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Usability in product development practice; an exploratory case study comparing four markets

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Abstract

This study explored how usability was dealt with in four product development organizations active in different sectors: high-end automotive, professional printers and copiers, office coffee makers and fast moving consumer goods. The primary differentiators of the selected cases were whether they were targeting businesses or consumers and the degree of product complexity. Interviews with 19 product development practitioners were conducted, focusing on three topics: 1) the product development process and the integration of user involvement, 2) multidisciplinary teamwork, and 3) organizational attitude towards usability. Based on the interviews, context descriptions of the companies were created and barriers and enablers for usability were identified. To verify the findings and to discuss remaining issues a feedback workshop was held in which the primary contact from each company participated. The results indicate that differences in product-market combination lead to differences in organizational attitude towards usability. The prioritization of usability in an organization seems to be influenced by the degree of product complexity (complex products are more prone to suffer from usability issues) and whether developers think that usability is a purchase consideration for their clients. The product-market combination a company targets also affects the methods for user-centred design that a company can apply and that are relevant. What methods for user-centred design are used also seems to be influenced by the attitude towards usability: if usability is considered more important, methods that require more resources can be applied.

Keywords: product ergonomics, usability, ergonomics integration, product development, case study

1. Introduction

In the past years the field of user-centred design has matured and a wealth of methodologies and methods for user-centred design (UCD) have been developed (e.g., Nielsen, 1992; Kanis, 1998; ISO, 1999; Fulton Suri and Marsh, 2000; Kwahk and Han, 2002; Martin and Hanington, 2012; Sanders and Stappers, 2012).

However, despite all this knowledge and design methodology, products and services with poor usability are still entering the market (Jokela, 2004; Den Ouden *et al.*, 2006; Pogue, 2006; Steger *et al.*, 2007: p.825). A striking example is a new nationwide public transport RFID card that was introduced in the Netherlands in 2009. The system design and its implementation caused numerous usability problems,

causing a public outcry about the poor usability of the system, and resistance against the introduction of the system.

And the aforementioned example is not unique, by far. Online banking, car dashboards, medical devices. Some of these products and services are usable, quite a few are not. So in those cases, *something* must have gone wrong during development. Perhaps the methodologies and methods for user-centred design do not actually work in the way their authors claim they do? Can it be that the methods are not known in industry? Or maybe the methods are not applied in practice because they don't take into account the context in which product development teams have to work?

In any case, human-centred design practice turns out to be very different from UCD principles and theory (Norman, 1996; Wixon, 2003; Steen, 2008). To be effective ergonomists need to not just be very capable at solving ergonomic challenges, but also need to engage in the organisational and strategic aspects of product development (Hendrick, 2008; Dul and Neumann, 2009; Theberge and Neumann, 2010).

Multiple authors stress that in academia there is not enough insight into the practical concerns of UCD and ergonomics practitioners, and that practice should be studied to understand the barriers and enablers for successful integration of UCD and ergonomics in product development (Grudin, 1991: p.435-436; Wixon, 2003; Gulliksen *et al.*, 2006; Caple, 2010). In the field of ergonomics numerous case studies have been performed on the integration of workplace ergonomics in product development (e.g., Broberg, 1997; Neumann *et al.*, 2009), but as of yet the integration of product ergonomics in product development has received less attention.

2. Aim

The goal of this study is to contribute to the understanding of how usability is dealt with in product development practice. It has a descriptive as well as a normative component (cf. Moenaert *et al.*, 2010): to obtain insight into how product development groups in large-scale multinationals deal with usability in the current practice of product development. The second – normative – aim of the study is to assess what factors in product development influence the usability of products either positively or negatively.

3. Literature

Below a review of literature on three subjects is provided: 1) the concept of usability and its relation to ergonomics is discussed, 2) key methods for creating usable products and 3) existing studies of usability in product development practice.

3.1. Usability and ergonomics

Since 2000 the International Ergonomics Association defines ergonomics as follows (IEA, 2014):

"Ergonomics is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance."

Within ergonomics there are domains of specialisation, focusing on the different aspects of the fit between people and products/systems, namely physical ergonomics, cognitive ergonomics and organizational ergonomics.

Ergonomics as a discipline and profession are about developing products and systems that fit well with people's needs and capabilities. The goal and definition of ergonomics seem to be comparable to User- or Human-Centred Design (HCD/UCD) (ISO, 2010), which is described by Vreedenburg *et al.* (2002a) as follows:

"In user-centred design solutions that fit the user should be taken as a starting point and product quality should be measured from a user point of view, taking into account needs, wishes, characteristics and abilities of the projected user group."

Usability is a, related but complementary, concept that defines the quality of the interaction between people and systems. If ergonomics and human-centred design are the means to create products that fit people, usability is how we measure the fit.

The concept of usability originated from the field of human-computer interaction where it was applied to 'visual display terminals' (Shackel, 1984). Many perspectives on and definitions of usability have been developed over the years (Hertzum, 2010), but the ISO 9241-11 Standard (ISO, 1998, p.2) contains what is considered the most widely accepted definition of usability (Jordan, 1998; Jokela *et al.*, 2003):

"Usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

Though the construct of usability emerged from the field of Human-Computer Interaction, it does not solely apply to cognitive and sensorial usage issues. The concept of usability helps to define and operationalize the quality of the interaction and experience, and can be applied to physical or digital products alike. In addition, the definition of the satisfaction component of usability includes 'freedom from discomfort', which also includes physical interactions.

The ISO-definition of usability contains two *user performance* measurements (effectiveness and efficiency) and one *user experience* measurement (user satisfaction). This aligns with the definition of ergonomics by the IEA in which the goals of the profession are described as optimizing human well-being and system performance.

3.2. Methods for creating usable products

Over time a large number of theories and methods have been developed that provide product developers with guidance on user involvement - collecting information about users and their environments (Lauesen, 1997) - in the different phases of product development (Nielsen and Mack, 1994; Kanis, 1998; Stanton and Young, 1998; Bevan, 2003). Two of the most prominent methodologies for creating usable products are Usability Engineering (Nielsen, 1992) and User-Centred Design (UCD) (ISO, 1999; Vredenburg *et al.*, 2002a). Guiding principles in both approaches are taking the user into account in all phases of product development, testing early and often, and performing iterative design cycles.

3.3. Studies of usability in practice

Though there is a considerable number of reports on the practice of ergonomics or usability in product development (e.g., Wiklund, 1994; Jordan *et al.*, 1996; Lauesen, 1997; Väänänen-Vainio-Mattila and Ruuska, 2000; Bouwmeester and Stompff, 2006; Lee and Pan, 2007; Hendrick, 2008), a large part of this consists of descriptions of usability departments and development projects by usability specialists or designers employed by the company being described, and mostly studies are not anonymized. These are factors that may have lead to somewhat less critical descriptions in most insider accounts of human/user-centred design practice (Lindholm *et al.*, 2003: p.vii; Steen, 2008: p.56). Finally, these accounts often do not report methods for data collection and interpretation, and thus it is hard to make an assessment of their trustworthiness (Graneheim and Lundman, 2004; Shenton, 2004).

There are also studies of usability in product development practice conducted by (external) researchers. In these cases data collection methods are usually questionnaires (Rauch and Wilson, 1995; Vredenburg *et al.*, 2002b; Venturi and Troost, 2004; Ji and Yun, 2006), interviews (Bekker, 1995; Borgholm and Madsen, 1999; Boivie *et al.*, 2003; Boivie *et al.*, 2006; Bruno and Dick, 2007), or a combination of both (Rosenbaum *et al.*, 2000; Gulliksen *et al.*, 2006; Neumann *et al.*, 2009). Informants are mostly usability specialists and interaction designers, and the focus is usually not so much on the product development process and team as a whole, but on usability-related activities and usability

departments. This despite the fact that several authors conclude that to achieve a high level of usability many disciplines must be involved (Rauch and Wilson, 1995; Gulliksen *et al.*, 2006) and a multidisciplinary approach is one of the principles of user-centred design (ISO, 1999; Vredenburg *et al.*, 2002a).

A returning topic of interest in the studies of usability in practice is what methods for user-centred design are applied, why, and when (Bekker, 1995; Clegg *et al.*, 1997; Helander, 1999; Rosenbaum *et al.*, 2000; Vredenburg *et al.*, 2002b; Boivie *et al.*, 2003; Boivie *et al.*, 2006; Gulliksen *et al.*, 2006; Ji and Yun, 2006; Bruno and Dick, 2007). And to what extent does the development process allow for user involvement and an iterative approach throughout the process (Clegg *et al.*, 1997; Boivie *et al.*, 2003; Boivie *et al.*, 2006; Gulliksen *et al.*, 2006; Ji and Yun, 2006; Bruno and Dick, 2007; Neumann *et al.*, 2009).

Apart from these methodological issues, the studies reviewed point out factors related to team composition (when are usability specialists involved?) and development team collaboration (Clegg *et al.*, 1997; Vredenburg *et al.*, 2002b; Boivie *et al.*, 2003; Venturi and Troost, 2004; Gulliksen *et al.*, 2006; Neumann *et al.*, 2009). Finally, the attitude towards usability within an organization is reported to be an important factor to influence whether a company can effectively conduct user-centred design (Bekker, 1995; Rauch and Wilson, 1995; Rosenbaum *et al.*, 2000; Venturi and Troost, 2004; Boivie *et al.*, 2006). Finally, for product development teams to function effectively, the development of shared understanding is critical (Kleinsmann and Valkenburg, 2008), especially when dealing with usability, which practitioners consider an ungraspable, fuzzy concept (Clegg *et al.*, 1997; Gulliksen *et al.*, 2006).

4. Method

This case study has a multiple case design with each case being a holistic case (Yin, 2009, p.59), and uses interviews as the primary source of information. Interviews are considered an efficient way of data collection as well as insightful, as the interviewees provide their perceived causal inferences (Yin, 2009, p.102). The unit of analysis (Patton, 2002, p.228-229; Yin, 2009, p.29) are product development groups of large product development organizations. During data collection and analysis the focus was on three subjects identified through the literature study: 1) the product development process (including user involvement), 2) development team composition and collaboration, and 3) the organization's attitude towards of usability.

