a precise way*
Gray outline on the push buttons	Contrast between the blacks	*Provide visual cues regarding available interaction*
		Facilitate distinction between interactable and non-interactable components by color contrasts
Bulging push button		*Provide cues regarding available push interaction visually and haptically*
U-shaped holder behind handle		*Allow static positioning of tube*
Tube		*Allow transportation of dirt from metal tube to the dust bag*
	The tube allows the user to feel free and flexible when using the upright as cleaner of details and small surfaces	*Provide flexible cleaning when detail cleaning and when cleaning small surfaces*
	The tube allows the user to feel free and flexible when using the upright as cleaner of details and small surfaces	*Provide ergonomic cleaning when detail cleaning and when cleaning small surfaces*
Metal pipe		*Allow distant cleaning*
		Provide support when moving the product
		Enable transportation of dirt from the nozzle to the tube
Handle on the main unit		*Enable grip while transporting the product*
Angled handle on the main unit		*Provide grip in an ergonomic way*
Transparent plastic on the main unit		*Enable examination of the dust holder content*
		Provide status of the dust holder content
Telescopic metal pipe		*Allow extended reach for dirt*
Button on top of the dust holder		*Allows release of the dust holder from the main unit*
Orange parts inside the dust holder		*Provide feedback regarding distinction of the dust holder*
Pattern of circular holes		*Allow air outlet*

Wheels		*Facilitate transportation of the product in an ergonomic way*
Accessories holders		*Provide positioning of the accessories within short reach*
Cord		*Provide electricity*
Indicator panels on the head		*Provide feedback about various statuses*
Handle release bar on the head		*Allow for angle modification of the main unit in relation to the head*
Pedal on the head		*Allow mode switch between bare floor cleaning and carpet cleaning*
Cord holder		*Provide cord storage*
Dust box lid release button		*Enable dust disposal*
Head		*Enable cleaning of big surfaces in an efficient way*
Main unit and handle combined into one thing		*Facilitate wall-to-wall carpet cleaning*
Bagless		*Ease maintenance*
		Decrease environmental impact
Head being huge		*Express power*
		Collect dirt in an effective way
Big wheels		*Facilitate movement between carpet and hard floor*

Sticks

(QUESTION) WHY...	(POSSIBLE REASON/ANSWER) BECAUSE...	FUNCTION (VERB + NOUN)
Angled stick	Gives the opportunity for the user to clean the floor ergonomically	*Provide grip in an ergonomic way*
Button on the end of the straight stick	Enables the user to shut it off or turn it on while holding the stick in the handle	*Enable shut off/turn on of the machine ergonomically and within short reach*
Button on the side of the straight stick	Enables the user to eject the handheld vacuum cleaner from the long, straight stick	*Facilitate switch between cordless mode and handheld mode*
Button on the front of the handheld stick	Enables the user the opportunity to turn the vacuum cleaner off while using it as a handheld	*Enable shut off/turn on of the machine while using it as a handheld*
Big button on the bottom end of the straight stick	Enables the user to angle the straight stick in relation to the head	*Enable reach to corners and beneath furniture in an ergonomic way*
	Enables the user to lock the stick orthogonally to the head	*Support longitudinal floor cleaning in an ergonomic way*
Head of the straight stick		*Support cleaning of big surfaces in an efficient way*

Head of the handheld		*Support cleaning of small surfaces with precision*
		Support cleaning of thin surface materials e.g. fabric
Transparent surface on the handheld	Enables the user to look into the vacuum cleaner and see how full it is and what dirt there is	*Enable examination of the dust holder content*
		Provide status of the dust holder content
Circular pattern on the handheld		*Enable air exit*
		Express power
Plastic material of the stick		*Facilitate cleaning of the machine*
Slot on the stick		*Provide positioning of the handheld into the stick*
Slot in the same shape as handheld		*Provide feedback regarding the placement of the handheld*
Handle on the handheld		*Provide grip*
Extended mouth on the handheld		*Support cleaning in a precise way*
Lights on the head of the straight stick		*Facilitate dirt discovering on surfaces*
Black plastic on the angled end of the stick		*Provide feedback regarding possible interaction*
		Prevent visualization of grease from the hand
Battery		*Enable cordless cleaning*
Docking station		*Enable charging*
		Provide fixed positioning for the product while charging
Brushes		*Support gathering of dirt into the head*
		Facilitate dirt removal from surfaces
Hole in the head		*Enable transportation of dirt from head to the handheld unit*
Hole in the handheld unit		*Enable transportation of dirt from the nozzle of the handheld unit to the dust holder*
Electrolux logo		*Provide brand acknowledgement*
Handheld unit		*Facilitate cleaning on surfaces other than floors/carpets*

