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Abstract

In a case study of the development of three electronic consumer products, we traced the origins of usability issues. Based on the data collected, an initial, explanatory framework was induced of important drivers of usability in product design. We conclude that – while usability methods mostly focus on gaining knowledge about users and usability issues – in many instances the primary cause of usability problems seems to be a lack of design freedom to implement usability-improving design changes. In addition, the organisational context seemed to influence the design process considerably. Thus, it can be concluded that to conduct user-centred design effectively, the design process should be considered holistically and the organisational context should be taken into account.

Keywords: user centred design, usability, case study, design practice, product development

Surveys of usability in practice and reports by usability practitioners show that over the years, usability has become an established discipline and that user involvement has found its way into the product development processes across different sectors (Venturi & Troost, 2004; Vredenburg, Mao, Smith, & Carey, 2002; Wiklund, 1994). Also, a considerable body of methodology for User-Centred Design (UCD), the process or approach that facilitates the development of products with a high level of usability, has been developed (e.g., ISO, 2010; Martin & Hanington, 2012; Nielsen, 1992). However, despite the methodology available, products with poor usability still come onto the market in considerable numbers and some authors even report an increase in products whose usability is not at the level that consumers expect (Den Ouden, Yuan, Sonnemans, & Brombacher, 2006; Jokela, 2004b; Kim & Christiaans, 2016; Steger, Sprague, & Douthit, 2007).

UCD practice is often very different from the way it is prescribed in UCD theory and methods (Norman, 1996; Steen, 2008; Wixon, 2003). Product development is a hectic and messy activity (at best) and applying usability methods and theory in this context is not straightforward. A number of authors have stressed that in academia there is not enough insight into or appreciation of the practical concerns of UCD practitioners (i.e. of the factors emerging from the organisational context that influence usability practices) and that to improve usability, product development practice should be studied, for example, through case studies (Grudin, 1991;

Gulliksen, Boivie, & Göransson, 2006; Wixon, 2003). That is, there is little grasp of the factors in the development process or organizational context that drive or inhibit successful design for usability.

In this paper, we report the findings of a case study, aiming to identify factors that influence usability issues in three product development projects of electronic consumer products that were conducted at one product development group.

1. Background

In order to identify and understand factors that influence usability in product development practice, first we need to define the concept of usability, get insight into what the properties are of a design/development approach that should lead to usable products and what factors facilitate or inhibit such a user-centred design approach.

1.1. Definition of Usability and User-Centred Design

The construct of usability originates 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 a widely accepted definition of usability (Jokela, Iivari, Matero, & Karukka, 2003; Jordan, 1998):

> *"…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."*

This definition implies that there is no such thing as *the* usability that is inherent to a product. Rather, usability is a function of the context in which the product is used (Bevan & Macleod, 1994). Focusing on the application of usability in development processes, the more recent ISO standard 9241-210 for human-centred design of interactive systems has been written with that aim. "It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction" (ISO, 2010, p. 1). It puts forward a number of principles for human-centred design, which build upon Gould, Boies and Lewis's (1991; 1985) principles of designing for usability:

- Design is based upon an explicit understanding of users, tasks and environments;
- Users are involved throughout design and development;
- Design is driven and refined by user-centred evaluation;
- The process is iterative;

- Design addresses the whole user experience;
- The design team includes multidisciplinary skills and perspectives.

Following a user- or human-centred design process is seen as making a large contribution to creating usable products (ISO, 1999; Preece, Sharp, & Rogers, 2007; Vredenburg, Isensee, & Righi, 2002). UCD is described as an approach that, instead of focusing on technological possibilities and quality measurement in terms of components, takes solutions that fit the user as a starting point and that measures product quality from a user's point of view, taking into account the needs, wishes, characteristics and abilities of the projected user group (Vredenburg, Isensee, et al., 2002).

However, although process, methods and principles for user-centred design are established and broadly accepted by industry, practice still shows a considerable number of poor products on the market. Therefore, the question remains to what extent these are actually applied and to what extent they can be used to achieve their intended effect.

1.2. User-centred design in practice

In literature on UCD and human–computer interaction, much emphasis is on the development of methods for generating knowledge about users and for evaluating usability and user experience (Battle et al., 2010; Bevan, 2003; Nielsen & Mack, 1994; Stanton & Young, 1998), and on assessing the effectiveness, reliability and validity of the methods that produce that knowledge (e.g., Faulkner, 2003; Gray & Salzman, 1998; Hertzum & Jacobsen, 2001; Jääskö & Mattelmäki, 2003; Jeffries, Miller, Wharton, & Uyeda, 1991; Karat, Campbell, & Fiegel, 1992; Sauer, Seibel, & Rattinger, 2000).

However, Wixon (2003) points out that the effectiveness of usability testing methods should not only be considered from a theoretical perspective (how good are they at uncovering usability problems in a controlled situation), but also from a more pragmatic standpoint: how effective these methods are when applied in product development practice. Research into the application of design methods has shown that their successful application is not straightforward and that design research should take into account personal, social and contextual factors (e.g., Daalhuizen, 2014; Dorst, 2008) particularly when the aim is to develop methods (Blessing and Chakrabarti 2009). For example, it has been shown that method usage depends on the individual prerequisites of the professional that applies the method (Daalhuizen, Person, & Gattol, 2014).

Based on a review of studies of usability in practice Van Kuijk, Kanis, Christiaans, & Van Eijk (2016) identified five primary categories of factors of influence:

1. User involvement: how, and to what extent knowledge about users is brought into the design/development process, and factors that stimulate and limit this;

2. Design/development process: the type of development process structure (e.g. waterfall versus spiral/agile) and when in the process user involvement is executed;
3. Team: the skills and knowledge of team members of the design/development team, when and how usability expertise is available on the team, and team communication;
4. Company culture: to what extent teams, individual team members and upper management understand and support the value of usability;
5. Prioritization of usability in projects: whether the decision-making style and process of teams stimulates the prioritization of usability.

This analysis seems to indicate that though (methods for) user involvement and the structure of the development process are indeed important factors, also other, more contextual factors play a role, a finding that was supported by case studies of product development practice by Van Kuijk et Al. (2016; 2015) who observed an 'outside-in' effect of the organizational context on the product development process, and by the work of Badke-Schaub and Frankenberger (1999) who found that product development processes are influenced by prerequisites of the task, individual group and the (organizational) environment. Furthermore, product development processes are also influenced by changes in the organisational infrastructure, such as the introduction of new IT systems (Kalay, 2006).

1.3. Usability capability maturity

The notion that an organizational approach is required to execute user-centred design in practice is also the idea behind the development of usability capability maturity models. These are tools rooted in quality management that, according to Pigosso, Rozenfeld, & McAloone (2013) can help organizations to:

- assess their strengths and weaknesses (describe their current state),
- develop a roadmap for improvement (transition to desired state),
- benchmark themselves to standards and practices of other organizations.

Capability maturity models (CMM) typically identify five or six 'maturity' levels, from low to high, and for each level, the defining activities or organisational properties are specified (Jokela, Siponen, Hirasawa, & Earthy, 2006). A well-known example of this is the CMM model for software engineering (Paulk, 2002). In addition to these 'staged' models there are also so-called 'continuous' models, based on the SPICE model (from the ISO 15504 standard), which does not rate the whole organisation with one single figure, but separately rates the performance of different key processes in an organisation (Jokela et al., 2006).

To assess to which extent an organisation is capable of creating usable products, a number of usability capability models have been developed both in practice and academia (e.g. Earthy,

1998; Jokela, 2004a; Jokela et al., 2006). Based on a review of usability capability maturity models Jokela et al. (2006) conclude that all models include an assessment of the performance of user-centred design activities in product development projects, and that most models also address, to some extent, the management of user-centred design activities. Especially the higher levels of the Usability Maturity Model (Earthy, 1998) pay considerable attention to iterative implementation of user-centred solutions and to a corporate culture that supports user-centred design.

1.4. Usability of electronic consumer products

In this study we focus on usability in designing electronic consumer products. There are very few studies on usability in practice that specifically focus on electronic consumer products (Van Kuijk et al. (2016), even though this product category differs considerably from other categories, particularly in terms of design for usability. In the following section we explore the aspects that characterize electronic consumer products.

In general, one can observe that in addition to their physical manifestation (embodiment, mechanics, controls), electronic consumer products rely on microelectronics or information technology to offer functionality. As a consequence, their appearance does not have a one-to-one relationship with the functions they offer, and although "…devices may look simple in their system parameters concerning the physical layout, they are difficult to operate as a consequence of the complexity of the underlying system" (Standaert, 2004, pp. 2-3). In comparison to non-electronic products, electronic consumer products provide fewer visual clues as to what the products are for and how to operate them (Den Buurman, 1997; Jordan, 1994).

Furthermore, electronic consumer products have undergone an increase in functionality, miniaturisation, integration in networks and increasing diversity of contexts of use (Buxton, 2007; Den Ouden, 2006; Lindholm, Keinonen, & Kiljander, 2003). These trends can be considered at least partly detrimental to usability, because if the design effort invested is not increased, products with more elaborate functionality are generally harder to use than those with a limited number of functions (Keijzers, den Ouden, & Lu, 2008; Rust, Thompson, & Hamilton, 2006). This problem is typically aggravated if a large number of functions have to be accessed through a small user interface (UI) (Keinonen, 1998). When creating products that are to be used in networks (e.g. a TV set that is connected to a set-top box, hard-disk recorder and a home cinema set), designers are faced with the challenge that although the user experience is influenced by the product/service ecosystem as a whole (Buxton, 2007), a product development group often has influence on the design of just one of the system elements (van Kuijk et al., 2016). Finally, with an increase in the number of environments in which a product

is to be used, the challenge of designing a product that is usable in all situations becomes greater (van der Bijl-Brouwer & van der Voort, 2009).

These are trends that – in addition to the commoditisation of the electronic consumer products market (Wever, 2009), which puts pressure on development time and budgets – make it increasingly challenging to design usable electronic consumer products.