4.1. Case selection

A maximum variation case sampling strategy was employed, the purpose of which is to explore variations and identify important common patterns (Miles and Huberman, 1994, p.28). The primary differentiators of the cases were whether they were targeting businesses or consumers and the degree of product complexity (Figure 1). Companies that participated in the study were all large-scale multinational companies located in Western Europe. Only companies that conducted product development activities in-house were included in the study.

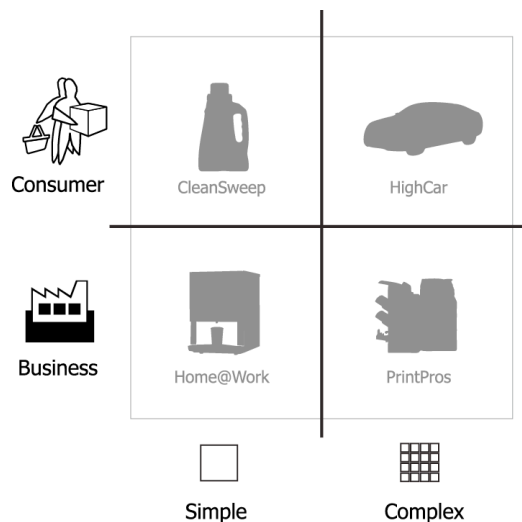


Figure 1: Distribution of the cases across markets (business versus consumer) and degree of product complexity (simple versus complex). CleanSweep was the household care division of a multinational making fast-moving consumer goods, HighCar developed sophisticated cars, Home@Work in-office coffee vending machines, and PrintPros professional printing and documentation systems.

4.2. The cases

CleanSweep

A product development group in the household care division (products for cleaning and maintenance of homes) of a multinational that developed and sold fast-moving consumer goods. The parent company had over 100.000 employees worldwide and can be characterized as structured and organized. It was well established and competing successfully worldwide. With regard to human-product interaction, especially the packaging of CleanSweep's products played an important role as it 1) enabled the use of the product, e.g., a broom for floor wipes, and 2) kept the contents (powder, wipes, etc.) together.

HighCar

Interior department of a developer and manufacturer of high-end cars, with more than 50.000 employees. It was large, mature, operating and selling worldwide, and highly organized. The company was a successful global competitor and the HighCar brand was considered to stand for advanced technology, progressive design and sustainability. The interior department was mature, but had only recently started to pay more attention to digital user interfaces (primarily of the dashboard).

Home@Work

Part of a large, well-established and highly organized multinational that competes successfully worldwide. The study took place at a medium-sized, local division that developed coffee concepts for the out-of-home market (mostly offices). Next to coffee and tea, the division aspired to deliver the best coffee equipment and technical services. It developed products and service for the local market and was one of the primary local competitors. Though its end users were the people who drink their beverages, such as office workers, Home@Work's coffee machines were purchased by office managers, and thus Home@Work operated in a business-to-business market.

PrintPros

Medium-sized developer of printing equipment and digital document solutions for professionals. Its goal was to assist office workers and printing professionals in producing, distributing, presenting and archiving documents by offering a combination of ICT applications and productive and usable equipment. PrintPros operated in a business-to-business market, serving mainly offices and professional printing studios. It developed its products in one central location, operated worldwide and competed successfully in specialized markets.

4.3. Interview setup

The interviews were conducted by academic researchers that were not involved in product development or employed by the companies involved, took place in a private setting, and were recorded using digital audio recording equipment. Each interview took between one and one-and-a-half hours. Nineteen interviewees were selected based on two criteria: the interviewee 1) was closely involved in product development; and 2) fulfilled a role that allowed him/her to provide a perspective on the practice of product development and usability.

Interviewees

Based on a literature review and exploratory interviews Van Kuijk (2006) identified the following product development roles as relevant for studying usability in product development practice:

- Product/project manager: coordinates product development, determines priorities;
- Marketing manager: collects market information, defines marketing strategies;
- Designer: transforms product requirements into specifications;
- Usability specialist: evaluates and improves the usability of products;
- Development engineer: responsible for technological and production aspects.

An itemized description of the informants can be found in appendix I.

Interview procedure

The interviewer was introduced to the interviewees as studying product development in practice. The term usability was not mentioned in order to prevent response bias. The interview was conducted with the use of a general interview guide, which ensures that with all interviewees the same basic lines of inquiry are explored, but within each of the subject areas the researcher "is free to explore, probe and ask questions that will elucidate and illuminate that particular subject" (Patton, 2002: p.343).

The interview topics guide contained the following subjects:

- Personal data and background information;
- Introduction (goal and setup of interview, anonymization, interviewee background);
- Description of product development (process, team) at development group;
- Description of interviewee role in product development;
- Interviewee's description of usability;
- Usability-related activities in product development at company;
- Involvement of interviewee with usability-related activities;
- State of usability at company and possibilities for improvement;
- Interviewee attitude towards usability;
- Success factors for usability.

The complete topics guide, including the interview questions can be found in Appendix II.

4.4. Data analysis

Relevant interview segments were transcribed and the resulting documents were sent to the interviewees for verification. During data analysis, properties, situations or conditions that were obstructing for or contributing to usability were identified, and were labelled as barriers or enablers (Kleinsmann, 2006, p.74). For each company the barriers and enablers were categorized according the three pre-defined subjects: 1) product development process, 2) working in a multidisciplinary team, and 3) attitude towards usability. In addition there was a category for 'remaining issues'; for capturing relevant issues that did not fit the pre-defined categories. The resulting product development group analyses consisted of a context description and overview of barriers and enablers. The context descriptions of the development groups should provide researchers and practitioners with sufficient detail to convey the situations that were investigated (Shenton, 2004) and thus the possibility to assess the transferability of the findings (Malterud, 2001). The analysis of each product development group (context description + barriers and enablers) were verified by the respective company representatives. Finally, a cross-case analysis was conducted to identify similarities and differences between the product development groups (Yin, 2009, p.156).

4.5. Feedback workshop

A workshop was organized to share the cross-case analysis with the participating companies and to have the findings verified by the participants (Shenton, 2004; Yin, 2009, p.182), as well as to explore a number of topics that had emerged during analysis. From company that participated in the study there was a representative in during the workshop (see Table 1).

Table 1: Overview of the workshop participants per company

Company	Role
<i>CleanSweep</i>	Industrial designer
<i>HighCar</i>	Interior designer
<i>Home@Work</i>	Manager technical development
	Human-centred design consultant
<i>PrintPros</i>	Usability specialist

5. Results per case

The results of each case study consist of 1) a description of the product development process of each company through a textual description and a supporting visual, and 2) an overview of the barriers and enablers for each of the cases.

To enable a comparison of the development processes of the different development groups we mapped development activities and user involvement on a standardized representation of the product innovation process. For this we selected the Delft Innovation Model (Buijs, 2003), because it 1) stresses the generation-wise (circular) approach to product development that was common in the cases we investigated, 2) explicitly includes the 'product in use' phase, and 3) explicitly includes evaluations and iterations, which are important principles of usability engineering and user-centred design (Nielsen, 1992; ISO, 1999; Vredenburg *et al.*, 2002a).

The working definitions that we used for categorizing techniques for data collection and methods for user-centred design that were mentioned by interviewees can be found in Appendix III.

5.1. CleanSweep | Household care products

Development process description

Within CleanSweep there were two types of product development processes (Figure 2): one focused on improving existing products, while the second, innovation projects, encompassed the development of new products. A project could take one to three years, depending on the type of project. In innovation projects, in-depth interviews with consumers were organized to identify opportunities. Once such an idea had been formulated, brainstorm sessions were organized leading to a so-called idea board: a sketch of the idea complemented by a few sentences to explain the concept. Idea boards were subsequently evaluated with consumers in order to narrow down the amount of ideas.

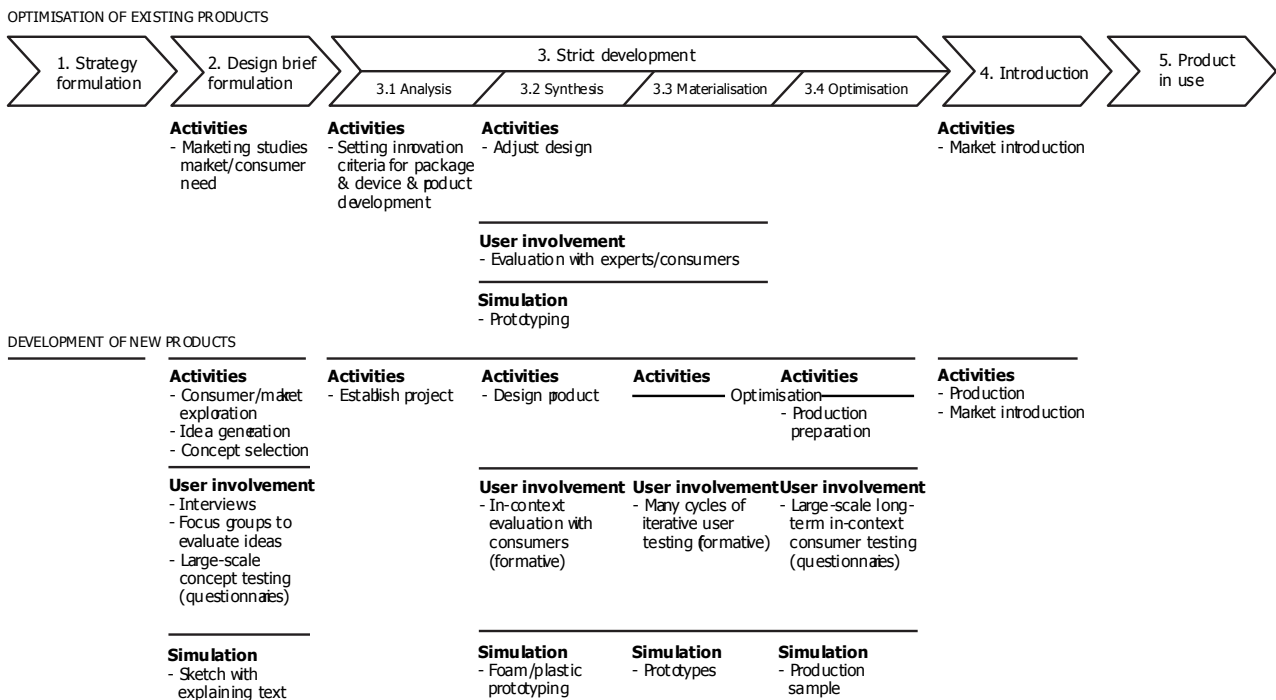


Figure 2: A simplified representation of the development process of CleanSweep for 1) optimising existing products and 2) innovating products, outlining development activities, methods for user involvement, and simulations of designs per phase, mapped on a linear representation of the Delft Innovation Model (Buijs, 2003).