Robotics

(QUESTION) WHY...	(POSSIBLE REASON/ANSWER) BECAUSE...	FUNCTION (VERB + NOUN)
Round	Support the main function: automatically clean the floor.	*Provide automatic cleaning of floor*
		Facilitate movement along walls and other surfaces
Brushes	Gather dirt from the floor into the machine	*Collect dirt that are harder to reach*
	Free dirt that is stuck on the floor	*Facilitate cleaning of floor*
Push button on the front	Release dust box to be able to empty the dust box	*Allow emptying of dust*
Two grooves on the push button on the front	Make the user understand that it is a push button	*Provide feedback about possible interaction*
Transparent dust box front	Enable the user to see through the dust box wall so that they can observe the status of the dust box	*Provide feedback about dust box status*
Parting line between dust box and the robot unit	Facilitate the possibility of removal of the dust box	*Provide feedback about separation possibilities*
Remote control	Enable the user to control the vacuum cleaner from afar.	*Enable distant maneuvering*
	Enable the user to set the vacuum cleaner	*Enable distant controls*
	Prevent the user to interact with the vacuum cleaner in a non-ergonomic way	*Prevent unergonomic interaction*
White button on base unit		*Allow release from charging station*
Light on charging station		*Provide feedback when product is properly connected*
		Provide feedback about battery status
Camera		*Allow situation awareness*
Clock		*Provide time*
Up-side-down V button	Change between modes	*Allow different cleaning modes*
Battery indicator		*Provide feedback about battery status*
Miele logo		*Provide brand acknowledgement*
Base unit		*Allow charging in an automatic way*
		Provide a designated space for the machine to return to
		Provide storage of cleaning tools
Play/pause button		*Provide activation/deactivation of machine without starting over the route*
Meshwork on top		*Provide air outlet*
Battery		*Enable cordless cleaning*
Thin design		*Enable reach beneath furniture*
Why the specific size/diameter		*Enable reach in-between chair leg*
Height-adjusting wheels		*Enable transport on any surface*

APPENDIX 8 – TOP-LEVEL FUNCTIONS

1. Keep home clean
    1.1. Allow easy access/preparation
    1.2. Discover dirt
    1.3. Collect dirt
        1.3.1. Remove dirt from surfaces effectively
        1.3.2. Transport dirt
        1.3.3. Encapsulate dirt
        1.3.4. Store dirt
        1.3.5. Prevent dirt leakage
    1.4. Allow dirt disposal
    1.5. Be sustainable
        1.5.1. Be environmentally sustainable
        1.5.2. Facilitate and encourage ergonomic use
        1.5.3. Encourage social interaction
    1.6. Automation
        1.6.1. Reduce user effort
            1.6.1.1. Enable time-efficient cleaning
        1.6.2. Enable manual control
    1.7. Enable mobility
        1.7.1. Enable transport
    1.8. Prevent interior damage
    1.9. Allow easy maintenance
    1.10. Last an entire cleaning session
    1.11. Be compatible with a variety of surface materials
    1.12. Be compatible with different kinds of dirt
    1.13. Reach & clean a variety of areas
    1.14. Move interior/furniture
    1.15. Be hygienic
    1.16. Allow high precision
    1.17. Provide vacuum cleaner position in relation to room/house/user etc.
    1.18. Provide system status
    1.19. Provide interaction cues
    1.20. Prevent harm
    1.21. Eliminate risk of collecting non-dirt objects
    1.22. Ease decision making
    1.23. Ease storage
    1.24. Express the Electrolux brand
    1.25. Express power
    1.26. Enable cost-efficient manufacturing
    1.27. Age with dignity
    1.28. Allow personalization