1.5. Conclusions

From the literature overview we can conclude that in spite of the many existing usability methods and techniques, products with poor usability still enter the market. Particularly in the domain of electronic consumer products an increase in usability problems has been observed. This is partly due to the increasing complexity and multi-functionality of these products. Whereas traditionally usability literature discusses usability methods and their implementation from a (mainly theoretical) product development project perspective, it does not provide an explanation as to why the aforementioned gap between theory and practice exists. A few studies suggest that the organizational context should be taken into account. They note that the influence of contextual, organizational factors on the product development process, are an important reason for why usability is not always addressed in the same way and with the same attention. There is a need to better understand those factors, the way they exert their influence, and how they are related. Such understanding is crucial to bridge the gap between usability theory and practice and to contribute to a successful practice of user-centred design.

2. Aim

The overall aim of this research is to increase the capability of industry to create usable products. Firstly, by providing design practitioners with new insights on usability in product development (which can serve as starting points for improvement), and secondly by increasing the capability of design researchers to generate new approaches and methods for UCD that are effective and efficient because they fit with practice.

In order to reach these goals, we performed an in-depth case study. The results provide a deeper understanding of how product usability is influenced during development of electronic consumer products. Our aim was not to uncover how UCD/usability methods are used, but to identify factors in a product development organisation that can positively or negatively influence usability during product development. Thus, this study takes usability issues in products as a starting point and then reconstructs the ‘history’ of those issues, to identify any factors that influenced usability, during the product development process, and in the organisational context.

Therefore, the primary research question of this study was:

> *What factors in development of electronic consumer products influence the usability of these products and how are these factors related?*

The contribution of this paper is twofold. Firstly, it offers design researchers insight into factors that influence usability during the development of electronic consumer products, thus informing future research into usability as well as method development. The generated insights are captured in a framework that connects the identified factors with each other and clusters strongly related factors in so-called drivers for usability.

3. Method

In this study, we seek to uncover drivers of usability in design practice, and thus we engage in theory building. Case study research is put forward as a useful approach for theory building (Eisenhardt & Graebner, 2007), particularly if the phenomena that are studied are closely linked to the context of application and can thus only be reliably observed in practice (Graneheim & Lundman, 2004). We provide a detailed description of the research method, in order to increase 'transparency' or 'traceability' (Eisenhardt & Graebner, 2007; Malterud, 2001a; Miles & Huberman, 1994) and promote the trustworthiness of this study (Graneheim & Lundman, 2004; Shenton, 2004).

3.1. Case design and selection

The case study consisted of three embedded cases in the form of three product development projects within one business group. Investigating different projects within the same organizational context allowed us to identify factors on project level and detect recurring patterns across cases (which strengthened the findings).

In the remainder of the paper we will refer to the organization that we studied as 'AV@home'. At the time of the research, AV@home was a business group that was part of the consumer products division of a large, multinational developer of both professional and consumer electronics, with over 50,000 employees worldwide. AV@home developed audio-visual home entertainment products. AV@home was a premium brand that had recently been positioned to promise technology that is easier to experience. The organisation wanted to employ a user-centred development process, while keeping at the forefront of technology. The organization thus had an explicit goal to strive for a high level of usability.

Inclusion criteria for the selected product development organisation were that the business group showed the ambition to develop usable products, performed product development in-house and featured a way of working that was representative of product development teams in

a corporate context (see section 4.1 for a description of the business group). To ensure detailed answers from participants, we choose to have specific product development projects as the unit of analysis. Projects were selected based on five criteria. See table 1.

Table 1: Criteria for product development projects to be shortlisted for selection

Condition	Details
Recent project	The product had been launched no longer than a year ago, so product development team members would be able to recall the project.
Product is on the market	Possibility for the researchers to subject the product to a usability test.
	Market feedback (i.e. helpdesk calls and customer satisfaction surveys) available.
Recent project + designed in-house	Access to the development team members, which means: • the product was primarily conceived and designed (but not necessarily developed) in-house; • the team members are still employed by the company.
Usability evaluation performed	Data are available on usability issues that played a role during the product development project.
Usability weaknesses present	The product has at least some usability weaknesses.

Through a dimensional sampling approach (Miles & Huberman, 1994, quoting Johnson (1990)) with product type, proposition (high/medium/low end) and degree of in-house development (in-house versus external) as dimensions, we arrived at a final project selection (see Table 2). The properties of these development projects are described in further detail in section 4.2.

Table 2: Overview of the selected product development projects and their properties

Product	Proposition	In-house/external
DVD recorder	Low-end	External software/hardware platform
Hard-disk recorder	Low-/mid-end	Designed and developed completely in-house
Home theatre system	High-end	External software platform, hardware partly proprietary

3.2. Identifying usability issues of the case products

We defined usability issues - following the definition in the ISO 9241-11 standard (ISO, 1998) - as situations where the extent to which a user can interact with the product with effectiveness, efficiency and satisfaction is either so low that it can be labelled as problematic (usability weakness), or so high that it can be labelled as better than the norm or than expected (usability strength). To identify usability issues of the products, we relied on documents from AV@home reporting usability evaluations and inspections during product development, as well as post launch information. This was supplemented by the researchers with a usability test of the product as sold in shops and by online consumer reviews. See Table 3 for an overview of sources used.

Table 3: Overview of the sources used to determine the usability issues in the products, indicating when the information was collected and by whom, and what type of data the study yielded (qualitative descriptions or quantitative summaries), and the level of detail of the data.

Data source	Moment of evaluation	Conducted by	Type of data	Detail	Description
Formative user experience test	During development (using early version of the case product)	AV@home usability consultant	Qualitative	High	Usability test of which the aim was to identify issues that should be improved in the remaining development time.
Summative user experience test	During development (using late version of the case product)	AV@home usability consultant	Qualitative and quantitative	High	The goal of this pre-release test was to assess whether the level of usability of the product was sufficient for the product to be launched.
User interface guidelines benchmark	During development (using an early version of the case product)	AV@home benchmark expert	Quantitative	Low	Benchmark test designed to assess whether a product adheres to internal guidelines with regard to terminology, dialogue screens and response times.
Customer satisfaction questionnaire	After development (on the final case product)	AV@home market research	Quantitative	Low	Satisfaction questionnaire among product owners who registered themselves with the company. Indicates the satisfaction of users with the product, and the product aspects that contributed to this opinion.
Customer service data	After development (on the final case product)	AV@home market research	Quantitative	Low	Categorised overview of the number of questions or remarks from people who called the company's customer service line.
User tests at university of technology	After development (using the final case product)	Researchers	Qualitative	Medium	Per product, two groups of Master students conducted a usability evaluation of the products, including a user test. One group focused on the out-of-the-box experience (installing and first use), the second group on the everyday usage of the product.
Online customer reviews	After development (of the final case product)	Researchers	Qualitative	Low	Analysis of consumer questions and reviews collected from three websites (Kieskeurig/CNET/ Amazon.co.uk). Does not provide very detailed information, but does show what product aspects users are satisfied/dissatisfied with.

3.3. Data collection: interviews with product development teams

In order to learn how the identified usability issues were dealt with during product development, interviews were conducted with members of the product development teams.

Selecting usability issues to discuss

Roughly 40 usability issues were identified per product, of which a selection was made to discuss during the interviews. The issues were selected to cover a broad range of tasks and product components, because different types of usability issues might be caused by different underlying factors. In the end, 25 usability issues were selected per product; of which twenty were weaknesses and five were strengths. We selected both strengths and weaknesses to

balance the negative and positive aspects of design for usability as well as to limit the chance of interviewees adopting a defensive attitude.

Interviewee selection

To mitigate bias through retrospective sense-making by image-conscious informants, Eisenhardt and Graebner (2007) suggest using numerous and highly knowledgeable informants who view the local phenomenon from diverse perspectives. Following their suggestion, 19 interviewees were selected that fulfilled different roles in the product development teams (see Table 4) with most of them having been deeply involved in the case projects.

Table 4 indicates in which of the three case projects each interviewee had been involved, with some interviewees having experience with multiple case projects. Primary actors were product development team members who worked on one of the three selected product development projects. Secondary actors were members of the business group who either had a facilitating role for one of the projects, or were involved in many projects simultaneously, but to a limited degree.

Table 4: Overview of interviewees (primary and secondary), their roles, and the projects they were involved in.

Primary actors	**Description**	**DVD recorder**	**Hard-disk rec.**	**Home theatre**
Product planner	Conceives the idea for the product, and identifies the target group, what user needs the product should target and in what way.	-	-	1
Product manager	Responsible for getting the product from the product concept stage, through development, to market introduction.	2	3	4
Project manager	Coordinates the development project, oversees the planning and budget.		5	6
Product designer	Designs the physical appearance of the product, and partly the physical user interface of the product.	7	7	8
Interaction design	Designs the onscreen user interface of the device, and partly the physical UI.	9	9	-
Development engineer(s)	Responsible for designing and implementing the software, hardware and concrete form of the product.	-	-	10
Usability specialist	Conducts usability tests and evaluations.	11	-	-
Quality manager	Responsible for the extent to which the product meets quality standards as stated by legislation, by AV@home in general and for a specific project.	12	13	14
Secondary actors	**Description**			
UI function manager	Responsible for the user interface concept that is used in a majority of AV@home products. Acts as a usability consultant for important development projects.	-	15	-
Business planner consumer interaction	Coordinates cross-project and strategic activities to improve the overall user experience of the products. Acts as a usability consultant for important projects.	-	16	16
UI guidelines test coordinator	Executes benchmark tests during product development of the time-response and UI design guidelines.	17	17	17
Usability test coordinator	Plans and coordinates the execution of user tests.	18	18	18
Customer service manager	Coordinates the distribution of aftersales feedback from helpdesks within the business group.	19	19	19

Sensitising interviewees

To sensitise the interviewees' memories about the projects, we gave them a sensitising card set (Figure 1) with each card concerning one of the usability weaknesses or strengths. The card set also helped to keep the focus of the interview on the specific usability issues of the product. We asked the interviewees to go through the card set before the interview and to select the five issue cards they wanted to 'definitely discuss' and five issue cards they would 'like to discuss if there is time'.