The most promising idea was then described in a concept board, consisting of three parts: (1) the insight on which the concept is initially based, (2) the benefits of the concept to the consumer, (3) the reason for the consumer to believe that the concept would answer to the promises it makes. The concept was then brought into a quantitative consumer evaluation involving about 250 consumers per country, to assess whether the product would be a success or not; whether there is a need for the product. If this was assessed to be the case, the next stage was to establish a project. Subsequently the products were prototyped in foam or plastic and evaluated with consumers in appropriate contexts, which was usually in the homes of consumers.

With all qualitative feedback gathered, optimization was started: many cycles of improving and evaluating with consumers. After that the project team started developing the necessities for the production line. A first sample of the product was used to conduct a second in-home user test: the product was sent to consumers to be used at home for a couple of weeks. If the results were good, the concept was presented to upper management in order to receive project commitment so that the required investments could be made and production could be initiated.

Barriers and enablers

Table 2: Barriers and enablers at CleanSweep

	(-) Barriers	(+) Enablers
<i>Product development process</i>	<ul style="list-style-type: none"> - Evaluating a product's usability was done in a rather late stage at which point there is minimal opportunity to change a design. - In case no user problems emerged during a concept & use test (which was mainly about testing perceived usability and attractiveness on the shelf), no further examination was conducted into any other usage-related aspects, of for example the packaging, because further user testing was not a standardized activity in the development process. As a consequence it was hardly ever revealed why a consumer might like (or dislike) a bottle or a box. - Even if consumer evaluations pointed out that a particular concept really appeals to consumers in multiple ways, there might be limited possibilities to actually make the necessary changes to production lines required to produce the product. 	<ul style="list-style-type: none"> + During product development, CleanSweep tried to select the appropriate method to reach the goals that were set, rather than sticking to prescribed methods. + Interviews were often performed in the homes of consumers, which was considered to lead to a higher 'reliability' of information. + In case a project team had created a concept but a prototype was not yet available, concept boards were found to be a practical substitute to use as stimulus during evaluation with consumers. + Context and concept boards were found to help to obtain rich information from consumers, which in turn facilitates the creation of a good product proposition. + Competitor products were used as a benchmark to assess whether a product was an improvement even though it was completely new to CleanSweep's portfolio. + There was a desire to take usability into account already during design phases, as there is more opportunity to change the design in this stage.
<i>Multidisciplinary teamwork</i>	<ul style="list-style-type: none"> - There was a tendency to perceive quantitative results as a better starting point for creating new concepts and to dismiss qualitative studies/evaluations as being unreliable. 	<ul style="list-style-type: none"> + Having talented drawers and prototype builders on the project team was considered beneficial as, for instance, a designer with good drawing skills can be helpful during consumer sessions with idea boards: in case a consumer gives an inspiring comment, the designer can react to that by instantly adapting an idea board and verify the new visualization with the consumer. + To translate consumer feedback

	(-) Barriers	(+) Enablers
		successfully into product features, product researchers organized and ranked information: this helped the designers to interpret the feedback and creating suitable concepts.
<i>Attitude towards usability</i>	– To receive project commitment (investment of capital) from upper management, the team was obliged to have collected consumer feedback concerning the concept at least once.	+ To receive project commitment (investment of capital) from upper management, the team was obliged to have collected consumer feedback concerning the concept at least once.
<i>Remaining issues</i>	– Because the concept & use tests were quantitative in nature, they usually involved a large amount of data. As a consequence, product researchers often found it quite complex to understand all the data, and to detect patterns, which made concept & use tests very time-consuming.	+ A desire was expressed for increasing knowledge about user-related aspects by building, maintaining and using a knowledge database. This was considered a systematic and 'scientific' way to integrate usability in the design process. Being able to review previous user tests would make it possible to make an assessment of an idea in the early stages of a project.

5.2. HighCar | high-end automotive

Development process

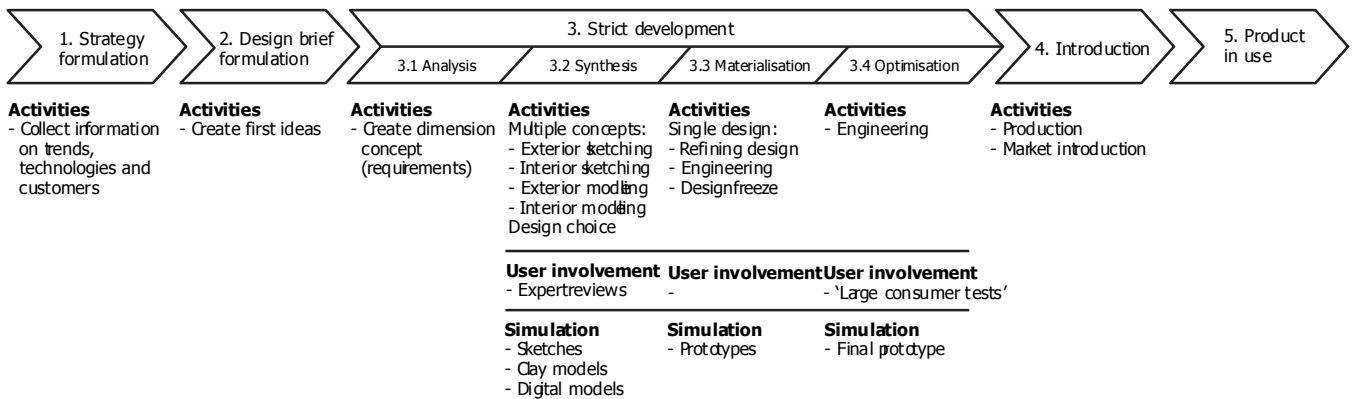
The product development process (Figure 3) of a new car took HighCar about five years. At the start information was gathered on trends, ideas, customers, new technologies, etc. Then a product planning team was compiled, which started to create the overall concept for the new car. Based on the first ideas and information a 'dimension concept' was created, which, in combination with interior components and the engine/wheel/axis base, was conceptualized into a 'package model' and a dimension plan (list of requirements). Based on the requirements the design department first defined the outward appearance of the car, after which work would start on the interior design. Interviewees stressed that at HighCar the exterior design had priority over the interior design. After the sketching-phase, models were made, in the computer as well as in clay.

Out of multiple competing exterior and interior models, one exterior model and subsequently the most suitable interior model were chosen. At this point the development departments started implementing the design. About two years later the product development project was finished and production could start.

The development of a new user interface, which can be applied across models, was considered a separate product development project.

In the early stages of the development of a new UI, usage of existing machines or products of any kind was analysed, in order to translate existing solutions to user issues in a car, and expert reviews were conducted. During the development process prototypes and simulations of the car concept were built and usability tests were conducted, using techniques such as observational research, interviews and checklists. In the final stages of development usability was once more evaluated, through a final usability test. In some cases a car equipped with a logging system could be used for collecting data about all user interaction.

DEVELOPMENT OF A NEW CAR



DEVELOPMENT OF A NEW UI CONCEPT

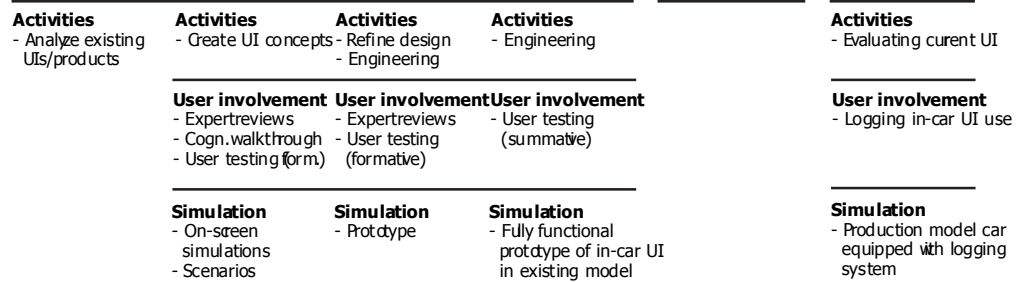


Figure 3: A simplified representation of the product development process of new cars (upper part) and new UI concepts (lower part) at HighCar, outlining development activities, methods for user involvement, and simulations of designs per phase, mapped on a linear representation of the Delft Innovation Model (Buijs, 2003).

Barriers and enablers

Table 3: Barriers and enablers for usability at HighCar

	(-) Barriers	(+) Enablers
<i>Product development process</i>	<ul style="list-style-type: none"> - Modelling digitally might be helpful in early development stages; however, it does not provide the sensation of a real model, which was considered essential for an evaluation of the car concept (both exterior and interior). - It was difficult to evaluate cognitive ergonomic aspects in the early phases of UI development, as in this phase no functional prototype was available yet, which is a prerequisite for a user test. - HighCar did not apply a standard user test format, but customized the setup of the evaluation depending on the question at hand. However, it was considered not efficient and rather discouraging to completely set up a usability evaluation test time and time again. 	<ul style="list-style-type: none"> + At the start of a project, in order to derive learnings that could be applied to the design of a car, the team studied the usage of a wide variety of products, from other types of vehicles to computer games. + User tests of user interfaces were preferably conducted with more than one concept, which allows for the comparison, and thus for a more grounded choice.