APPENDIX 9 – SURVEY ANALYSIS

	WANTED PROPERTIES	CANISTER	UPRIGHT	CORDLESS	ROBOTIC
Storage	Easy to store Easy to access Possible to hide Minimal storage footprint	Hard/bulky storage	Hard to store Easy to store	Easy to store (needs power outlet) Easy to access	(Space efficient)
Size /weight	Small Lightweight Compact	Big Bulky Heavy	Big Heavy Bulky	Neat Small Light	Small (Compact)
Effectiveness/ cleaning ability	Effective Powerful: Good suction power Clean in one go	Effective Powerful	Effective Powerful (Ineffective)	Ineffective Weak Not powerful enough	Ineffective Low suction power (Powerful)
Sound	Quiet Silent No noise	Noisy Loud	Noisy	Noisy Silent	Silent (Noisy)
Versatility/ flexibility	Flexible Reach Adaptable User-adaptable Customizable Multi-use Versatile - different surfaces - different surface materials - beneath furniture - tight spaces - on furniture - above floor - corners - vacuuming+moping - handle light and heavy material - handle wet material	Versatile Flexible Good reach - beneath furniture	Doesn't reach beneath furniture Good for broadloom rugs Hard to reach everywhere	Flexible Inflexible Versatile Crumbs For smaller areas/spots/households/mobile homes Good enough for daily basis/in-between upkeep cleaning Not a main device Kids can use it as well	Inflexible Cannot clean carpets, doorsteps, corners, surfaces, furniture, stairs, skirtings Some areas uncleaned / missed spots Good for everyday cleaning Not excluding weekly cleaning / complement needed Cannot reach everywhere
Time/ efficiency	Fast Agile Quick Efficient cleaning	(Slow)	(Inefficient)	Quick Efficient	Time saver You can do other things meanwhile
Effort /Usability	Easy to use Easy to understand Intuitive Convenient Low effort	Easy to use Cumbersome	Cumbersome Inconvenient	Easy - to access - to use Practical Handy/right at hand/available Freedom Convenient	Automated Needy Practical Simple/easy Convenient Lazy Comfortable
Reliability	Reliably remove dirt Provide satisfying results	Reliable Good/best results	-	Dishonest Not trustworthy/reliable Dissatisfactory	Not trustworthy Confused/stupid/lost /not smart enough Missing spots
Maneuverability /movability /controllability	Nimble Low friction Easy to handle Follow instructions Stable Easy to move around/maneuver Easy to carry Mobile Don't get stuck	Clumsy Unstable - falling over Doesn't follow you Difficult to carry and handle	Clumsy	Nimble Easy to move around (Clumsy) (Hard to maneuver)	(Nimble) (Clumsy) (Getting stuck) (Not controllable)

Maintenance /service	Easy maintenance Easy to change the bag and filters Large bag/storage capacity Easy to clean Easy to service Intuitive maintenance Self-cleaning Minimum maintenance Show status of bag/filters No bag	Full bag	How does it work? Enough dust capacity?	Small dust storage capacity Has to be emptied often No need of a bag	Getting stuck/jammed/tangled (Small dust storage capacity) (Has to be emptied often)
Cord/ battery/ power	Long cord No cord Rechargeable batteries	Tangled cord Switching power outlets	Cord	Charging (often) Battery worries: - Malfunctioning battery - Battery life - Degrading battery - One charge lasting? (No cord is good)	(Charging) (No cord)
Hygiene	Hygienic Clean Fresh Don't leave a smell	Clean Smelly	Dirty Dusty	(Clean)	(Fresh home)
Aesthetics /appearance	Aesthetically pleasing Unobtrusive Nice design	Ugly	Ugly	Colorful Sleek	Cute Invisible/unnoticeable
Ergonomics	Ergonomic Ergonomically correct	Back pain	Poor ergonomics Carrying all dirt	Ergonomic Not ergonomic	-
Safety /harm /damage	Safe - kids - pets humans Non-harming/damaging - furniture/interior - walls - floor - don't leave marks Distinguish between dirt and valuables Prevent stumbling	Hitting surrounding things	-	-	Dangerous/harmful - Dogs - Toes/socks (Destroying stuff) (Can stumble on it)
Sustainability	Reusable Lasting Durable Environmentally friendly	(Warm)	-	Bagless	(Always on?) (Unnecessary cleaning) (energy efficient)
Feel /Structural design	Robust Rugged Sturdy Premium feel Precise Stable	Robust Durable Many parts	(Robust) (Toyish)	Plastic Breaks easily	(Fragile)
Accessories	Good head nozzle Brush Small/thin nozzle - for radiators Good brush between head and floor Pet brush Nozzle for furniture - sofa - bed Nozzle cleaner	Many parts	(Good nozzle)	-	-
Emotions/ expressions/ general opinion/ associations	Cozy Friendly Happy Playful	Standard/traditional /classic/well-known/usual/normalregular/familiar Boring	America Old-fashioned Housewife Hotels	Modern (Cool/nice)	Modern Creepy Fun Like pet/family member/cleaning partner