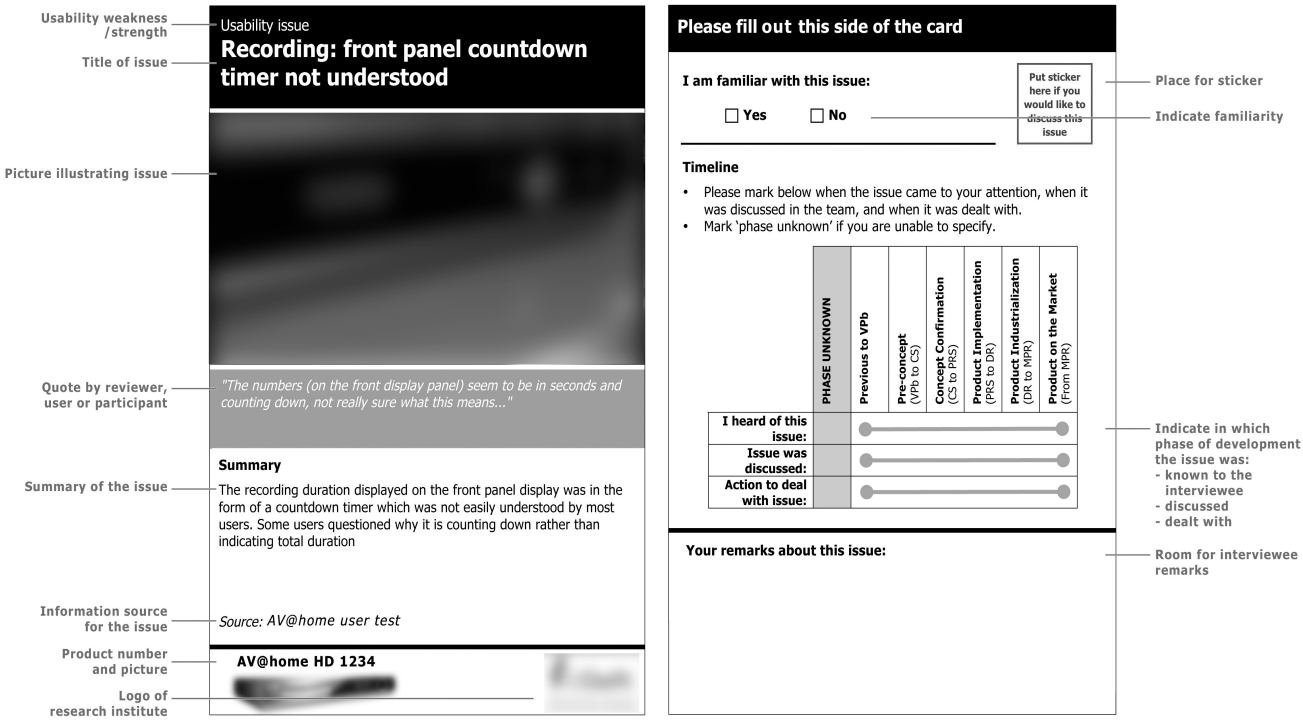


Figure 1: The front and back of the sensitizing card set (with blurred picture and anonymized serial number).

Conducting the interviews

A semi-structured interview approach was used. The interviews were recorded on video to capture both audio and the interviewees' references to the card set. Both researchers involved in data collection were present during the interview: one conducted the interview, and the other took notes, operated the audio and video recording equipment, and checked that all topics in the interview guide were covered. The interviews took place in on-site meeting rooms and were scheduled to last about an hour.

3.4. Data processing: creating jointly told tales

Transcription

All interviews were transcribed in full by the researcher who conducted the interview. Most interviews were conducted in English; those that were conducted in the native language of the interviewee and interviewer were translated into English.

Selecting usability issues for analysis

For further analysis, we selected only those usability issues which had been discussed to a sufficient extent by interviewee(s) to be able to conduct an analysis of the circumstances that influenced that issue's 'lifecycle' (see overview of selected issues in Table 5).

Table 5: Overview of the selected usability issues about which sufficient data were collected through the interviews. Sources for identification of the issue and type of task it was related to are indicated.

		Source					
	Usability issue description	AV@home test	Test by MSc.	Satisf. quest.	Helpdesk	Online reviews	**Task**
Hard disk recorder	Back button not working in every menu		●				Overall
	Device slow, interaction cumbersome					●	Overall
	Starting up the device takes a long time (20-30 seconds)	●				●	Powering on device
	Powering on device: late feedback	●					Powering on device
	Channel installation: talks a long time and insufficient feedback	●					Setup
	Onscreen TV guide installation procedure unclear		●	●	●	●	Setup
	Connecting device in set-top box setup is complicated	●	●	●	●		Installation
	Pushing 'HDD list button' only displays a list of recorded TV programmes (not of other content, which is expected)		●				Play media
	Unclear what remote control button to use to access timed recording menu	●	●				Setting timed recording
	Recording: front-panel countdown feedback not understood	●					Direct recording
	Complicated to mark a segment for recording in Time Shift Buffer	●					Recording from TSB
	Feedback when transferring content does not indicate transfer progress	●					Transfer USB contents
DVD recorder	Connecting device in set-top box setup is complicated	●		●			Setup
	Countries not listed alphabetically (in Dutch) during setup		●	●			Installation
	Automated channel installation: takes a long time and insufficient feedback		●				Installation
	Starting timed recording requires device to be in standby	●	●	●			Setting timed recording
	Disc space warning does not point out possibility of reducing recording quality	●	●				Setting timed recording
	Feedback message when (accidentally) exiting timed recording menu not clear	●					Setting timed recording
	'Timer' button label (on remote) not identified as access to timed recording		●				Setting timed recording
	'Disc' not the most obvious label for access to DVD menu (on remote)	●	●	●			Play media
	Remote control layout (no clear hierarchy and grouping)	●	●	●			Overall
	Remote control unresponsive	●	●				Overall
	Device responds slowly		●	●			Overall
	Overwriting a recording (not completely understood by users)	●					Setting recording prefs.
	[Strength] Timed recording easily found and programmable	●		●			Setting timed recording
Home Theatre	The front panel display is difficult to read since it is too dim	●					Installation
	Difficult to navigate top-tier icons	●					Installation
	HDMI setup (digital audio & LPCM) is not understood	●					Installation
	The disc compartment accidentally slides open during unpacking	●	●				Setup
	Label 'To Subwoofer' on the rear panel is confusing	●					Setup
	Rear panel cover is difficult to close due to cables that are hard to fit in	●	●	●			Setup
	Un-ergonomic cable management: too many connectors in a small place	●	●	●			Setup
	The FM antenna and the FM connector seem not to fit together	●					Setup

Creating 'jointly told tales'

All documents and transcripts were entered in the Atlas.ti software suite for qualitative data analysis. Following Eisenhardt and Graebner (2004), the interview text was broken down into meaning units (interviewee quotes describing a particular situation or subject), which were subsequently accompanied by condensed meaning units (interpretations by the researcher) to form an equivalent of Van Maanen's 'jointly told tales' (van Maanen, 1988). Table 6 presents an example of this process. For each meaning unit, the interviewee's words were presented alongside the researcher's interpretation, to make the analysis transparent and traceable. Next, it was identified to which of the phases of the usability issue lifecycle (e.g. cause of problem, problem detection, design, etc.) each 'jointly told tale' belonged. Finally, from the interpretation, we derived factors, events or circumstances that had influenced the usability of the product in a positive (+) or negative (-) way.

Table 6: Example of how the transcript of an interview with an individual informant was analysed.

Interviewee's words	**Researcher's interpretation**	**Category**	**Factor**
"The main reason is that this [EPG Name], complete with how it works and looks, comes from a supplier."	Electronic programming guide was purchased 'as is' from supplier.	Cause of problem	(-) Purchasing (critical) product component externally
"We get quite some complaints from people, saying: that electronic programme guide, I don't get that. It's completely different from the rest of the product; the way of interacting, the menus, everything works differently all of a sudden."	Negative feedback about the EPG received through helpdesks and Internet	Problem detection	(+) Number of devices on the market in which issue is present (increases feedback) (+) Knowledge in team of usability issue

3.5. Data analysis: identifying the origins of usability issues

To lay a foundation for an explanatory framework of how usability is influenced during product design and development, first an analysis was needed of the origins of the individual usability issues.

Exploring temporal and causal relationships

The jointly told tales formed the building blocks for tentative/temporal causal networks (Miles & Huberman, 1994). The events and circumstances that according to one interviewee had led to a specific usability issue were arranged in a network that represents what Miles and Huberman call 'the map in the head of local informants'. Based on these networks we started to reconstruct the timeline of a usability issue during product development. We categorised the events and circumstances (column 3 in Table 6) using a categorisation scheme that followed the 'lifecycle' of usability issues (Table 7).

Table 7: Categorisation scheme of usability issues, the 'usability issue lifecycle'

Category	Definition
Rise & prevention of problem	How the usability issue came into being, be it in the current development project or in a predecessor. In case of prevention also indicating what prevented the issue.
Problem detection	How and why a product development team or one of its members learnt about an issue, and whether and, if so, to what extent information was collected about this.
Problem assessment	The severity (impact, frequency and persistency) the product development team or its members attributed to a usability issue.
Improvement design & implementation	The options that were considered to solve or improve the usability issue, and how and to what extent they were implemented.
Improvement evaluation	Whether and, if so, to what extent the chosen solution solved the usability issue, and whether there was information collected about this.
Succeeding project(s)	Whether and, if so, to what extent a usability issue persisted or a solution was implemented in a succeeding project

Integrated causal networks

Based on the temporal/causal networks per interviewee, we created integrated causal networks (Miles & Huberman, 1994, p. 156) showing the most important independent and dependent variables and the relationships among them. Per usability issue, one integrated causal network was created. The summary below, in combination with Figure 2, presents an example of such a causal network, consisting of an explanatory text and a visualisation. The numbers in the explanatory text below refer to the numbers in the figure. The example discusses a usability weakness that surfaced in the hard-disk recorder case: the back button, which is used to exit a menu screen, did not work consistently throughout the product's user interface.