	(-) Barriers	(+) Enablers
<i>Multidisciplinary teamwork</i>	<ul style="list-style-type: none"> - A user interface in a car is intertwined with the overall interior of a car and does not have its own inherent shape or design. For successful communication to other team members or decision makers, an operating concepts developer was dependent on the availability and visualization skills of a designer that would visualize the concept. - It was indicated that HighCar would do better in terms of usability if there would be a larger group of people working solely on the topic of usability testing, and when if there would be a usability lab. 	<ul style="list-style-type: none"> + When developing interfaces three departments were continuously collaborating: (interior) design, ergonomics and electronics. Especially a good cooperation between ergonomics and design was seen as a contributor to making usable user interface designs. + A good network between departments was considered essential for sharing information and changing a design to improve usability, as the latter requires multiple disciplines to work together. + With regard to convincing decision makers, showing alternative concepts, e.g. of an interface, contributed to understanding and therefore persuasion. Being able to provide precise information about a concept's advantages and disadvantages, preferably in the form of models or mock-ups, was considered a powerful communication tool between developers and the board.
<i>Attitude towards usability</i>	<ul style="list-style-type: none"> - Design was perceived as a very important role in product development. Yet, their main responsibility was styling and the designers were not encouraged to take usability into account. - The opinion of upper management about an idea or concept had a very high impact. The highest manager considered himself to be one of the most ideal test persons concerning any aspect of HighCar-cars, which might not actually have been the case. - The automotive sector was described as a conservative industry, somewhat reluctant to innovate, also on the level of human-product interaction. - Automotive design was described as focused mostly on the exterior aspects of the car, such as performance and styling. Subsequently, user interfaces and usability issues were considered to never be a designer's most important considerations. 	<ul style="list-style-type: none"> + HighCar staff had the attitude that a product is never finished: there is always room for improvement. + At the time human-machine interaction was a relatively unexplored area in the automotive industry. This provided the company with the opportunity to pioneer the field, which increased motivation to pay attention to interaction aspects.

5.3. Home@Work | office coffee machines

Development process

Home@Work developed products according to its own standardized New Product Development (NPD) process (Figure 4). After an opportunity or a problem in the market had been identified, idea generation and concept definition took place. This was followed by a feasibility and specification phase, and in turn by development, which consisted of three sub-phases: basic design (which also might be done during feasibility), detail design/engineering, and prototyping. In the subsequent market test stage about forty coffee machines would be distributed among clients for a test period of roughly four months. In crucial projects a smaller, internal 'market-test' was conducted before the actual market test. When the product passed the market test, market introduction was prepared.

Additionally, preceding this NPD process there was an innovation process during which idea generation was supported by insights gained through sessions with clients and consumers.

Previously, involving end-users had been done on a rather ad hoc basis, but at the time of research the company was heading towards more user involvement. Usability tests, with external test users, were conducted once there was a prototype of the machine, which was halfway the development phase. Occasionally usability was tested in an earlier stage, using so-called low-fidelity prototypes (e.g. drawings) to represent the different states of a display. Home@Work's own operators and service engineers usually evaluated a first production sample on operator friendliness. Incidentally, information about usage of a machine was gathered by video recording user interactions with a former version of a coffee machine.

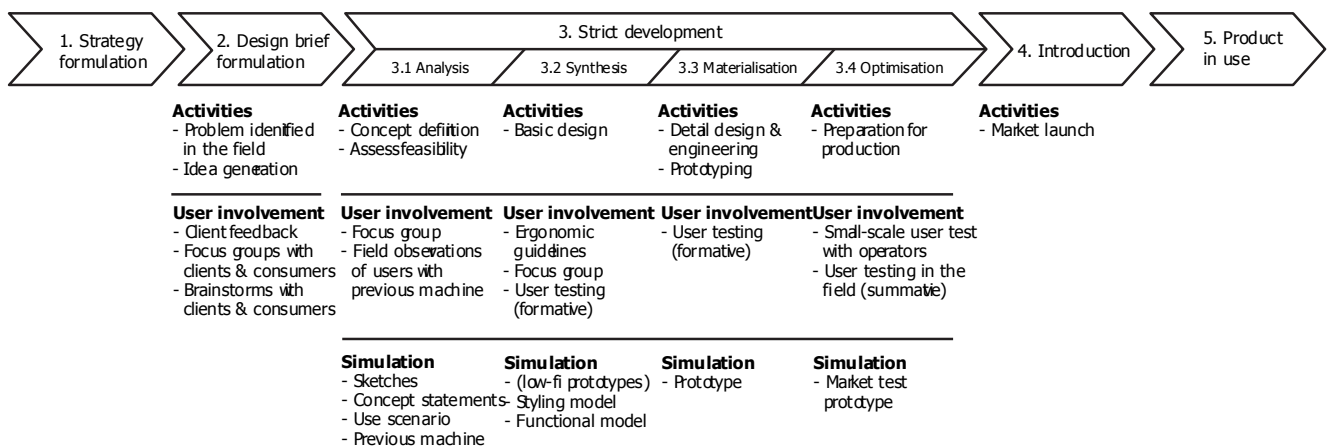


Figure 4: A simplified representation of the product development for office coffee machines at Home@Work, outlining development activities, methods for user involvement and simulations of designs per phase, mapped on a linear representation of the Delft Innovation Model (Buijs, 2003).

Barriers and enablers

Table 4: Barriers and enablers for usability at Home@Work office coffee machines

	(-) Barriers	(+) Enablers
<i>Product development process</i>	<ul style="list-style-type: none"> - Within Home@Work the results of formative user tests were not considered very convincing, due to their qualitative character and small number of participants. - It was not unusual that, during (late-stage) market test a lot of usability problems were revealed, even though the machine was evaluated on usability at an earlier stage in the project. This was attributed to the fact that in the market test users had to operate the machine on their own, whereas in the earlier usability test, the user was continuously accompanied by a test leader. - It was found difficult to uncover which functions (especially of high-end machines) were actually being used. - As Home@Work's products were used in a wide variety of usage contexts it was difficult to define the context of usage for a product (i.e. a coffee machine). 	<ul style="list-style-type: none"> + To optimize the execution of user evaluations in the concept phase, during evaluations it was monitored whether the presentation (concept statement, visualization and/or use scenario) was understandable to a client or consumer. If not, the presentation was changed. + There was a belief that the quality of a product is related to the number of tests to which it is subjected, which includes usability tests. This stimulated the execution of usability tests. + Design guidelines seen as a contributor to creating a more usable design. + Development of the UI was at times a separate process from that of the coffee machine itself. In a user test of the interface it was considered important that the simulation provided a similar experience as a real machine, which was done by fitting an existing product with redesigned components. + It was considered crucial to identify,

	(-) Barriers	(+) Enablers
		before conducting usability-related activities, exactly what information the development team needed, and for what purpose.
<i>Multidisciplinary teamwork</i>	<ul style="list-style-type: none"> - The coffee machines that Home@Work developed had very dissimilar designs. It was argued that there was a need for an overall design manager to ensure that the concept of a new coffee machine aligned with existing product concepts, especially with regard to the user interfaces. - The involvement of usability or interaction specialists in product development was prompted by a team identifying a human-product interaction issue. Usability and interaction specialists were not pro-actively involved in product development. 	<ul style="list-style-type: none"> + To convince management of a selected concept, it was considered helpful to show videos of concept evaluations with clients/consumers, in order to reinforce the selection considerations with the more 'emotional' impact of the videos. + When evaluating a product's usability, it was considered important that the team attended one of the tests, which makes it easier for the team to interpret - and subsequently implement - test results. + For a usability problem to be dealt with, it needs to be understood and acknowledged by all team members involved in the product development process. + The external human-centred design consultancy considered not being involved in design activities a benefit, because otherwise they would not have been able to provide an objective evaluation of the design.
<i>Attitude towards usability</i>	<ul style="list-style-type: none"> - The notion existed that the (end-)user interface of a coffee machine is not at all complicated, so the chances that something goes wrong during usage are minimal. This reduced the priority of usability. - User testing was not considered very 'exciting' by some product development team members and thus not worth spending a lot of resources on. - Within Home@Work there was a tendency to think that there was sufficient know-how on how to design usable products inside the company and that thus user testing was not (always) necessary. - Upper management was mostly focused on selling coffee and did not have a very thorough understanding of how to conduct product development. As a consequence development time was limited, and, with that, the available time for evaluating concepts on, for example, usability. 	<ul style="list-style-type: none"> + Home@Work had the ambition of conducting more user involvement; to evaluate early product <i>ideas</i> with clients/consumers in a structural way, instead of ad hoc. + There was a belief that even though making a product usable may not increase profits right away, it will result in more loyal customers, which in turn contributes to the success of the company.

5.4. PrintShop | professional printers and copiers

Development process

At PrintShop each development project (Figure 5) started with a project definition, based on an exploration of markets and technologies. After the approval of the project definition the actual development process started. The process consisted of several phases, and overall could be divided into two distinct parts: (1) translating the project definition into requirements and next into a technically feasible product concept, and (2) refining the concept further into an actual product. After market

introduction the product was monitored to learn about 'child diseases' and acquire buyer/customer feedback.

At the start of a project usability engineers would conduct user research and communicate this information to the team, for example, through personas. A usability test was usually set up in such a way that people of the project team could attend the test so they could see users interacting with the product. Or afterwards they could watch a video compilation. Analysing user test results, as well as recommending design changes, was usually done by a usability engineer in cooperation with an interaction designer. The team believed that every usability-related research question demands a specific approach and thus methods.