		(A "real" vacuum cleaner)			Future Smart Technology Unnecessary
Allergies	Cleaning the air (e.g. HEPA filter)	-	-	-	-
Pets	Easy removal of pet hairs/fur	(Animal)	-	-	-
Dirt		(Sand (Dirt)	-	Crumbs	-
Price		(Cheap)	-	(Expensive)	Expensive
Tube/ hose		(Too long hose)	-	-	-
Applications			-	(Professional context)	-
Most used words	1. easy - 42 times (15.7%)	1. heavy - 12 times (7.5%)	1. heavy - 19 times (12.5%)	1. easy - 26 times (14.8%)	1. expensive - 9 times (6.5%)
	2. good - 18 times (6.7%)	2. noisy - 11 times (6.9%)	2. old - 13 times (8.6%)	2. weak - 11 times (6.3%)	2. modern - 7 times (5.0%)
	3. silent - 17 times (6.4%)	3. bulky - 11 times (6.9%)	3. bulky - 10 times (6.6%)	3. quick - 10 times (5.7%)	3. easy - 7 times (5.0%)
	4. store - 12 times (4.5%)	4. effective - 11 times (6.9%)	4. ugly - 9 times (5.9%)	4. battery - 8 times (4.5%)	4. time - 6 times (4.3%)
	5. effective - 11 times (4.1%)	5. cord - 10 times (6.3%)	5. noisy - 8 times (5.3%)	5. small - 6 times (3.4%)	5. future - 6 times (4.3%)
	6. cleaning - 11 times (4.1%)	6. hard - 9 times (5.6%)	6. clumsy - 7 times (4.6%)	6. enough - 6 times (3.4%)	6. smart - 6 times (4.3%)
	7. power - 10 times (3.7%)	7. powerful - 7 times (4.4%)	7. big - 7 times (4.6%)	7. nimble - 5 times (2.8%)	7. lazy - 5 times (3.6%)
	8. quiet - 9 times (3.4%)	8. store - 7 times (4.4%)	8. furniture - 6 times (3.9%)	8. store - 5 times (2.8%)	8. good - 5 times (3.6%)
	9. clean - 9 times (3.4%)	9. good - 6 times (3.8%)	9. hard - 5 times (3.3%)	9. modern - 5 times (2.8%)	9. small - 5 times (3.6%)
	10. small - 8 times (3.0%)	10. flexible - 6 times (3.8%)	10. fashioned - 5 times (3.3%)	10. light - 5 times (2.8%)	10. silent - 5 times (3.6%)
	11. low - 8 times (3.0%)	11. clean - 5 times (3.1%)	11. easy - 5 times (3.3%)	11. power - 5 times (2.8%)	11. automatic - 4 times (2.9%)
	12. long - 8 times (3.0%)	12. standard - 5 times (3.1%)	12. powerful - 4 times (2.6%)	12. ineffective - 4 times (2.3%)	12. stuck - 4 times (2.9%)
	13. light - 7 times (2.6%)	13. traditional - 5 times (3.1%)	13. America - 4 times (2.6%)	13. clean - 4 times (2.3%)	13. reach - 4 times (2.9%)
	14. too - 7 times (2.6%)	14. easy - 5 times (3.1%)	14. loud - 4 times (2.6%)	14. low - 4 times (2.3%)	14. job - 4 times (2.9%)
	15. brush - 7 times (2.6%)	15. clumsy - 4 times (2.5%)	15. store - 4 times (2.6%)	15. time - 4 times (2.3%)	15. cleaning - 4 times (2.9%)
	16. flexible - 6 times (2.2%)	16. big - 4 times (2.5%)	16. difficult - 4 times (2.6%)	16. effective - 4 times (2.3%)	16. fun - 3 times (2.2%)
	17. suction - 6 times (2.2%)	17. cumbersome - 4 times (2.5%)	17. cord - 3 times (2.0%)	17. handy - 4 times (2.3%)	17. ineffective - 3 times (2.2%)
	18. cord - 6 times (2.2%)	18. bags - 4 times (2.5%)	18. housewife - 3 times (2.0%)	18. powerful - 4 times (2.3%)	18. low - 3 times (2.2%)
	19. compact - 6 times (2.2%)	19. boring - 3 times (1.9%)	19. reaching - 3 times (2.0%)	19. good - 4 times (2.3%)	19. saving - 3 times (2.2%)
	20. nozzle - 6 times (2.2%)	20. reach - 3 times (1.9%)	20. bag - 3 times (2.0%)	20. convenient - 4 times (2.3%)	20. home - 3 times (2.2%)
Most commented categories	**Size/weight:** Small Lightweight	**Size/weight:** Big/bulky Heavy	**Size/weight:** Big/bulky Heavy	**Effectiveness/power:** Ineffective	**Flexibility/versatility:** Inflexible