Fragment of causal network description: 'Back button not working in some menus'
Cause and prevention of problem

The software architecture of the product was inherited from a predecessor product (3). It was decided to use existing software because doing so would save time (1). The product manager indicated that he considered this a conscious trade-off; in the ideal case, the software architecture would have been made from scratch so that software and hardware could have been designed to work together (2).

Problem detection

The issue did not surface in the usability development test (7), which might be due to the test setup, which focused on first use of the product (4). In the test, participants use the product for a short while, directed by tasks, meaning that a more advanced use case was not being performed in the test (5). The product manager discovered the issue when he was using an early version of the product at home (11), and communicated it to the team (9). The use test coordinator indicated she was familiar with the issue, because it had also surfaced in other products (8). All in all, even though the issue did not surface in the usability test, the team did seem to have obtained knowledge about the issue (10).

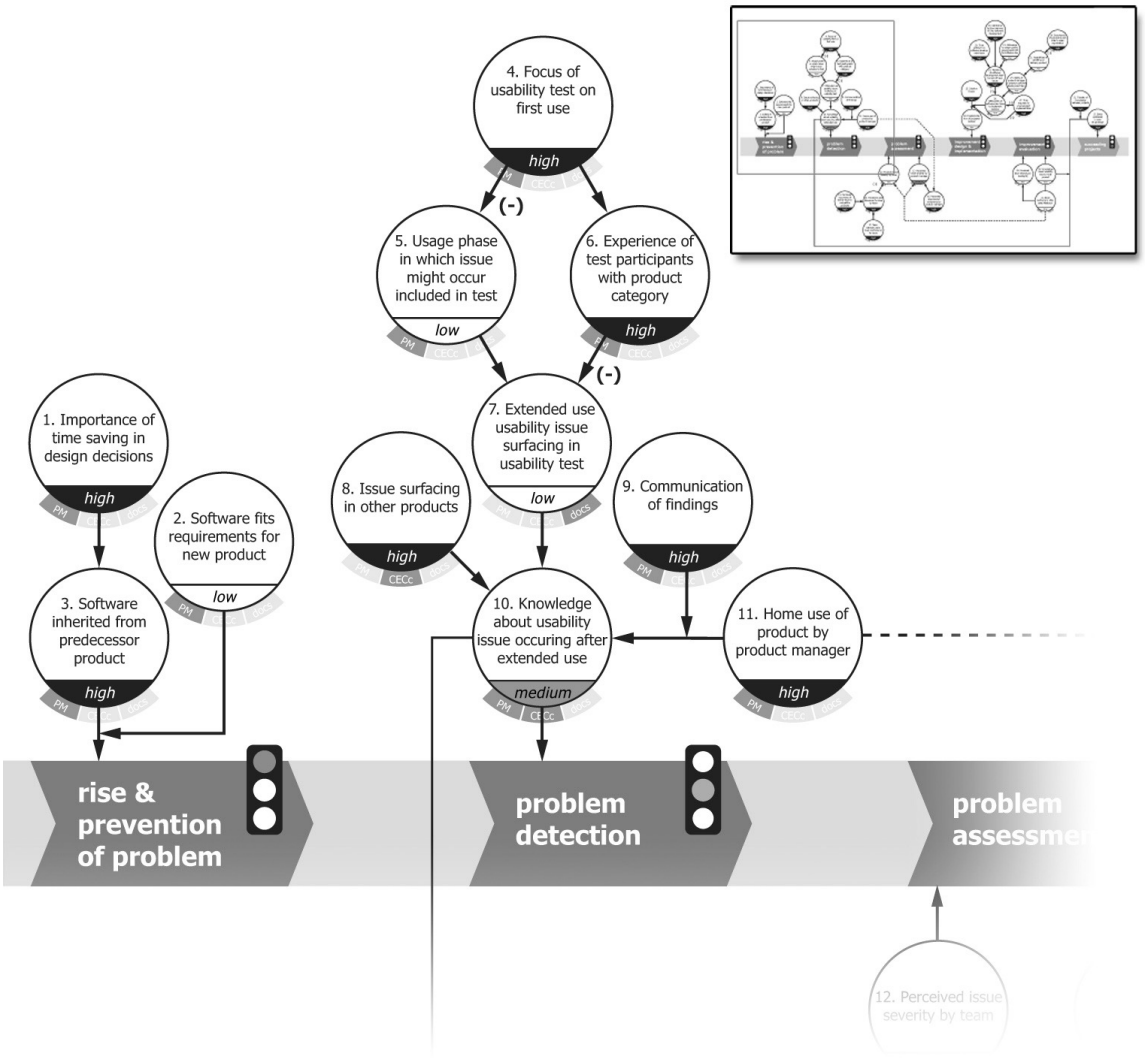


Figure 2: Part of the visualized causal network for the usability issue 'Back button not working in some menus'

3.6. Inducing the framework

In this phase, we used the integrated causal networks of each usability issue to induce what is referred to by Miles and Huberman (1994, p. 222) as a causal model: "*empirically grounded networks of variables with causal connections, drawn from multiple case analysis, with the goal of deriving a testable set of propositions about the complete network of variables and interrelationships*". Miles and Huberman also stress that due to the complexity and contextual nature of causal relationships, the developed models might have more of an explanatory than a predictive nature. This is why we have opted to use the term 'framework' rather than model.

An important step in reducing the number of variables in the models was 'factoring': the identification of commonalities or patterns in the events and circumstances that interviewees described (Miles & Huberman, 1994). To create the causal model, we took an approach based on the four 'rules of thumb' for the creation of causal models proposed by Miles and Huberman (1994). In doing so, a first version of a framework was derived from the causal network of a

first usability issue. Next, in iterative steps, the framework was adapted by analysing the causal network of the next usability issue, and then the next, and so forth. We continued this process until we had analysed the causal networks of all 35 usability issues. Then, following Eisenhardt (1989), we went through all causal networks again from the beginning, to check whether the framework was 'stable'.

This produced a framework with 10 factors, balancing the framework's communicative (requiring simplicity) and explanatory (requiring richness) power. Secondly, in the causal networks that we based the framework upon, factors were often connected to what Graneheim & Lundman (2004) call themes: 'a thread of an underlying meaning (…) on an interpretative level'. The three themes were: 1) the prioritization of usability in a team or organization, 2) the act of executing user-centred design, and 3) whether the organization was able to implement the desired design. To highlight the pivotal role that these factor-networks played we gave the framework three thematic areas that we labelled 'drivers'.

3.7. Verification of case description and framework

To verify the results of the study, a member check was performed in which the results were presented to informants involved in the product development projects that were investigated. Some of the informants had been interviewed as part of the case study, others had not. The member check was performed to corroborate or refute essential facts and evidence (Miles & Huberman, 1994; Yin, 2009, quoting Schatzmann & Strauss, 1973). This involved verification of the case context description and of an early version of the framework by informants at AV@home. Furthermore, an assessment was made of the transferability of the results within the same company, by presenting the results at AV@home's TV business group and AV@home's internal user testing consultancy. The sessions were audio-recorded and transcribed. Based on the input of the informants, additions and changes were made to the case context description and to the framework. Generally, the informants at AV@home considered the findings accurate, while the informants at sister groups found the findings recognizable and applicable to their organizations as well.

4. Case context description

This section provides a description of the business group's organisational structure and approach to product development at the time of the research, as well as of the three product development projects that formed the embedded cases. Detailed or 'thick' descriptions are considered to increase the credibility of case studies (Malterud, 2001b; Shenton, 2004). Thick descriptions also facilitate a better assessment of the transferability of the results. A rich context description provides other researchers that conduct a related (case) study to explain similarities

and differences between their results and this study, or could provide an indication of whether the framework developed is applicable to other design and product development contexts.

4.1. The AV@home business group

4.1.1. Organisation and location

Table 8 shows what actors were involved in product development and how they were distributed over the departments at AV@home. Some of the departments were part of the AV@home business group, whereas others (namely the Design and the Consumer Experience department) were part of the parent company.

Table 8: Overview of the development team members and their affiliated departments

AV@home business group	Product management department	Product planner Product manager Project manager Consumer experience test coordinator Business planner consumer interaction
	Development engineering department	UI function manager Mechanical project leader Electrical project leader Software project leader
	Quality management department	Quality project leader Customer service manager
Design group of parent company	Local design department	Product design consultant Interaction design consultant
Consumer Experience group of parent company	Consumer Experience department	Consumer experience consultant

Product Management, Quality Management, and Engineering were located in one office space, and seated by discipline. The Design department and the Consumer Experience group were in the same building as the business group, but in separate office spaces.

AV@home's employees had 5 to 10 years of working experience in consumer electronics, and personnel turnover was considerable. Upper management was involved only to a limited extent in the content of product development projects but monitored projects on process and resources.

4.1.2. Product development process

AV@home's product development process was divided into two major phases: pre-development and development. In the pre-development phase (which was referred to as 'value creation'), the product concept was defined. During the development phase (or 'value delivery'), the concept was refined, implemented and brought to the market. Figure 3 shows a simplified representation of AV@home's product development process.