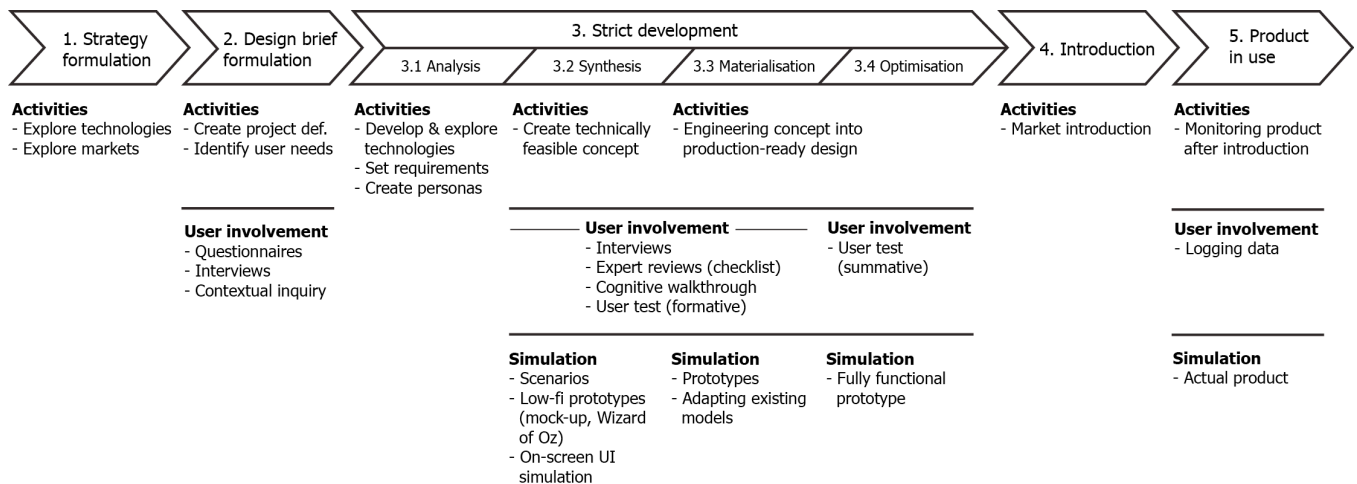


Figure 5: A simplified representation of the product development processes of professional printing products at PrintPros, outlining development activities, methods for user involvement, and simulations of designs per phase, mapped on a linear representation of the Delft Innovation Model (Buijs, 2003).

Barriers and enablers

Table 5: Barriers and enablers for usability at PrintPros professional printers and copiers

	(-) Barriers	(+) Enablers
<i>Product development process</i>	<ul style="list-style-type: none"> - As users find it hard to formulate what they need or would like in a product, it is hard to identify a product's appropriate functionality (even for products that have been on the market for a while). - Test results can vary considerably, depending on whether they are conducted with internal or external participants. - Stimulus material influences outcomes: user testing with only a user interface was believed to cause a different user experience than testing with a complete product. - Early testing usually involved immature stimulus material and was conducted with internal participants. Both aspects were considered to possibly influence the 'external validity' of the test results, and thus the appropriateness of resulting design decisions. - The transfer of information from user tests from one project to the next is 	<ul style="list-style-type: none"> + When developing a completely new product, usability issues were considered from the start. + Usability-related findings from previous projects were consulted. + Even after product launch user feedback sessions were organized to acquire information about usability issues in the final product. + Many iterations of smaller-scale tests and redesigns were preferred over a single, but extensive design-test cycle. Many iterations were believed to lead to a higher number of identified and fixed usability issues. + During user tests the tasks the participants had to perform were formulated as a desired outcome (goal), which should prevent participants being (mis)guided by the instructions. + PrintPros made use of personas to put the user front and centre already at the

	(-) Barriers	(+) Enablers
	<p>complicated by the fact that it may not be clear what information is needed in the new project.</p> <ul style="list-style-type: none"> - The lack of a knowledge database made the retrieval of past user test results dependent on recollection by and communication between team members. - Users did not have a channel to share their thoughts, complaints and questions with the R&D department. 	<p>start of a project, which results in more consistent early design decisions.</p>
<i>Multidisciplinary teamwork</i>	<ul style="list-style-type: none"> - There was a concern that when a usability specialist would not only evaluate a product, but also contribute to its development, his or her objectivity and critical view might be lost. 	<ul style="list-style-type: none"> + The design department was involved from the start of a project, which reduced the focus on purely technical aspects and made the project more user-focused from the beginning. + When sharing user test results with the development team, the presence of usability engineers and interaction designers was considered to improve the translation of results into design specifications.
<i>Attitude towards usability</i>	<ul style="list-style-type: none"> - User tests were conducted rather ad hoc, and were not a formal part of the development process. - Among upper management, usability was at times perceived as not exciting enough to give attention to it. This influenced priorities that were set in projects. 	<ul style="list-style-type: none"> + Usability was perceived as an opportunity to differentiate products. + PrintPros aimed at installing a product at its clients with default settings that were adapted to the needs of the user within that particular context.

6. Cross-case comparison

In this section the result of the case study are presented, encompassing three main subjects: 1) an itemized overview of the product development context at each of the development groups, 2) a cross-case comparison of barriers and enablers, and 3) a discussion of relations that we identified between variables in the cases.

6.1. Case study context summary

The main properties of the four development groups are summarized in Table 6.

Table 6: summary of the context properties of the four cases included in the study

Case properties	CleanSweep	HighCar	Home@Work	PrintPros
Company				
<i>Core product</i>	Household care	High-end cars	Coffee	Professional printers and copiers
<i>Market</i>	Consumer	Consumer	Business	Business
<i>Usability department</i>	Product research department (user and consumer research)	External institutes and - recently established - usability department	Marketing department and external human-centred design consultancy	Well-established. Two usability engineers in industrial design department
Product				
<i>Product complexity</i>	Limited	High	Considerable	High
<i>Target group diversity</i>	Large	Limited	Considerable	Considerable

Case properties	CleanSweep	HighCar	Home@Work	PrintPros
<i>User groups</i>	End users	End users	End users, service and maintenance staff	End users, service and maintenance staff
<i>Purchase frequency</i>	High	Low	Low	Low
Product development process				
<i>Development time</i>	1 - 3 years	±5 years	1-3 years	5 – 10 years
<i>Formalization (standardized, prescribed)</i>	High	High	High	Low
<i>Unique characteristics</i>	Distinction between follow-up and radical new products	Separate processes: interior vs. exterior design, car vs. UI	Separation between concept and product development	Separation between concept and product development
User involvement				
<i>User research</i>	Considerable	Limited	Limited	Considerable
<i>User testing</i>	Extensive	Considerable	Considerable	Extensive
<i>Formalization</i>	High	Low	Low	Low
<i>Formative / summative</i>	Formative & summative	Mostly formative	Mostly formative	Formative & summative
Product development team				
<i>Team composition</i>	Core team, extended team varies per phase.	Coordinated by core team, representatives from all departments.	Core team with representatives from various disciplines.	Large multidisciplinary teams, divided into sub-teams.
<i>Team collaboration</i>	Meetings	Meetings	Meetings, brainstorm sessions, issue tracking system	Brainstorms, meetings, and informally in project room
<i>Team member location</i>	Per department	Per department	Per department	Both in project rooms and per department
<i>Explicit definition of usability</i>	No	No	No	No
Attitude towards usability				
<i>Priority of usability</i>	Medium	Low	Low	High
<i>Attitude towards usability</i>	Gaining interest in usability (as trigger for repurchase). Primary focus on consumer appeal of concept.	Hard to measure, and contribution to company success not clear.	Own products considered simple: usability not very important. Potential product differentiator, not exciting.	Strategic product differentiator. Long-term benefit, improving customer loyalty.
<i>Primary product priorities</i>	Performance (of powder, liquid, etc.)	Styling and performance	Coffee quality, brand identity.	Productivity, reliability, quality, costs.

6.2. Barriers and enablers across cases

The following section offers a cross-case comparison of how the four product development groups dealt with usability for each of the three main research topics, namely the 1) the product development process (including user involvement), 2) multidisciplinary teamwork, and 3) teams' and organizations' attitude towards usability.

Development process and user involvement

All companies reported to explore consumer/user needs, desires and wishes prior to starting actual product development. PrintPros had the unique strategy of monitoring predecessor products for usability issues. At CleanSweep already during the concept phase concepts and ideas were thoroughly evaluated with consumers through both summative and formative evaluations. PrintPros, HighCar and Home@Work reported that whether user evaluations could be conducted usually depended on the availability of a prototype. Usability seemed to be mostly in focus in user evaluations with high-fidelity prototypes. PrintPros indicated that they preferred to conduct tests with external test participants, whereas Home@Work and HighCar mainly tested with internal test participants (i.e., colleagues), the latter mainly for reasons of confidentiality. The methods for user involvement that were used across the companies are summarized in Table 7.

Table 7: Methods and techniques for user-centred design per product development group, organized by moment of application during the product development process (top = more likely to occur early in the development process, bottom = more likely to occur in the later stages of product development). A working definition of each of the methods for user involvement can be found in Appendix III.

Timing	Method	CleanSweep	HighCar	Home@Work	PrintPros
Later stages ← → Early stages	Interviews	•		•	•
	Focus group	•		•	
	Market (client) feedback			•	
	Contextual inquiry				•
	Analysing existing products		•		
	Creative session with clients/users			•	
	Concept testing	•			
	Personas			•	•
	Cognitive walkthrough		•		•
	Expert review	•	•	•	•
	Questionnaire	•		•	•
	Formative user testing	•	•	•	•
	Summative user testing	•	•	•	•
	Eye-tracking	•			
Logging usage data		•		•	

A final important aspect of user involvement was how ideas, concepts and products were represented (see Table 8). A story or description is a representation through a few lines of text; a scenario extends this with information on user-product interaction over time; visualizations may guide a concept or story but may also merely emphasize the aesthetic qualities of a concept; mock-ups or lo-fi prototypes make a concept three-dimensional; UI simulations present mostly the interaction concept of a product, and high-fidelity prototyping refers to providing users with an initial working model of the product.

Table 8: Forms of representation of product ideas or concepts when evaluating with consumers, arranged according to presentation mode maturity, from 'low-fidelity' to 'high-fidelity'.

'Fidelity'	Representation	CleanSweep	HighCar	Home@Work	PrintPros
Low ← → High	Story/description	•		•	
	Scenario	•		•	
	Visualization	•	•	•	
	Mock-up/lo-fi prototype	•		•	•
	UI simulation		•		
	Hi-fi prototype	•	•	•	•
	Adapt existing product		•	•	•

Usability in multi-disciplinary teams

PrintPros had its own usability engineers who worked out of the industrial design department, but on a day-to-day basis were present in product development projects. Each of the projects had a sub-team completely devoted to developing human-product interaction concepts. HighCar had a team for human-product interaction concepts, but this operated rather independent from the product development projects. Both CleanSweep and Home@Work did not have dedicated in-house departments for usability. Home@Work employed a human-centred design consultancy for conducting usability evaluations when considered necessary, whereas CleanSweep, mainly relied on the expertise of their product researchers for studying usability-related aspects, as well as on the interest taken in usability issues by other roles involved, e.g., packaging developers.