	Effectiveness/power: Effective Powerful **Sound:** Silent **Flexibility/versatility:** Flexible Versatile **Effort/usability:** Easy to handle Intuitive	**Effectiveness/power:** Effective Powerful **Maneuverability/ movability:** Clumsy Unstable Doesn't follow you **Power/cord:** Tangled cord **General opinion:** Standard Traditional	**Flexibility/versatility:** Not reaching beneath furniture **Effort/usability:** Cumbersome Inconvenient **Maneuverability/ movability:** Clumsy **General opinion:** America Old-fashioned	Not powerful enough **Flexibility/versatility:** Limited to smaller tasks **Effort/usability:** Easy to use Handy/convenient **Power/cord:** Charging Battery worries **General opinion:** Modern	Only floor Not reaching everywhere **Time/efficiency:** Time-saver **Effort/usability:** Automated Convenient **Reliability:** Not trustworthy Confused/stupid/lost /not smart enough Missing spots **General opinion:** Modern Future Creepy
Pros		Effective Powerful Versatile Flexible Good reach Reliable Good/best results Robust Durable Easy to use	Effective Powerful Good for carpets	Easy to store Easy to access Neat/small Lightweight Flexible Versatile Kids can use it as well Quick Efficient Easy to use Practical Handy Convenient Nimble Easy to move around Colorful Sleek Good for quick cleaning in small areas No cord Bagless	Small Silent Time saver Automated Practical Convenient/comfortable Cute Unnoticeable
Cons		Hard/bulky in storage Big/bulky Heavy Noisy Cumbersome Clumsy Unstable Difficult to handle Tangled cord Switching power outlets Ugly Back pain Hitting surrounding things	Big/bulky Heavy Noisy Cannot reach everywhere (e.g. beneath furniture) Cumbersome Inconvenient Clumsy Cord Dirty/dusty Ugly Poor ergonomics	Needs power outlet in storage Ineffective Not powerful enough Inflexible Not a main device Not trustworthy/reliable Dissatisfactory Small dust storage capacity Charging (often) Battery worries Plastic Breaks easily	Needy Lazy Ineffective Low suction power Inflexible Can only clean floors (limited surfaces) Cannot reach everywhere Complement needed Not trustworthy Not smart enough Missing spots Small dust storage capacity Dangerous/harmful - Pets - Feet - Children - Stumble on it Getting stuck Not controllable Expensive
Interesting notes		Standard A real vacuum cleaner Clean dirt and sand	America Old-fashioned	Modern Clean crumbs	Unnecessary cleaning Modern Creepy Future Unnecessary

APPENDIX 10 – USER EXPERIENCE ANALYSIS

Pleasures

Most of the pleasure comments are about the *results* of cleaning…

	IDEO	SOCIO	PSYCHO	PHYSIO
It is pleasurable that it is clean – you know, see, feel and smell. You appreciate the results.			Know that it is clean o Satisfaction o Joy o Calmness o Freshness o Freedom o Well-being o Feeling healthy	See, feel and smell that it is clean o Satisfaction o Joy o Calmness o Freshness o Freedom o Well-being o Feeling healthy
It is pleasurable to be done when you don't like cleaning	Be done cleaning when you don't like it o Relief o Satisfaction o Calmness o Freedom o Pride		I did clean even if I don't like it o Relief o Satisfaction o Calmness o Freedom o Pride	
It is pleasurable to have a clean home in front of other people.		Having a clean home in front of other people that like and assume that homes are clean o Pride		
It is pleasurable to be in a clean environment. People like cleanliness and thrive in clean homes	Being in a clean home when you like cleanliness or dislike dirt o Like o Satisfaction o Joy o Freshness o Well-being			

Some people like cleaning, mainly due to other factors than the cleaning itself…

	IDEO	SOCIO	PSYCHO	PHYSIO
It can be pleasurable to clean if you like cleanliness (you like the result)	Cleaning if you like cleanliness o Like o Satisfaction o Joy			
It can be pleasurable to clean if you do pleasurable things simultaneously				Cleaning while listening to music, being creative, exercising o Joy o Satisfaction o Creativeness
It is pleasurable to see/hear/feel the difference. Feedback that it becomes clean				Seeing the difference, hearing dirt go through the pipe o Pleasure o Satisfaction o Freshness o Joy

People prefer cleaning tasks that are quick and easy…

	IDEO	SOCIO	PSYCHO	PHYSIO
Quick and easy cleaning is more pleasurable than the opposite	Cleaning if it is quick and easy o Satisfaction o Like			

Some comments are about the tools' capabilities…

	Ideo	Socio	Psycho	Physio
It is pleasurable to see and hear the suction from an effective vacuum cleaner (especially when the bag is new)	Vacuum cleaners should have good suction power o Satisfaction o Like o Surprise			Seeing and hearing the suction from an effective vacuum cleaner o Satisfaction o Like o Surprise
It is pleasurable when a cleaning tool can be used to several things and reach everywhere	Using a versatile tool o Satisfaction o Like			