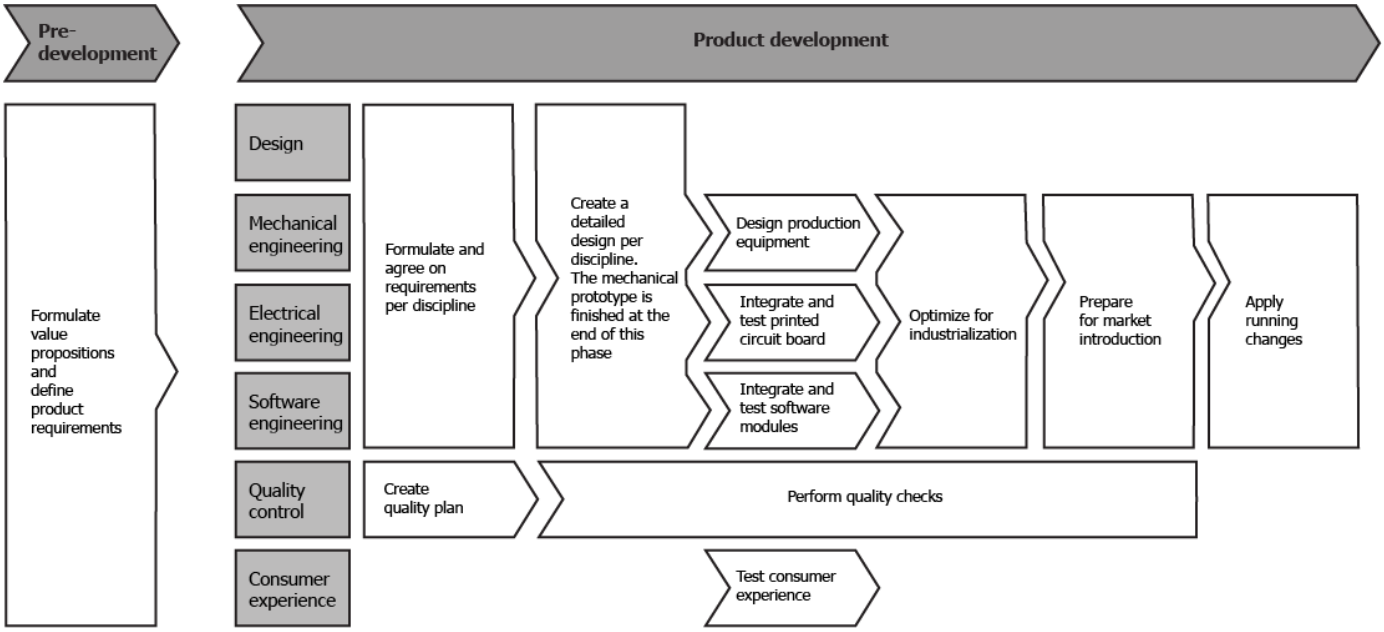


Figure 3: Simplified representation of the AV@home product development process between concept creation and mass production

Development

The development process was formally documented, and each phase featured explicitly defined deliverables that had to be presented in milestone meetings, during which project leaders had to convince their colleagues and the upper management that the project was on track. Requirement setting was an important element of AV@home's development process, as many disciplines had to cooperate and the people from each discipline had to have a clear overview of the project and the product requirements.

User involvement and representation

At AV@home, user involvement during product development occurred in three ways, namely through evaluations based on user interface guidelines, usability testing and systematically evaluating feedback from the field, as described below.

- User interface guidelines: AV@home used a set of guidelines to assess whether a product design meets the group's quality standards. These requirements included usability-related aspects, such as response times and standardised UI behaviours.
- Usability evaluation: Use tests, in which externally recruited participants interacted with prototypes or early product versions, were usually conducted twice during product development projects. In a first test, which had a formative character, the goal was to highlight what product aspects could be changed to improve usability, primarily for the initial phases of use, such as 'unpacking', 'installing' and 'first use'. The goal of a

possible second test, which had a summative character, was to assess whether the product's overall user experience – again, mostly for initial use – was acceptable to consumers. In both user tests, one of the most important aspects to be investigated was the usability of the products.

- Feedback from the field: Usability feedback from the field was gathered through home tests of the first samples (0-series) of products by employees, customer service contacts (through telephone and Internet), product returns and customer satisfaction questionnaires. At the time of the research, customer satisfaction had just been introduced as a new measure of product success.

4.1.3. Product development team

In the pre-development phase, a relatively small team conceived and explored the initial product concept. In this phase the team consisted of a product planner, product manager (part-time), product designer and the heads of the teams in the engineering disciplines (mechanical, electrical, software). Once actual development started this team was expanded, but the initial team coordinated tasks and made the most important decisions. Informal communication was limited and the teams relied largely on meetings and email/PowerPoint to communicate.

4.2. The product development projects

The following section provides a description of product and project characteristics, as well as an indication of the level of usability of the product, for each of the cases.

4.2.1. Case 1: Hard-disk recorder

Product description

This product could record TV programmes on an internal hard disk, from which the recordings could then be archived to DVD. Recordings could be programmed through an onscreen TV guide. Another important feature was that the product stored the last three hours of the channel that the user watched to hard disk, allowing the user to pause or rewind a live TV programme (s)he was watching. In the product proposition, ease of use was explicitly mentioned as a user benefit. The product was targeted at a low to mid-price segment.

Usability

It became evident from user tests, as well as from the aftersales feedback (helpdesk and customer satisfaction questionnaire), that the usability of this product was judged as poor. It had a considerable number of usability weaknesses, including weaknesses that had a severe impact on usage and/or primary use cases. A large number of usability weaknesses were related

to slow response times, button labelling, the UI concept for continuous recording (replaying recent broadcasts from short-term working memory), programming timed recordings and the lack of feedback that the device was recording.

Project description

This product was developed almost entirely in-house, based on requirements that were set by the development group itself (as opposed to purchasing a platform or product from third-party suppliers). The hardware and the software architecture were inherited from a predecessor product. The user interface was the first full-fledged implementation of a new UI paradigm that had recently been copied from the TV development group. The product was described as complex and extensive (in comparison to, for example, DVD recorders and home theatre systems). The physical appearance of the product was based on a styling strategy that the design department had determined for that year, and the remote control had a standardised layout that was used for a large part of the product line.

The project had a distributed software development team. The on-site team worked on the user interface. A team in another Asian country developed the system software. A team in Europe wrote the drivers for the hardware components. Although all software developers were part of AV@home's parent company, they worked on a contract basis, which meant that they could only spend a limited amount of time on the project.

The project ran for almost two years – which is relatively long for AV@home – due to serious problems with the stability and performance of the system that arose during implementation. Overall, the project was described as 'challenging', 'intense' and 'eye-opening'.

During the project, above-average attention was paid to collecting user feedback from previous projects, and to user testing. However, because of software problems, user tests were only performed late in the process. Two user tests were performed: one when the design of the product was fairly detailed, and one (using the final product) just before product launch. In addition, in an early phase of product development, the product was subjected to user interface guidelines and response times benchmark evaluations.

4.2.2. Case 2: The DVD recorder

Product description

In contrast to the hard-disk recorder, this product offered only basic DVD recording – no onscreen TV guide or advanced connectivity – because it was AV@home's most basic, entry-level DVD recorder. The target group was avid TV-watchers who might also own a camcorder and would like to archive home videos and TV programmes. In the product proposition, it was explicitly stated that the product should be easy to use.

Usability

The usability of this product was evaluated as rather good. In the aftersales feedback (customer care and satisfaction questionnaire), the usability of the product was evaluated positively. The biggest usability weaknesses to emerge in the user tests concerned how to install and setup the product (especially in combination with a cable or satellite receiver). The recordings dialogue and the responsiveness of the remote control presented a number of smaller problems.

Project description

The hardware/software platform was purchased from a third-party supplier, and had been used in a previous product, which had received favourable customer reviews. The user interface was an integrated part of the software platform and – also because of the contract with the supplier – could be adapted only to a very limited extent. The physical appearance of the product was based on the overall styling strategy for that year, and the standard remote control design for the whole range was used.

An internal team at AV@home developed the product in cooperation with the third-party supplier. From project start to market launch, the project took about one year, of which the implementation (from product proposition to production) took about six months. The project was described as very straightforward and smooth and it was finished within the projected timeframe. Cost was a very dominant decision-making criterion in this project, because the product was intended as a low-margin, high-volume product.

During product development, a usability guidelines benchmark test and a formative user test were performed, but no pre-launch summative user test was conducted.

4.2.3. Case 3: The home theatre system

Product description

This product offered the possibility to watch DVDs and TV programmes in Dolby Surround Sound. It was a high-end product with a new, distinctive physical appearance: the product could be mounted on the wall (below a flat-screen TV), which was possible because of the application of a new technology developed by AV@home's parent company. The target group was described as sophisticated and established, but not showy. Members of the group were considered design-oriented and to be owners of flat-screen TVs.

Usability

Overall, the usability of this product was considered fairly good with regard to daily use, but installing it and setting it up was more complicated. The majority of the usability weaknesses were related to the physical installation (making cable connections etc.) and the setting up

(choosing the right settings) of the product. In addition, a number of usability weaknesses were identified with regard to playing or displaying media (music, video, photos).

Project description

Innovative components were developed in-house, but more standard components – including the product's hardware/software platform – were purchased from third-party suppliers. The user interface was an integrated part of the software platform, and was therefore not readily adaptable. The software platform (and the user interface) had been applied in earlier products.

As the project would introduce a new product proposition and technology onto the market, it was given a high priority and thus received extra attention from upper management. Even though the product was very innovative, not much extra time had been budgeted to develop the innovative components; as a result, time pressure was described as high.

To test usability, in an early phase of the project a physical mock-up of the cable connection bay was made and evaluated by the team members. Later in the project, a benchmark test of adherence to usability design guidelines was conducted as well as two formative user tests.

5. Framework of drivers of usability in practice

Based on our case study we defined factors that influence the usability of products during product development. These factors are brought together in a framework (See Figure 4) that provides indications of how factors were observed to influence each other. The framework helps to explain why certain product development projects succeed at delivering products that have a high level of usability, while others fail. Visualizing the relationships makes explicit the 'testable set of propositions' (Miles & Huberman, 1994, p. 222) that the factors and their relationships form.