At PrintPros a strong cooperation was reported between usability engineers and interaction designers, which was experienced as beneficial for the translation of user test results into design specifications. This also was the case at HighCar, where design, ergonomics and electronics collaboratively generated and evaluated designs. Contrary to this, at Home@Work the consultancy responsible for usability tests intentionally did not get involved in design activities such as translating the test results into a design, in order to remain unbiased towards the design.

Another important issue was the communication of the results of usability evaluations. Whether this was a critical issue or not seemed to depend, among others, on the degree of cooperation between the team members: if teams cooperated closely, as for example at PrintPros, less attention seemed to be given (and required) to actively convey the results of usability evaluations. Table 9 shows various media used to communicate the results of evaluations. At HighCar mock-ups and prototypes were used to present the outcomes of user tests, which had already been translated into solutions. Finally, even though from both literature and from the interviews it became clear that product developers often consider usability a fuzzy, ungraspable concept, in none of the participating companies an attempt had been made at establishing an explicit, shared definition of usability.

Table 9: Media for communication usability-related test results to team members/management

Media for user test communication	CleanSweep	HighCar	Home@Work (+ HCD consultant)	PrintPros
Visualizations		•		
Mock-ups/prototypes		•		
Video compilations	•		•	•
Written report	•		•	•
Discussion	•	•	•	•
Workshop			•	

Attitude towards usability

All product development groups reported that usability was in the project aims, though there were differences regarding its priority. At PrintPros usability was a relatively high priority, at Home@Work usability was referred to as 'ergonomics' and considered a part of the brand values, and HighCar mainly prioritized aesthetics and performance. At CleanSweep the importance of usability depended on the type of packaging: whether it was a usage device (e.g., a brush) or a container (e.g., a bottle). At CleanSweep, usability was reportedly becoming more important, because of the success of previous usability efforts and the awareness of the growing importance of usability due to an aging population.

PrintPros, Home@Work and CleanSweep – in varying degrees – considered usability a product quality that contributes to market success, and perceived usability as a way to differentiate their products in the marketplace. Additionally, PrintPros and CleanSweep believed usability would become even more crucial for product success in the future, because of respectively an expanding area in which it is relevant (social contexts, workflow) and the aging population. Home@Work considered their products 'inherently easy to use' and the usability of its machines superior to that of competitors. Usability evaluation was not a very big priority and the company did not expect to increase this in the future. At PrintPros, Home@Work, and CleanSweep, it was indicated by subsequently two project managers and a design manager that usability was perceived as not delivering radical product improvements, and therefore not worth the effort of investing development time and resources. HighCar did not see usability as a quality that contributed to product success. Aspects as styling and power were considered more important. However, the accomplishments of the successful new user interface system had given usability an improved status.

6.3. Relations between variables in the investigated cases

Product/market combination influences attitude towards usability and choice of methods

The definition of usability as formulated by the ISO organisation is sufficiently generic to be applied across product categories and markets. Though the operationalization may differ, manifestations of the dimensions of usability, namely effectiveness, efficiency and satisfaction about use, can be found in interactions across a wide range of products. However, though the concept of usability may be applicable to a great diversity of products, in this study we found that the prioritization of usability within a company may differ greatly, which seems to have a large impact on a company's proficiency to execute user-centred design. The prioritization of usability within a company seems to depend on the complexity of the products that are developed, and on whether the company perceives usability as an important purchase consideration among buyers.

The product-market combination a company targets seems to influence the urgency to deal with usability. For example, professional printing products (PrintPros) are so complex that if no attention would be paid to their human-product interaction, the products would become utterly inoperable. On the other hand, fast-moving consumer goods (CleanSweep) are much less complex, and were considered less likely to become hard to use.

In three out of four cases interviewees pointed out that a distinction should be made between who buys and who uses the product. The two business-to-business companies explicitly distinguished (corporate) purchasers and end-users. In the two business-to-consumer companies the people that purchased the product would usually be the user as well, though the fast moving consumer goods company also took into account the demands of the retailers. Though selling to different stakeholders than to the actual end-users, the manufacturer of professional printing equipment did give a high priority to usability, because it considered usability something that in the long run would improve customer loyalty. On the other hand, the developer of high-end cars, for whom the buyer was the end-user, did not give quite such a high priority to usability. The companies making high-end cars and office coffee machines indicated that for their target group usability was not an important purchase consideration, and therefore it was not as high on their list of priorities.

The type of product that a company developed also seemed to influence the type of methods for user-centred design that were used. These products evoked the need for a particular type of information, or the type of product allowed, or did not allow, for a certain type of simulation or evaluation.

Prioritization of usability trigger for user involvement and team composition

A high prioritization of usability seemed to trigger a company to start looking for possible ways to deal with usability in its product development, both in terms of user involvement methods as well as team composition. PrintPros, where usability was a very important product quality, featured an in-house usability group, usability engineers were an integral part of the product development teams, and user involvement occurred throughout the product development process. CleanSweep had been increasing the amount of attention given to usability and indicated that they were now looking for suitable usability-related methods. At HighCar the development of an in-car user interface had been a success, and, reportedly as a consequence, usability got more attention during product development and the user-interface group started expanding.

Multidisciplinary makes communication of user involvement critical

Creating and implementing a design is a highly multidisciplinary activity, involving a variety of disciplines, such as designers, engineers, and project managers. However, *evaluating* that design is much less multidisciplinary; a usability evaluation is usually carried out by one single role: the usability specialist. But to follow-up on any of the issues that were identified in the usability evaluation, once

again the involvement of all or many disciplines is required. Because most team members are not involved in usability evaluations and because they are not experts in this field, the communication of usability evaluations is a critical issue.

7. Conclusion

The case study seems to indicate relations between a company's product/market combination, attitude towards usability and methods for user-centred design (see Figure 6). The product-market combination that a company targets seems to influence 1) the attitude of a company towards usability, and 2) the methods for user centred-design that are applied.

The degree of product complexity (complex products are more prone to suffer from usability issues) and whether developers think that usability is a purchase consideration for their clients seem to influence the prioritization of usability.

The product-market combination a company is active in also seems to affect the methods for user involvement design that a company is able to apply and that are relevant. What methods for user-centred design are used also seems to be influenced by the attitude towards usability: if usability is considered more important, methods that require more resources can be applied. In addition the phase of the product development process seems to influence the choice of methods, as this translates into demands on the methods used because of the 1) knowledge need that the development team has in that phase (research question), 2) 'maturity' of the design (e.g. idea, concept, design), and 3) type of simulation that can be used in a user test (e.g. sketch, on-screen simulation, interactive 3D-prototype). This implies that the chance that (new) ergonomic methods will actually be applied in practice increases if these methods are designed so that they can be adjusted to the development context at hand.

Prioritization of usability also seems to influence the presence and integration of user-centred design specialists (usability specialist, interaction designers) in the product development team.

Finally, methods for user centred-design as well as team composition iteratively affect the usability of the product.

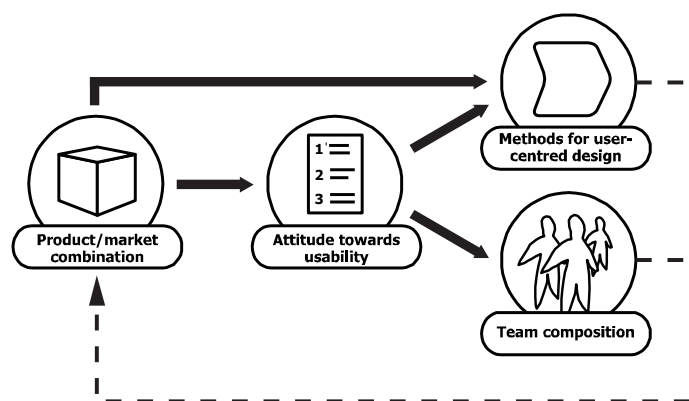


Figure 6: Visualization of the proposed relations between the product, attitude towards usability, user-centred design methods and team composition.

8. Limitations

8.1. Interviews as primary information source

This case study was primarily interview-based. Interviews are an efficient way to build up the number and depth of cases, which enable a researcher to cover more informants and include more cases (Eisenhardt and Graebner, 2007). We were very much interested in the views of product development

practitioners on how to deal with usability in product development. Through their (possibly extensive) experience they may arrive at insights that outsiders, such as researchers, might not arrive at. However, using interviews as the primary source of information also introduces issues as poor recollection, bias, or lip service. Though this study takes advantage of the knowledge and experience of product development professionals and provides an insight into how they view their work, their beliefs and attitudes, it seems wise to complement this type of study with interviews using other data sources, such as direct observation, documents and artefact analysis.

8.2. A product development perspective

In qualitative research reliability is usually expressed in terms of dependability: whether if a work were repeated, in the same context, with the same methods and with the same participants, similar results would be obtained (Shenton, 2004).

An important question is to what extent the results of this research were dependent on who executed it. Did the fact that this case study was executed by researchers with a background in design research influence the results? We believe they did. All researchers involved were (originally) educated as industrial designers. An organizational psychologist or a sociologist would have probably made different observations and interpretations. This does not render the findings useless, but it does mean that when looking at the results, you should keep in the back of the head you are looking through the eyes of a product developer.

8.3. Transferability

Transferability refers to the extent to which the findings can be transferred to other settings or groups (Malterud, 2001); in qualitative research this is used in preference over the term 'external validity' or 'generalizability' (Shenton, 2004). In this study diversity in case selection was one of the goals. But if we look at what the cases have in common, and thus to what type of cases the results of the study are more likely to be transferable to, we can see commonalities. All cases were:

- product development organisations of physical products;
- large organisations thus featuring a division of functions and a certain degree of formalization;
- organizations employing a stage/gate type development process.