Displeasures

People don't like dirt in general…

	IDEO	SOCIO	PSYCHO	PHYSIO
Seeing and feeling dirt or mess creates displeasure	Seeing or feeling dirt when you don't like dirt o Disgust o Unclean o Dislike o Irritation/annoyance			Seeing and feeling dirt o Disgust o Unclean o Dislike o Irritation/annoyance
Dirt can make the home feel displeasurable (especially for allergists)	Dirt when it should be clean o Discomfort o Intolerance o Unclean o Illness			

People don't like to clean in general, even though they like the results – they see it as an obligation and a necessary evil…

	IDEO	SOCIO	PSYCHO	PHYSIO
It is displeasurable to know that you have to clean	Knowing that you have to clean when you don't like cleaning o Obligation o Stress o Irritation o Anxiety o Unhappiness o Distress o Repulsion/resistance	Have to clean to have a clean home in front of others o Obligation o Stress o Irritation o Anxiety o Unhappiness o Distress o Repulsion/resistance	Psychologically wearing to know that you have to clean o Obligation o Stress o Irritation o Anxiety o Unhappiness o Distress o Repulsion/resistance	
It is displeasurable to spend time	Don't like spending time cleaning		Tiring to spend time cleaning	

cleaning. Time that could be spent doing pleasurable things. When your time is limited. When you are tired.	o Stress o Displeasure o Tiredness o Feeling busy		o Stress o Displeasure o Tiredness o Feeling busy	
It is displeasurable to clean because it is heavy and cumbersome (vacuum cleaner and to move interior around)			Cumbersome to clean o Displeasure o Irritation o Tiredness	Heavy and cumbersome to move vacuum cleaner and interior around o Displeasure o Irritation o Tiredness o Feeling of being harmed
It is displeasurable to clean because it creates back pain. Reaching down, etc.				Hurts when bending down while cleaning o Displeasure o Feeling of being harmed o Hurt
It is displeasurable to start cleaning. It feels like an obstacle to overcome. Taking the vacuum cleaner or other tools out of storage.			Mental obstacle to start cleaning o Feeling limited o Irritation o Obligation	Heavy and hard to fetch the tools from storage o Feeling limited o Irritation o Obligation

Some displeasures are due to the design of the vacuum cleaners…

	IDEO	SOCIO	PSYCHO	PHYSIO
It is displeasurable when the vacuum cleaner or other tool becomes an obstacle to cleaning or other activities. Tangling cord, not reaching everywhere, hitting interiors, tipping over, hard to drag, vacuum cleaner in the way, clumsy, getting stuck in carpet, things getting stuck in nozzle/pipe etc.			Hard to handle the tool - the tool is an obstacle o Irritation o Fear o Anxiety o Disappointment o Unhappiness	Physically demanding and cumbersome to use the tool. The tool is an obstacle o Irritation o Fear o Anxiety o Disappointment o Unhappiness
It is displeasurable when the vacuum cleaner or other tool is damaging or collecting valuables			Hard to use and trust the tool o Anxiety	
It is displeasurable when the tool is not as effective as expected. Difficulties collecting dirt, low suction power (especially when bag is not empty)	Using tools that are not effective when you think they should be effective o Uncertainty o Disappointment o Frustration o Dissatisfaction			Seeing and feeling the dirt still there. Poor auditory feedback. o Uncertainty o Disappointment o Frustration o Dissatisfaction

Some displeasures are due to the sound of the vacuum cleaner…

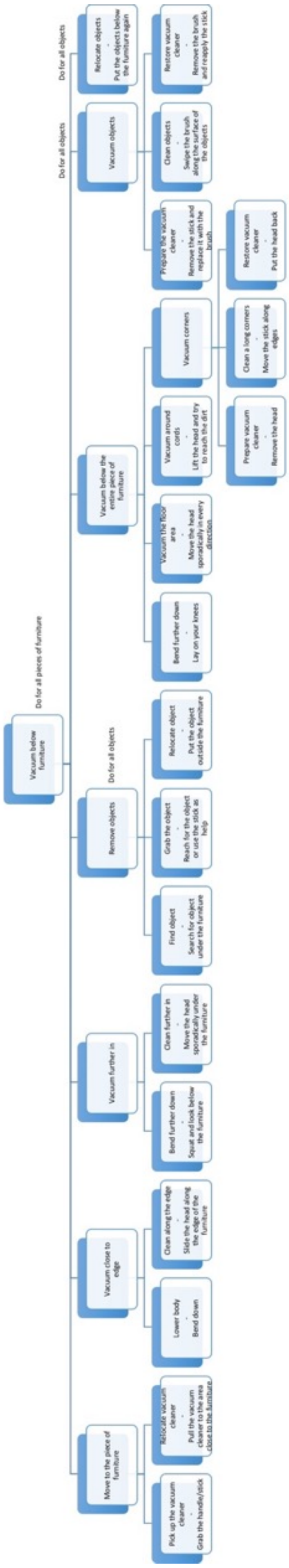
	IDEO	SOCIO	PSYCHO	PHYSIO
The sound is displeasurable because it is loud and noisy. (Like dogs barking)				Unpleasant sound from tool o Displeasure o Irritation/annoyance o Tiredness
It is displeasurable that you cannot hear other things while vacuuming.	Not being able to do things simultaneously as you clean o Frustration o Irritation o Annoyance o Disappointment			Unpleasant sound covering other sounds that you want to hear o Frustration o Irritation o Annoyance o Disappointment
It is displeasurable to know that others are disturbed by the sound		Cleaning when you know others are disturbed by the sound o Guilt o Stress o Anxiety		