The framework features three drivers of usability: *Prioritisation*, *User-Centred Design* and *Design Freedom*. Each driver consists of a thematic cluster of factors, each of which influence usability in a distinct manner. For example, if a company does not have a UX department, then no resources were made available for usability, which is linked to prioritising. Or, if a design team leaves an error in the product because they are not aware of the usability problem it causes, then there is a 'knowledge' issue. The necessary knowledge might not have been obtained by the company, or it was not spread in the company, which is linked to the company's UCD capability. But even if that knowledge was available to the team, they might not have had the 'design freedom' to apply it, leading to usability issues in the product in spite of the available UCD capability. A lack of design freedom can be related to the mutability of the product, which in turn can depend on the product design (was for example the software designed to

accommodate changes in a later stage) or on how far the project has progressed (in later stages more decisions have been taken, resulting in less design mutability).

The framework is illustrated in figure 4, with the arrow-shaped boxes representing activities or processes, and the square boxes representing the outcome of those activities or processes. Following Eisenhardt and Greabner's (2007) suggestion on how to present emergent theories, we present and explain the visualized framework, provide definitions for each of the constructs, and present supporting empirical evidence for the presence of and relations between these constructs in the form of 'vignettes'. Vignettes are "focused descriptions of a series of events taken to be representative, typical or emblematic" (Miles & Huberman, 1994, p. 81).

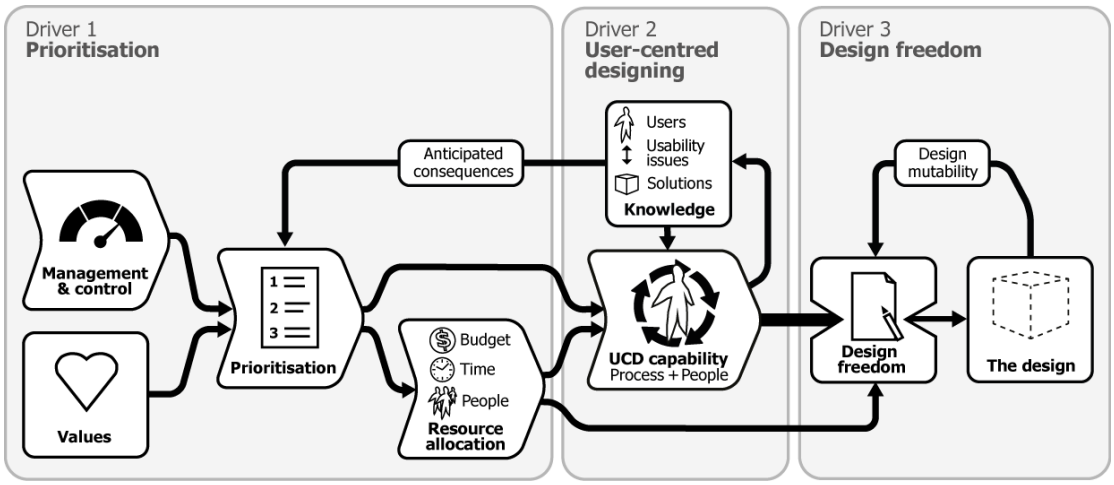


Figure 4: Framework of drivers of usability in product development practice, featuring three networks of factors, forming the three primary drivers in light-grey areas, and the factors in arrow-shaped and square boxes

5.1. Driver 1: Prioritisation

5.1.1. Prioritisation of usability

Definition

Prioritisation refers to putting tasks, problems and product properties in order of importance, in order to deal with the most important issues first. Two types of priorities were identified:

- Product priorities (e.g. appearance, quality/reliability, price, branding and usability);
- Project priorities (e.g. deadlines, project budget and team size).

Influenced by

Prioritisation of usability was found to be influenced by:

- Management and control: how an organisation aims to influence decision making through the allocation of means, communicating priorities and rewarding results (e.g. through key performance indicators).
- Values: the philosophies or principles that guide the conduct of product development team members, teams and organisations (e.g. 'products should always look good').
- Anticipated consequences: expectations that product development team members, teams and organisations have about the effects of their decisions and actions (e.g. product returns).

Examples

Table 9 provides illustrative instances (vignettes) of how prioritisation was found to be affected.

Table 9: Vignettes that illustrate how prioritisation of usability was influenced by management & control mechanisms, values of individuals or the organisation, and by the anticipated consequences of usability issues

Related factors	**Vignettes**
Management & control → *Prioritisation*	The design department's primary responsibility in the organisation was to ensure a consistent styling across product lines. Designers indicated that they were hardly given the chance to move beyond that role. Designers were the only role in the organisation that did not have customer satisfaction as performance indicators.
Values → *Prioritisation*	There was a considerable difference between the approaches of the product manager of the DVD recorder and that of the hard-disk recorder. The DVD recorder product manager was project-focused: she wanted to deliver the product on time and within budget, and compromised the product quality significantly to achieve these goals. The product manager of the hard-disk recorder was more concerned about the properties of the product, and compromised project goals.
Anticipated consequences → *Prioritisation*	In a user test of the DVD recorder, the remote control was found to be unresponsive. Both the usability evaluator and the rest of the team anticipated that this might cause customers to return the product, and thus the issue received a high priority to be fixed.

Influence on

Prioritisation can have a direct or an indirect effect. A direct effect is when one of the alternatives at hand is chosen and the choice is not influenced significantly by the resources it requires. It is a matter of, all things being equal, choosing the better option (in the model in Figure 4: this is visualised by the upper arrow from 'prioritisation' to 'UCD capability'). In the case of indirect effects, the influence is exerted through the allocation of resources.

Examples

Table 10 provides illustrative instances of how prioritisation of usability affected the ability to conduct user-centred design and resource allocation.

Table 10: Vignettes that illustrate how prioritisation of usability was found to influence user-centred designing directly and through the allocation of resources

Related factors	Vignettes
Prioritisation → *UCD capability*	The UI paradigm was designed with light grey texts on a white background, which was known to reduce legibility because of the limited contrast, but it was thought to look more aesthetically pleasing.
Prioritisation → *Resource allocation* → *UCD capability*	During implementation of the hard-disk recorder, there was enormous time pressure and the available working hours were mostly devoted to dealing with reliability problems. As a consequence, usability problems were not dealt with.
Prioritisation → *Resource allocation* → *Design freedom*	In the home theatre system project there was not enough budget to pay the supplier to implement changes that would improve the usability of the onscreen interface.

5.1.2. Resource allocation

Definition

Resources are the means that a development team can use to fulfil product requirements, namely:

- Product budget (what can be spent on product components);
- Project budget (what can be spent on development activities);
- Working hours (mostly depends on team size and project runtime, which in turn depend on project budget);
- Time (some activities require the execution of a minimum time span).

As development projects progress, the available resources generally decrease: financial resources and working hours are spent, investments have been made (e.g. on tooling) and the remaining time until to product launch decreases. The available resources were observed to be influenced considerably by a product's priority, projected sales price and profit margin, and stage of development the project was in.

Influence on

Resource allocation exerts influence on (see also Table 10):

- The UCD capability of a team or organisation (see section 5.2.1)
- Design freedom (see section 0)

5.2. Driver 2: User-centred designing

This driver refers to the activity of 1) generating the required knowledge needed to create usable products and 2) integrating this knowledge in a design. Thus, it refers to both the knowledge-generating activities (analysis and evaluation) and the synthesising activities (synthesis, simulation, decision) of the basic design cycle (Roozenburg & Eekels, 1995, p. 88).

5.2.1. UCD capability

Definition

UCD capability is the extent to which a development team or organisation is able to plan and execute user-centred design. For the purpose of this study, UCD capability was identified as having two primary elements:

- Process: the product development methodology that a development team or organisation employs and the methods and techniques that it selects. For example, stage–gate versus more iterative development process; whether and, if so, when the process accommodates user research activities such as field studies and user tests; and what kind of user research activities are conducted;
- People: the staff that execute the aforementioned process and how they are organised. For example, how skilled team members are in UCD methods and techniques, which role heads the product development team, which team members have most decision-making power, the moment(s) during development at which usability specialists are part of the team and in which role (team member or advisor).

Influenced by

UCD capability was found to be influenced by:

- The prioritisation of usability (see section **Error! Reference source not found.**)
- Resource allocation (see section 0)

Influence on

We found that UCD produces two outcomes:

- Knowledge about the user group, about usability issues, and about possible solutions (see section 0)
- The design (section 5.2.3). The extent to which this design is in line with what the design team would want to create is mitigated by design freedom (see section 0)

Examples

Table 11 provides illustrative instances of how prioritisation of usability and the allocation of resources affected the ability of a development team to engage in UCD.

Table 11: Vignettes that illustrate the extent to which a team could engage in UCD was found to be influenced by prioritisation of usability and by the allocation of resources

Related factors	Vignettes
Prioritisation → *UCD capability*	During development of the hard-disk recorder the development team – due to AV@home's own internal guidelines – was not allowed to select a supplier with a more usable electronic programme guide, because AV@home would be that supplier's only client, and thus it would be too dependent on AV@home.
Prioritisation → *Resources* → *UCD capability*	The DVD recorder, a low-end product, was not subjected to a summative usability test. The hard-disk recorder and home theatre system, medium and high-end products, for which more resources were available, were subjected to summative usability tests.
Prioritisation → *Resources* → *UCD capability*	During implementation of the hard-disk recorder there was enormous time pressure and the available working hours were mostly devoted to dealing with reliability problems. As a consequence, usability problems were not dealt with.

5.2.2. Knowledge

The usability of products was identified as being influenced by knowledge about 1) the user group, 2) usability issues and 3) potential solutions:

- Knowledge about the user group (e.g. demographics, needs, skills, living context): enables setting the right requirements and prioritising the product's most important use cases. It also facilitates the creation of user-centred designs because the designers have a better understanding of the user group, product usage and the context of use.
- Knowledge about usability issues (e.g. cause, severity and occurrence): enables the product development team to create redesigns with better usability. This knowledge can be obtained through a wide variety of methods (e.g. user testing, after sales feedback, reviewing). If a team already knows about a usability weakness before product development starts, it can include requirements or propose designs that solve the issue. If a team becomes aware of the weakness during the development process, a design iteration can be performed to optimize the design.
- Knowledge about solutions (available technologies, UI designs and product designs): enables the generation of more usable solutions. The more knowledge of potential technologies, UI designs, and product designs a team has, the wider the range of options it can consider. This knowledge can originate from the company's own products, competitor products and research projects, and more indirectly from the team members' experience and education.