9. Recommendations for future research

The interviewees gave remarkably linear descriptions of their product development processes, almost without any parallel activities or iterations. This may have been caused by the fact that they were asked to describe the product development process orally, which offers less of an opportunity for structuring activities in parallel than by, for example, drawing the process.

It became evident that in user-centred design it is important not only to conduct the user involvement activities (e.g., focus groups, home visits, usability tests), but also to communicate the findings from these activities in an effective way. So when studying user involvement in companies, it should not only be studied what methods are applied and how, but also how the results of user involvement are communicated.

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11. References

- Bekker, T. (1995) An analysis of user interface design practice : Towards support for team communication. Industrial Design Engineering. Delft, Delft University of Technology. PhD.
- Bevan, N. (2003) UsabilityNet Methods for User Centred Design. Human-Computer Interaction: Theory and Practice (Part 1), Volume 1 of the Proceedings of HCI International. Heraklion, Crete, Greece, , Lawrence Erlbaum.
- Beyer, H. and K. Holtzblatt (1997) Contextual Design: Defining Customer-Centered Systems: Elsevier.
- Boivie, I., C. Aborg, J. Persson and M. Lofberg (2003) "Why usability gets lost or usability in in-house software development." *Interacting with Computers* 15 4): 623-639.
- Boivie, I., J. Gulliksen and B. Goransson (2006) "The lonesome cowboy: A study of the usability designer role in systems development." *Interacting with Computers* 18 4): 601-634.
- Bont, C. J. P. M. d. and J. P. L. Schoormans (1995) "The effects of product expertise on consumer evaluations of new-product concepts." *Journal of Economic Psychology* 16 4): 599-615.
- Borgholm, T. and K. H. Madsen (1999) "Cooperative usability practices." *Communications of the ACM* 42 5): 91-97.
- Bouwmeester, K. d. and G. Stompff (2006) Bridging the gap between literature and practice: usability testing. IEA2006: 16th World Congress on Ergonomics, Maastricht, The Netherlands.
- Broberg, O. (1997) "Integrating ergonomics into the product development process, ." *International Journal of Industrial Ergonomics* 19, Issue 4 4): 317-327.
- Bruno, V. and M. Dick (2007) Making usability work in industry: an Australian practitioner perspective. Proceedings of the 19th Australasian conference on Computer-Human Interaction: Entertaining User Interfaces. Adelaide, Australia, ACM.
- Bruseberg, A. and D. McDonagh-Philip (2001) "New product development by eliciting user experience and aspirations." *International Journal of Human-Computer Studies* 55 4): 435-452.
- Buijs, J. (2003) "Modelling Product Innovation Processes, from Linear Logic to Circular Chaos." *Creativity and Innovation Management* 12 2): 76.
- Caple, D. C. (2010) "The IEA contribution to the transition of Ergonomics from research to practice." *Applied Ergonomics* 41 6): 731-737.
- Clegg, C., C. Axtell, L. Damodaran, B. Farbey, R. Hull, R. Lloyd-Jones, J. Nicholls, R. Sell and C. Tomlinson (1997) "Information technology: a study of performance and the role of human and organizational factors." *Ergonomics* 40 9): 851 - 871.
- Den Ouden, E., L. Yuan, P. J. M. Sonnemans and A. C. Brombacher (2006) "Quality and Reliability Problems from a Consumer's Perspective: an Increasing Problem Overlooked by Businesses?" *Quality and Reliability Engineering International* 22 7): 821-838.
- Dul, J. and W. P. Neumann (2009) "Ergonomics contributions to company strategies." *Applied Ergonomics* 40 4): 745-752.
- Eisenhardt, K. M. and M. E. Graebner (2007) "Theory building from cases: opportunities and challenges." *Academy of Management Journal* 50 1): 25-32.
- Fulton Suri, J. and M. Marsh (2000) "Scenario building as an ergonomics method in consumer product design." *Applied Ergonomics* 31 2): 151-157.
- Graneheim, U. H. and B. Lundman (2004) "Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness." *Nurse Education Today* 24 2): 105-112.
- Gray, W. D. and M. C. Salzman (1998) "Damaged merchandise? A review of experiments that compare usability evaluation methods." *Human-Computer Interaction* 13 3): 203-261.
- Grudin, J. (1991) "Obstacles to user involvement in software product development, with implications for CSCW." *International Journal of Man-Machine Studies* 34): 435-452.
- Gulliksen, J., I. Boivie and B. Göransson (2006) "Usability professionals--current practices and future development." *Interacting with Computers* 18 4): 568-600.
- Helander, M. G. (1999) "Seven common reasons to not implement ergonomics." *International Journal of Industrial Ergonomics* 25 1): 97-101.
- Hendrick, H. W. (2008) "Applying ergonomics to systems: Some documented "lessons learned"." *Applied Ergonomics* 39 4): 418-426.
- Hertzum, M. (2010) "Images of Usability." *International Journal of Human-Computer Interaction* 26 6): 567-600.
- IEA. (2014). "What is ergonomics?" Retrieved May 18, 2014, 2014, from <http://www.iea.cc/whats/index.html>.

- ISO (1998) ISO 9241-11 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11: Guidance on usability. Geneva, Switzerland, International Organization for Standardization.
- ISO (1999) ISO 13407 - Human-centred design processes for interactive systems. Geneva, Switzerland, International Organization for Standardization.
- ISO (2010) ISO 9241 Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems (formerly known as 13407). Switzerland, ISO.
- Ji, Y. G. and M. H. Yun (2006) "Enhancing the Minority Discipline in the IT Industry: A Survey of Usability and User-Centered Design Practice." *International Journal of Human-Computer Interaction* 20 2): 117 - 134.
- Jokela, T. (2004) "When good things happen to bad products: where are the benefits of usability in the consumer appliance market?" *Interactions* 11 6): 28-35.
- Jokela, T., N. Licari, J. Matero and M. Karukka (2003) The standard of user-centred design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. *Proceedings of the Latin American Conference on Human-Computer Interaction, Rio de Janeiro, Brazil, ACM publishers.*
- Jordan, P. W. (1998) *An Introduction To Usability: Taylor and Francis.*
- Jordan, P. W., B. Thomas and B. A. Weerdmeester (1996) *Usability Evaluation In Industry: Taylor and Francis.*
- Kanis, H. (1998) "Usage centred research for everyday product design." *Applied Ergonomics* 29 1): 75-82.
- Kleinsmann, M. (2006) *Understanding Collaborative Design. Industrial Design Engineering. Delft, Delft University of Technology: 309.*
- Kleinsmann, M. and R. Valkenburg (2008) "Barriers and enablers for creating shared understanding in co-design projects." *Design Studies* 29 4): 369-386.
- Kwahk, J. and S. H. Han (2002) "A methodology for evaluating the usability of audiovisual consumer electronic products." *Applied Ergonomics* 33 5): 419-431.
- Lauesen, S. (1997) *Usability Engineering in Industrial Practice. INTERACT'97, Discovering New worlds of HCI, Sydney, Australia, Chapman & Hall.*
- Lee, D.-S. and Y.-H. Pan (2007) *Lessons from Applying Usability Engineering to Fast-Paced Product Development Organizations, In: Usability and Internationalization. HCI and Culture.: Springer Berlin / Heidelberg: 346-354.*
- Lindholm, C., T. Keinonen and H. Kiljander, Eds. (2003) *Mobile Usability. How Nokia changed the face of the mobile phone: McGraw-Hill.*
- Malterud, K. (2001) "Qualitative research: standards, challenges, and guidelines." *The Lancet* 358 9280): 483-488.
- Martin, B. and B. Hanington (2012) *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions: Rockport Publishers.*
- Miles, M. B. and A. M. Huberman (1994) *Qualitative Data Analysis; An Expanded Sourcebook. Thousand Oaks: Sage Publications.*
- Moenaert, R. K., H. Robben, M. Antioco, V. De Schampheleere and E. Roks (2010) "Strategic Innovation Decisions: What You Foresee Is Not What You Get*." *Journal of Product Innovation Management* 27 6): 840-855.
- Neumann, W. P., M. Ekman and J. r. Winkel (2009) "Integrating ergonomics into production system development - The Volvo Powertrain case." *Applied Ergonomics* 40 3): 527-537.
- Nielsen, J. (1992) "The usability engineering life cycle." *IEEE Computer* 25 3): 12-22.
- Nielsen, J. and R. L. Mack (1994) *Usability inspection methods. New York: Wiley.*
- Norman, D. (1996) *Design as Practiced, In: Bringing Design to Software. T. Winograd (eds.). New York, USA: ACM Press.*
- Patton, M. Q. (2002) *Qualitative Reserch & Evaluation Methods. Thousand Oaks, CA, USA: Sage Publications.*
- Pogue, D. (2006) *Heavily hyped cellphone won't make you a chocoholic. New York Times. New York.*
- Rauch, T. and T. Wilson (1995) "UPA and CHI surveys on usability processes." *SIGCHI Bull.* 27 3): 23-25.
- Redish, J. G., R. G. Bias, R. Bailey, R. Molich, J. Dumas and J. M. Spool (2002) *Usability in practice: formative usability evaluations - evolution and revolution. CHI '02, Minneapolis, Minnesota, USA, ACM publishers.*