Some displeasures are due to others cleaning…

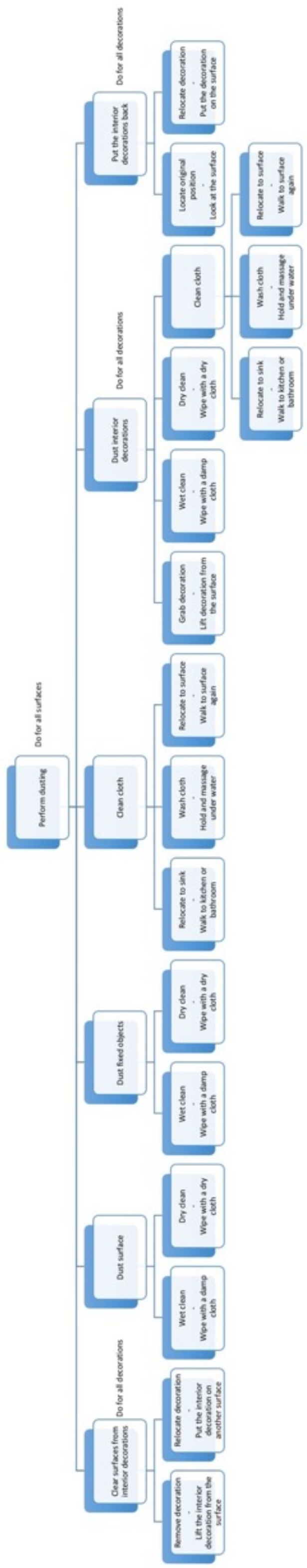
	IDEO	SOCIO	PSYCHO	PHYSIO
It is displeasurable when others are cleaning around you because it interferes with your plans, you cannot do other things	Not being able to do other things when someone else is cleaning o Feeling hindered o Irritation			Listening to disturbing sounds from cleaning tools when you are not cleaning o Feeling hindered o Irritation
It is displeasurable when others are cleaning around you because you feel that you should help		Know you should help when others are cleaning o Guilt o Stress		
It is displeasurable when others are cleaning around you because you are not in control. You don't know if the results will be good enough	You don't feel in control when others are cleaning around you o Distrust/doubt			

APPENDIX 11 – HTA

Surfaces Beneath Furniture



Surfaces Above Floor Height



APPENDIX 12 – USE CASES

Surfaces Beneath Furniture

Use case name	Vacuum beneath the couch
Use case number	1
Primary actor	Filip (the person cleaning)
Secondary actor	-
Context	At home, by the couch
Abstract	Filip is in the middle of cleaning their apartment and is using the vacuum cleaner to remove dirt from beneath the couch.
Goal	Clean beneath couch.
Pre-condition(s)	Dust, fibers and bits beneath couch. Height: 1 dm. Carpet 1 dm beneath couch. Boxes and cables beneath couch. Filip is already using the vacuum cleaner.
Normal course (initialization(what triggers), process steps, termination)	Initialization (what triggers): Dirt beneath couch. Cleaning session already initiated. Part of cleaning. 1. Filip grabs the handle of the vacuum cleaner 2. Filip pulls the vacuum cleaner towards him and towards the couch 3. Filip bends down 4. Filip slide the vacuum cleaner head along the edge of the couch 5. Filip squats down and look beneath the couch 6. Filip moves the vacuum cleaner head sporadically on the floor beneath the couch 7. Filip searches for objects beneath the couch 8. Filip grabs the objects with his hand or the head of the vacuum cleaner and put them on the floor next to the couch 9. Filip lay on his knees 10. Filip moves the vacuum cleaner head sporadically in every direction 11. Filip lift the head of the vacuum cleaner to try to vacuum on top of cords 12. Filip removes the head of the vacuum cleaner 13. Filip moves the stick along the corners and edges of the wall and couch 14. Filip puts the head back on the stick 15. Filip removes the stick from the handle of the vacuum cleaner 16. Filip looks for and grabs the brush nozzle 17. Filip applies the brush nozzle 18. Filip swipe the brush over the objects that were relocated earlier 19. Filip removes the brush nozzle and puts it back into its storage 20. Filip reapplies the stick to the handle of the vacuum cleaner 21. Filip puts the objects beneath the couch again 22. Filip rises up Termination: 23. Filip vacuums along the edge of the couch again and continues the rest of the cleaning session
Alternative course	- Filip uses a mop - Filip uses a robotic vacuum cleaner - Filip excludes the area beneath the couch from cleaning session