As can be seen in Figure 4: , knowledge is both an output of and an input for user-centred design. The knowledge that is created through analysis (e.g. field studies, interviews, questionnaires) and evaluation activities (e.g. concept test, user test, cognitive walkthrough) is fed back into the design process and used in synthesis and decision-making activities.

5.2.3. The design

The primary goal of engaging in a design process is to create a design. During the process, the design can vary in its degree of maturity, and design representations take various forms, such as a sketch, a scenario, detailed UI design, CAD drawings, etc. Ultimately, the design process will result in the documented plans that are necessary for the production of the product (Roozenburg & Eekels, 1995).

However, to be able to do so, the aforementioned knowledge (about users, usability issues and potential solutions) is needed. So, in the design process, producing knowledge is not a goal as such, but an important, intermediary outcome that is fed back into the design process, and that also 'feeds' the members of the product development team who execute that process in terms of expertise and knowledge. In other words, knowledge helps them grow.

Examples

Table 12 provides illustrative instances of how knowledge is both output and input of UCD.

Table 12: Vignettes that illustrate the iterative relationship of the UCD capability with knowledge about users, usability issues and possible solutions. User-centred designing both produces and needs this knowledge.

Related factors	**Vignettes**
UCD capability → *Knowledge*	To test whether users could fit all cables and connectors in the back of the home theatre system, a physical mock-up of the back panel of the product and the team tried it out.
	User tests did not detect the issue that the 'back' button on the hard-disk recorder remote control did not work consistently across menus. Thus, the test report did not mention the problem, nor were any changes made. Later in the project, the product manager discovered the problem when using an early version of the product.
UCD capability → *Knowledge* → *UCD capability* → *A design*	Because it became clear from the usability test of the DVD recorder that the participants did not understand the warning text when a DVD did not have enough space for the recording, the team redesigned the warning message.
UCD capability → *Knowledge* → *UCD capability* → *A design*	Because the development group was based in Asia it had limited knowledge of the kind of product ecosystem in which people in the US and Europe (the target market) used their DVD and hard-disk recorders. For example, digital TV decoders were not common in the country where the products were developed, but their use was widespread in Europe and placed specific demands on the connectivity options a product should provide. This resulted in suboptimal connectivity with set-top boxes.
UCD capability → *Knowledge* → *A design*	For the home theatre system, very specific requirements were set for the maximum height of the product, because the team had learnt that a considerable number of users did not hang their flat-screen TVs on the wall, but put them on stands. In that case, the home theatre system would be placed in front of the TV and should not block the screen.

5.3. Driver 3: Design freedom

5.3.1. Design freedom

Definition

The extent to which a development team is able to implement a desired design.

Influence on

Design freedom influences whether a development team's UCD capability (see section 5.2.1) can be applied effectively. It is about whether the team is free to make design choices that they believe will lead to a usable design.

Influenced by

Design freedom is influenced by the allocation of resources (see section 0) and by the mutability of the design (see section 5.3.2).

5.3.2. Mutability

Definition

Mutability refers to the extent to which a design or product can and is allowed to be changed.

In general, as a product design matures its mutability decreases, as more product properties will have been specified, which places more limitations on subsequent design decisions. In addition, as a product matures, it becomes more 'intertwined' and changing one part of the design can have consequences – including unexpected ones – for another part. Guidelines and requirements reduce mutability by not allowing the designer to take certain design decisions.

Influenced by

Mutability is not only determined by the progress of the development process. The design of a product also might impact the mutability. Software that has a modular architecture is much easier to redesign than a single monolithic pile of software code. Or product hardware can be designed so that certain electronics can easily be replaced by a better component in a next generation of products. Mutability can also be limited due to early design decisions to base a new product on a predecessor (with limited changes), or because of the selection of a technological platform with certain limitations.

Mitigated by

If the mutability is limited, in some cases this can be mitigated by having sufficient resources available. For example, if the tooling for injection moulding has already been done, the resulting limited mutability can be offset by an increase in funding, which allows for new moulds to be made.

Examples

Table 13 provides illustrative instances of how design freedom played a role.

Table 13 Vignettes that illustrate how mutability and resource allocation influence design freedom

Related factors	Vignettes
The design → *Mutability* → *Design freedom* → *The design*	In the DVD recorder project, the use of a platform purchased from a third party severely limited the number of changes that the team was allowed to make to the user interface. In essence, only the graphics and button labelling in the onscreen UI could be changed.
	The software architecture of the hard-disk recorder was designed in such a way that once implemented, making changes to the software later in the process threatened the stability of the system, preventing proposed changes from being implemented.
	The hard-disk recorder was designed in such a way that users could install software updates after purchase, thus maintaining a certain mutability even while the product had already been purchased by consumers.
Resource allocation → *Design freedom* → *The design*	To save costs, a range of recording products shared the same physical remote-control design even though they differed substantially in functionality. In a higher end version of the hard-disk recorder a more expensive remote-control design was used, which proved more usable.
	In the home theatre systems project, there was not enough budget to pay the supplier to implement changes that would have improved the usability of the onscreen interface.

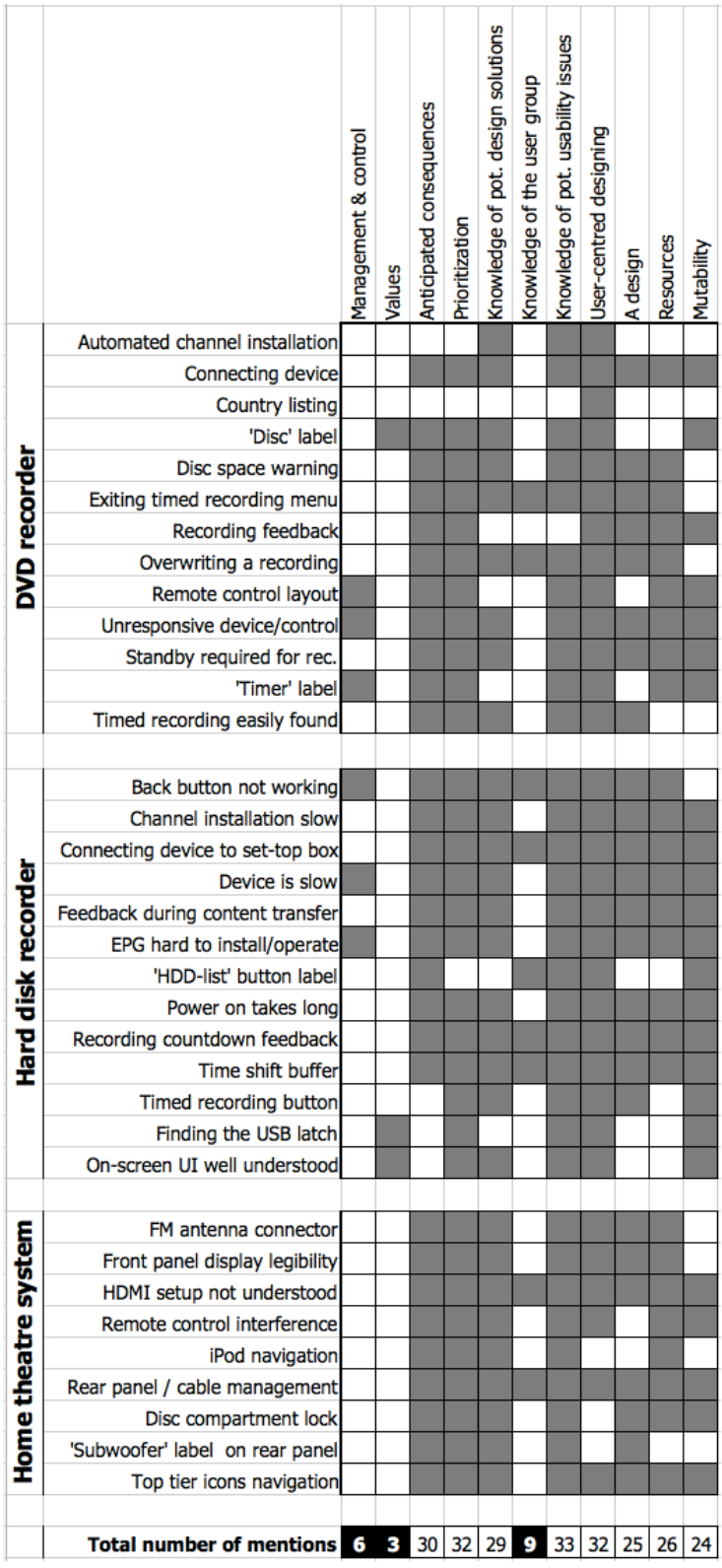
5.4. Groundedness

The following section provides an indication of the extent to which the framework was based on evidence from empirical data (Eisenhardt, 1989). **Error! Reference source not found.** indicates which of the factors were present in (black) or absent from (white) the causal networks that represented the events and circumstances that led to a usability issue. Three factors were less frequently mentioned, but nonetheless included in the framework for the following reasons:

- 'Management and control' mechanisms were mentioned six times in the causal networks. However, when they were mentioned, the informants seemed to attribute a considerable impact to them, pointing to, for example, their key performance indicators, the message that upper management sent out internal cost allocation models as reasons for prioritising usability (or not). Due to their large impact, it was decided to include 'management and control mechanisms' in the model.

  'Values' surfaced in only three causal networks. However, when we compared the approaches, opinions and actions of the three product managers, a distinct difference in prioritisation emerged that could not be solely attributed to rational considerations, but also seemed to depend on the values and beliefs of the actors. The influence of values was supported by the informants in the feedback presentation that was held at AV@home. Due to their power to explain certain issues that were hard to explain otherwise, we decided to include the factor 'values' in the model.
- 'Knowledge' of the user group surfaced nine times. However, when it was mentioned it was identified as having a very strong influence on the usability of the design. Due to its large influence and the methodological bias, it was decided to include 'knowledge of the user group' in the framework.