- Rieman, J., M. Franzke and D. Redmiles (1995) Usability evaluation with the cognitive walkthrough. Human factors in computing systems Denver, Colorado, United States ACM Press.
- Rogers, Y., H. Sharp and J. Preece (2011) Interaction Design; beyond human-computer interaction. Chichester, United Kingdom: John Wiley & Sons Ltd.
- Rosenbaum, S., J. A. Rohn and J. Humburg (2000) A toolkit for strategic usability: results from workshops, panels, and surveys. SIGCHI conference on Human factors in computing systems, The Hague, The Netherlands, ACM Press.
- Sanders, E. B.-N. and P. J. Stappers (2012) Convivial Toolbox: Generative Research for the Front End of Design: BIS.
- Shackel, B. (1984) The concept of usability, In: Visual Display Terminals. J. Bennet. (eds.). Englewood Cliffs, New Jersey: Prentice-Hall, Inc.: 45-81.
- Shenton, A. K. (2004) "Strategies for ensuring trustworthiness in qualitative research projects." Education for Information 22 (2004): 63-75.
- Stanton, N. and M. Young (1998) "Is utility in the mind of the beholder? A study of ergonomics methods." Applied Ergonomics 29 1): 41-54.
- Steen, M. (2008) The fragility of human-centred design. Industrial Design Engineering. Delft, The Netherlands, TU Delft. PhD.
- Steger, T., B. Sprague and D. Douthit (2007) Big Trouble with No Trouble Found: How Consumer Electronics Firms Confront the High Cost of Customer Returns. Accenture Communications & High tech, Accenture.
- Theberge, N. and W. P. Neumann (2010) "Doing `organizational work': Expanding the conception of professional practice in ergonomics." Applied Ergonomics 42 1): 76-84.
- Väänänen-Vainio-Mattila, K. and S. Ruuska (2000) Designing Mobile Phones and Communicators for Consumer's Needs at Nokia, In: Information Appliances and Beyond: Interaction Design for Consumer Products. E. Bergman (eds.). San Fransisco, USA: Morgan Kaufmann Publishers.
- van Kuijk, J. I., H. C. C. M. Christiaans, H. Kanis and D. J. van Eijk (2006) Usability in the Development of Consumer Electronics: Issues and Actors. IEA 2006, 16th world congress on ergonomics, Maastricht, The Netherlands.
- Venturi, G. and J. Troost (2004) Survey on the UCD integration in the industry Third Nordic conference on Human-computer interaction Tampere, Finland, ACM publishers.
- Vredenburg, K., S. Isensee and C. Righi (2002a) User-Centered Design; An Integrated Approach. New Jersey, USA: Prentice-Hall.
- Vredenburg, K., J.-Y. Mao, P. W. Smith and T. Carey (2002b) A survey of user-centered design practice. SIGCHI 2002 conference on Human factors in computing systems: Changing our world, changing ourselves Minneapolis, Minnesota, USA.
- Wiklund, M. E., Ed. (1994) Usability in Practice; How companies develop user-friendly products. Cambridge: AP Professional.
- Wixon, D. (2003) "Evaluating usability methods - why the current literature fails the practitioner." Interactions July + August 2003): 28 - 34.
- Yin, R. K. (2009) Case study research: design and methods. Thousand Oaks, California, USA: SAGE publications, Inc.

Appendix I: Interviewee descriptions

CleanSweep

Current role	Role description	Product development experience	Other working experience	Educational background	Age
Design manager	Designing products with the standing-out-on-the-shelf effect as a primary objective.	2 years at CleanSweep	Designer of train and aircraft interiors	Mechanical engineering, industrial design	36

Project engineer	Developing packaging concepts	10 years	R&D at packaging manufacturer, engineering at CleanSweep	Aerospace engineering	38
Package & Device developer	Matching a package concept with new technologies and initiatives of marketing.	13 years	Development of home appliances	Mechanical & aerospace engineering	45
Product researcher	Acquiring feedback from consumers and translating consumer input to product features.	13 years	Packaging developer for dish and surface care (at CleanSweep)	Chemical engineering & process technology	35

HighCar

Current role	Role description	Product development experience	Other working experience	Educational background	Age
Designer Interior	Designing multiple aspects of the car's interior	16 years	Industrial designer at a supplier	Industrial design	38
Ergonomics specialist	Belongs to the concept development department (first department with a new idea). Aims at influencing design to have better ergonomic conditions in the car.	14 years	-	Mechanical (car) engineering	36
Developer operating concepts	PhD student, researching how to confront users with different ways of operating in order to statistically compare operating concepts.	1 year	Work process design, ergonomics, psychological research	Mechanical engineering	27
Designer interior (supplier company)	Designing multiple aspects of the car's interior, fascinated by man-machine interaction.	4 years	Display graphics, 3D design	Industrial design	31
Human factors specialist	Concerned with human factors of haptic features as well as interfaces.	20 years	Human-machine interfaces (thermo-controls)	Mechanical engineering	50

Home@Work

Current role	Role description	Product development experience	Other working experience	Educational background	Age
Marketing manager	Monitoring the achievability of product ideas, the feasibility of concepts and products in the market.	3,5 years	Marketing, product management	Economics	31
Project manager	Responsible for financial aspects of products as well as project planning and people.	13 years	Products for people with disabilities, telecommunications (mechanical engineering, team lead)	Industrial design	39
Concept developer	Involved during early phases of a project, concerned with idea generation en concept definition.	20 years	Independent and in-house designer (furniture, consumer appliances), internal consultant/project manager (at Home@Work)	Electrical engineering, industrial design	48

Technical project manager	Responsible for technical aspects (product performance) and the list of product requirements.	7 years	Fresh-brew coffee machines: mechatronics and electronics	Electrical engineering	42
External usability consultant	Evaluates the usability of products and provides recommendations concerning product improvements.	15 years	Ergonomist at physical rehabilitation centre	Medicine	-

PrintPros

Current role	Role description	Product development experience	Other working experience	Educational background	Age
Interaction Designer	Designing interfaces, guarding the overall operating philosophy of the products.	18 years	-	Industrial design	43
Product Designer	Solving design problems of any kind, mainly involved during early stages.	15 years	Designer at design agency, SME	Industrial design	37
Usability Specialist	Acquiring and applying knowledge related to users of the product.	20 years	Language technology	Applied physics	46
Software manager	Managing design, implementation, integration, tests and delivery of product software.	2 years	Software architecture, research	Physics, neurobiophysics	36
Manager operating concepts	Being the interface between R&D and the market; involving sales departments and clients during the requirements process.	25 years	-	Electrical engineering	49

Appendix II: Interview protocol

Interviewee background

- Current role
- Years of experience in product development
- Other working experience
- Educational background
- Age

Opening (max 5 min.)

The interview has an open and exploratory character. My intention is to learn as much about [Company X] as possible, which means that you will preferably doing most of the talking.

The results of this interview will be processed anonymously, your name will not be mentioned anywhere.

We will discuss three themes in the coming 1,5 hours, being 1) the general setup of the product development process, 2) the practice of usability within the product development process and 3) your ideas about usability in the development process and the end-product.

To make it easier on yourself it might be useful to take a specific project in mind/as an example while answering.

The results of this study I would like to use as a source of information when developing a design tool that should contribute to successfully integrating usability in the product development process.

Theme 1: General setup of the product development process (max 20 min.)

- Could you tell me what the product development process looks like?
- Within your role, what are the different stages?
- What is your role in the product development process?
- What goals are set from your role? When is a project finished for you?
- How do you make sure the set goals are achieved?
- Do you work in project teams? How should I imagine a typical design team?
- Which disciplines are involved in the product development process/team?
- How do you experience that those teams function?
- What usually goes very well (enablers) and where do teams get in trouble (barriers)?
- Communication between disciplines?

Theme 2: Practice of usability within the product development process (max 30 min.)

- How would you describe usability in a couple of sentences?
- At which moments in the product development process is attention paid to usability?
- Which usability-related activities are usually carried out?
 - By whom?
- Are there user feedback-moments?
- In which sense/ on which moments do you deal with usability?
- Which usability engineering tools do you apply?
- What do you consider to be a 'user-centred' design process?
- Do you consider the product development process of this company user-centred? Why?

Theme 3: Your ideas about usability in the development process and the end product (max 30 min.)

- How do you experience the attention paid to usability within the product development process?
 - Successful?
 - Sufficient, too much, too little?
 - At the right moments within the development process?
 - Are the right people involved?
- Do you think that usability specialists should always be involved in a development process? Why?
- Do you think that usability / user-centred design is something that contributes to the success of a product?
- Philips now has the slogan 'Sense and Simplicity'. What do you think of this? What do you consider to be the idea behind this campaign?

Wrap-up (max 5 min.)

- These were my questions. Is there anything you'd like to add?
- Thank you very much for cooperating.
- Do you mind that I, should it be necessary, contact you in the near future?

Appendix III: Descriptions of methods for user-centred design

The following working definitions were used when labelling data collection techniques and methods for user involvement that were described by interviewees.

Data collection techniques

- Interview: talking to (prospective) users with the aim of learning about the participant and his/her relation to a product.
- Questionnaire: collecting information through a set of open-ended or closed questions in writing.

- Observational study: collecting information through observation of participants.
- Eye tracking: using cameras to track the gaze of participants, allowing for a reconstruction of where the participants were looking during the evaluation of a design or product.
- Logging usage data: evaluating how a product is used by accessing data stored in the product on frequency and sequence of use of functions and user interface elements.

Methods for user involvement

- Focus groups: a group of individuals, lead by a moderator, discuss of a topic or idea/concept/design, which produces information on experiences, opinions and attitudes, and in which the synergy between the participants is one of its distinctive characteristics (Bruseberg and McDonagh-Philip, 2001)
- Contextual inquiry / field study: collecting information on users and user-product interactions by observing and interviewing them in the field (Beyer and Holtzblatt, 1997)
- Concept testing: assessing whether a new product proposition or idea appeals to consumers (Bont and Schoormans, 1995)
- Creative session with clients/users: groupwise creation of ideas through creativity techniques, in which users/clients are part of the group.
- Personas: rich descriptions of typical users of the product under development that designers can focus on and design the product for (Rogers *et al.*, 2011)
- Cognitive walkthrough: a usability inspection technique (i.e., not involving users) for evaluating the design of a user interface, with special attention to how well the interface supports "exploratory learning," i.e., first-time use without formal training (Rieman *et al.*, 1995)
- Expert review: one or more people with usability expertise and knowledge of the user population review a product looking for potential problems (Rogers *et al.*, 2011)
- Formative user testing: usability activities that have the aim of finding out what problems are occurring in product use, what the underlying causes are, and to suggest possible solutions (Gray and Salzman, 1998; Redish *et al.*, 2002)
- Summative user testing: usability activities that have the aim of determining how good a particular product is in terms of usability compared with a previous version or competing products (Gray and Salzman, 1998; Redish *et al.*, 2002)