	- Filip put the head of the vacuum cleaner beneath the couch and hopes for the best - Filip moves the couch - Filip lifts the couch
Post condition(s)	Clean beneath couch. Boxes clean and beneath couch again.

Exception(s)	- No objects beneath the couch
	    o Skip steps 8, 15-21
	- No cords beneath the couch
	    o Skip step 11

Surfaces Above Floor Height

Use case name	Dust a shelf with interior decorations
Use case number	2
Primary actor	Filip (the person cleaning)
Secondary actor	-
Context	At home, next to the wall in the living room
Abstract	Filip is in the middle of cleaning their apartment and is using a wet cloth and a dry cloth to clean interior decorations and the surfaces on which they are placed
Goal	Clean, sparkling decorations and surfaces
Pre-condition(s)	Dust and fibers on the interior decorations and the surface around them. Height: 1.5 m. Fixed and non-fixed objects on the shelf. Filip is already using the vacuum cleaner and cloths to clean other parts of the apartment.
Normal course (initialization(what triggers), process steps, termination)	Initialization (what triggers): Dust on the interior decorations and the surface around them. Cleaning session already initiated. Part of cleaning. 1. Filip lifts the interior decorations from the surface 2. Filip puts the interior decorations on another surface meanwhile 3. Filip wipes the surface with a damp cloth 4. Filip wipes fixed objects with a damp cloth 5. Filip wipes the surface with a dry cloth 6. Filip wipes fixed objects with a dry cloth 7. Filip walks to the kitchen sink 8. Filip rinses the cloth under water in the sink 9. Filip walks back to the living room 10. Filip grabs the interior decorations from the other surface 11. Filip wipes the interior decorations with a damp cloth 12. Filip wipes the interior decorations with a dry cloth 13. Filip located the original position of the interior decorations on the cleaned surface 14. Filip puts the interior decorations in their original position 15. Filip walks to the kitchen sink Termination: 16. Filip rinses the cloth under water in the sink
Alternative course	- Filip uses the vacuum cleaner and brush - Filip uses a feather duster - Filip uses gas duster - Filip excludes surface cleaning from the cleaning session
Post condition(s)	Surfaces and interior decorations clear of dust. Interior decorations in the right place again.
Exception(s)	- No wet cleaning o Skip steps 3, 4, 7-9, 11, 15, 16 - No dry cleaning o Skip steps 5, 6, 12 - No fixed objects o Skip steps 4, 6 - No interior decorations o Skip steps 1, 2, 10-16

APPENDIX 13 – PUGH MATRICES

General

	CANISTER	WEASEL	PURIFY	SUR
Storage	0	1	1	1
Size/weight	0	1	1	1
Effectiveness/cleaning ability	0	0	-1	-1
Sound	0	0	1	0
Versatility/flexibility	0	-1	0	1
Time/efficiency	0	1	1	-1
Effort/Usability	0	1	1	-1
Reliability	0	-1	1	-1
Maneuverability/movability/controllability	0	1	1	1
Maintenance/service	0	0	-1	-1
Cord/battery/power	0	1	1	1
Hygiene	0	0	1	-1
Ergonomics	0	1	1	0
Safety/harm/damage	0	1	1	1
Environmental sustainability	0	0	0	0
Allergies	0	-1	1	-1
Dirt	0	-1	-1	-1
+		8	12	6
-		4	3	8
Sum		**4**	**9**	**-2**

User Experience Focus

	CANISTER	WEASEL	PURIFY	SUR
Actual cleanliness	0	-1	1	-1
Perceived visual cleanliness after cleaning session	0	0	1	0
Perceived olfactory cleanliness after cleaning session	0	0	1	0
Perceived haptic cleanliness after cleaning session	0	0	-1	0
Feedback while cleaning	0	1	-1	1
Minimal interference with primary user's other activities while cleaning	0	0	1	0
Minimal disturbance of side users	0	1	1	1
Mental obstacle in preparation	0	1	1	1
Mental demand while cleaning	0	1	1	-1
Overall cleanliness over time	0	1	1	-1
+		5	8	3
-		1	2	3
SUM	**0**	**4**	**6**	**0**

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