Table 14: An indication of groundedness for the factors that make up the causal model. For each usability issue it is indicated whether the variable was found (black) in the causal network or not (white). Knowledge was divided into three subcategories (about the user group, about usability issues, about solutions).



6. Discussion

6.1. How the organizational context drives usability practice

This study presents three drivers for usability that to a considerable degree emerge from the organizational context of the development process. This implies that the success and impact of usability practices and methods relies to a considerable extent on the organizational context.

The framework indicates that the design/development process that a company employs is only one of the factors influencing the creation of usable products. The 'user-centred design capability'-driver entails both the development process, including methods used in that process, but also the capabilities of the people that execute the process. This finding is supported by several authors pointing out that the people who execute the process are just as important as the process, or maybe even more so (Frankenberger, Badke-Schaub, & Birkhofer, 2012; Gulliksen et al., 2006; Kelly, 2010; Löwgren & Stolterman, 1999). And that how methods are applied or even *whether* they are applied is influenced by the properties of a team, of individuals and of the task at hand (Badke-Schaub & Frankenberger, 1999; Daalhuizen et al., 2014).

The current paper contributes by pointing out more specifically how the contextual factors (e.g., prioritization, resources, team capabilities) influence the execution of the design/development process and how effective this is in terms of delivering a usable product.

In particular, the 'design freedom' driver is interesting to discuss. Our study provides empirical support for the notion put forward by Wixon (2003) that most studies into user research methods judge these methods on how effective they are at identifying usability issues (under controlled conditions), but leave out of scope the goal of executing these methods in an organization, and fixing the usability issues of the product. The framework shows how knowledge about users and usability issues is only an 'intermediate product' of the user-centred design cycle; knowledge that only becomes valuable once it is integrated in a design and if that design can be implemented. So, where existing usability methods stop with user knowledge and usability testing, there our framework goes beyond these two issues.

When developing new methods for UCD practice, design researchers should be aware of the context these methods will be used in. As Wixon (2003) has argued, the effectiveness of these methods is typically tested under controlled conditions. Methods should also be tested for their reliability and validity in a natural environment. Already during development of these new methods, they should be assessed on more pragmatic aspects, such as required resources (staff, financial budget, time, equipment) and the required level of expertise to apply it.

This study showed that in many cases, a team has knowledge of a usability issue, but due to limited resources and design mutability, does not have the freedom to apply that knowledge. In

cases like these, methods that provide less reliable knowledge, but that make it available earlier in the development process (when design freedom is higher) is of more value to a design team than a method that provides knowledge with a high degree of certainty, but at a later time (when design freedom is likely to be low). This suggests that to develop UCD methods that are effective in practice, design researchers should not focus their efforts on issue detection only, but should develop methods that cover the full 'life cycle' of usability issues, including their coming into being, detection, exploring solutions and solving them.

Finally, the framework of drivers of usability shows that UCD methods are only one aspect of what determines a development group's ability to create usable products. Therefore, in some cases it might be recommendable that design researchers set out to develop 'interventions' rather than a priori set out to develop a new method for user involvement. An intervention could be an educational program on UCD for all development team members that are not directly involved in UCD-activities or changing the way that a usability expert briefs the development team about the results of a user test (e.g., inviting them to the test, asking them to help to analyse the results, compile an action list together in a workshop). But it could go as far as to changing team composition (to have the right skills on the team at the right moment) and office architectures (to facilitate a different way of collaborating).

6.2. A foundation for improving Design Capability Maturity models

The three drivers and the ten underlying factors of the framework developed in this study can provide a basis for the further development of a 'continuous' usability/UCD capability maturity model, based on the SPICE model (Jokela et al., 2006). The drivers or (groups of) factors would then form the 'key processes' that are used in such a model. This opens up the possibility of moving from capability maturity models that score organisations based on whether they execute what are considered 'best practices' to a model that uses the underlying factors that play a role in creating usable products, and *then* asks the question 'what are the methods, actions or circumstances that can influence these factors positively?' For example, in a number of the older UCD capability maturity models, an organization that does not conduct user testing in the final stage of product development would have a low score. However, if that company has an online service and does extensive online A/B testing instead of user testing, they still acquire knowledge about which design works best for users, and that is what we are aiming at. So, the framework of drivers of usability in practice can, by providing an overview of the goals, provide a theoretical foundation for improving usability capability maturity models, and in future research, in cooperation with practitioners, the factors mentioned could be linked to 'best practices'.

6.3. Transferability: drivers in design for X?

Design for usability is an instance of 'design for X' (see e.g., Eastman, 2012; Mørup, 1993), where X can refer to any design goal at any stage in a product's life that is in focus during the design of the product. For example, in design for experience, the focus is on the desired effect of a design on the 'total experience' of the user when interacting with a product (Norman, 2013). Design for X approaches typically support designers in understanding and anticipating the dispositional effects of their design decisions on the use phase of a product's life (how a user might experience the product). Alternatively, in design for manufacturing the focus will be on the desired effect of a design on its manufacturability (Andreasen & Olesen, 1990), with decisions having a dispositional effect on the production phase of a product's life. Any design project will typically have a focus on multiple 'X' areas. Design for X practices follow similar patterns (Andreasen & Olesen, 1990) and thus it can be expected that the findings from this study are applicable to other 'X' areas as well.

Therefore, in addition to testing the framework of drivers of usability against additional evidence from the UCD domain, it might also be worth exploring whether the framework can be generalized to other 'X' areas. That is, to test whether the current factors and their relations can be used to explain the manifestation 'X' areas other than usability. It could, for example, be investigated whether prioritisation, design capability and design freedom can also explain the extent to which an organisation is successful at developing sustainable, reliable or efficiently manufactured products.

7. Limitations of the study

7.1. Three embedded cases in one business group company

For our study we chose, by purpose, three embedded cases in only one business group. If the three cases (the development projects) would have been from three different companies, the case context would have differed considerably, and this would make it harder to identify factors on the project level as well as to identify repeating patterns (as the projects would differed much more), and repeating patterns strengthen the credibility of the results of a case study. However, studying three embedded cases in one business group also bears the danger that the drivers and factors identified are typical for that specific business group only. During the verification of the results we have already begun to assess the transferability of the results to business groups of the same parent company, but further research is needed to test the extent to which our results are representative for other companies, both within consumer electronics domain, and beyond.

7.2. Framework: a substantiated first step

The framework is a first step in interpreting, explaining and communicating how usability is influenced in the design and development of electronic consumer products, and requires further work to corroborate our findings. It should be considered as a description of the phenomena and must therefore correlate with reality and coincide with empirical referents as much as possible.

When developing the framework we stuck closely to the data, iterating back and forth between the causal networks of the individual usability issues on the one hand and the causal models, interviews and documents on the other hand. Second, to verify the accuracy of the models we performed a member check (Malterud, 2001b; Miles & Huberman, 1994) at the company were the study was performed. Participants in the member check considered the framework an accurate description of how usability was dealt with at AV@home.

7.3. Retrospective analysis: limitations in reconstructing timelines

Even though participants could describe in quite some detail the events that had taken place and the reasons for taking decisions etc., they were often not able to specify at what point in time or in what phase of product development these had taken place. However, as our goal was to identify influences, and not reconstruct the detailed chronological development of a product, the latter issue was not considered a substantial negative effect on the analysis.

7.4. More usability weaknesses than strengths

Much more information surfaced when discussing usability weaknesses with the interviewees than when discussing usability strengths. The interviewees were able to recall and explain much better what had gone wrong and why, than what had caused a certain aspect of the product to be very good in terms of usability. Because of this lack of information regarding the usability strengths, the results of the study apply more to usability weaknesses than to usability strengths.

7.5. Sensitising card set

The usability issues that interviewees wanted to talk about, based on the sensitising card set, were usually those that they had put a lot of effort into, were frustrated by or knew a lot about. Usability weaknesses that had escaped the attention of the interviewees during product development were usually not selected for discussion and were sometimes even dismissed as untrue after being confronted with them by the researchers. This may explain why a lack of mutability was attributed a relatively large role in causing usability weaknesses: the team members were less likely to be conscious of a usability weakness in cases where they were ignorant about the usability problem, or in cases where they perceived the problem as easy to

solve. In contrast, team members were more likely to be conscious of usability issues that had been difficult to solve, for example because there was a lack of mutability leading them to spent a considerable amount of time in trying to solve it nonetheless.

8. Conclusion

In this paper, we presented a model of usability in design practice that consists of three drivers: 1) prioritisation of usability, 2) user-centred designing and 3) design freedom.

The literature on usability and UCD has mainly focused on producing and evaluating methods for and knowledge of usability, with the underlying assumption that once practitioners apply these methods, usability will be increased. However, this study shows that just having knowledge of users and usability (part of driver 2) is not enough for successful design for usability. Product development teams also need to be able to apply this knowledge (driver 3: design freedom). Furthermore, usability needs to be prioritised within the development team and/or organisation (driver 1). We identified a large number of instances where teams were well aware of a usability issue, but were simply not given the time, budget or access to components to fix the issue. Both a development team's UCD capability and its design freedom were found to be highly impacted by the prioritisation of usability within the organisation (driver 1).

The study shows that besides methods for usability and user-centred design, there are other, contextual factors involved that can either drive or inhibit usability. These factors are grounded in the organisational context and are distinct from the design/development process and the methods of user involvement used in that process.

The framework developed provides a first step in identifying factors that inhibit the creation of usable products in product development practice, and the relation between those factors. It provides a basis for further development of UCD/usability capability maturity models.

The considerable (limiting) influence of resource allocation and of the design freedom driver suggests that when developing UCD methods, the goal should be to develop methods that lead to usability issues getting solved, instead of only getting detected.

The observed influence of the design context on the design process suggests that when developing design methods, design researchers should not only focus on the effectiveness, reliability and validity of that method under controlled circumstances, but also assess the applicability of the method in design practice.

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