From Difficult Artifacts to Easy to Use Designs

Tone Bratteteig
Department of Informatics
University of Oslo
P.B. 1080, 0316 Oslo, Norway
tone@ifi.uio.no

Guri Verne
Department of Informatics
University of Oslo
P.B. 1080, 0316 Oslo, Norway
guribv@ifi.uio.no

***Abstract*—There are many reasons why artifacts and systems become difficult to use. In this paper, we investigate difficulties as a basis for design for ease of use. Difficulties may stem from the artifact or system itself, or from the artifact or system in use in context. Technology introduces new tasks, and both learning new tasks and unlearning the old ways pose challenges. We propose that users' habits and previous knowledge are used as resources for design, and present a conceptual framework for design for coherence and simplicity from a user's perspective.**

Keywords: design; competence; ease-of-use; context.

I. INTRODUCTION

Usability is often defined as the ease of use and learnability of an artifact, sometimes narrowed down to specific users in a specified use context having specific achievement goals (e.g., ISO 9241). But what does "ease of use" mean more precisely? Nielsen [1] lists five aspects of usability: learnability, efficiency, memorability, low error rate, and satisfaction. Shneiderman and Plaisant [2] present a more elaborate list of eight aspects: consistency, universal design, feedback, closure of dialogs, reversal of action, control, error prevention, and memory load. Except for universal design, all the aspects are general and concern the design of the artifact seen as a stand-alone context-independent thing. Our research shows, however, that it is difficult to achieve a total independence of contextual design elements – it is impossible and even unwanted: "All products make some reference to either products extant during previous generations or products from different companies or product families." [3: 182]. Such references are important to build on when trying to understand how to use the product. Even well-designed stand-alone artifacts can be difficult to use for users not sharing the contextual competence pre-supposed in the design. We have seen this in our research, where we focus on elderly people and the technological support that is supposed to enable them to live independently in their homes longer [4]. In this paper we discuss how knowing how technology is difficult to use can be a basis for designing solutions that are easy to use.

The paper is structured as follows: In Section II, we give a review of literature about problems in using technology. In Section III, we present reports from two studies of use of technology: the use of public services like tax, and the use of common home artifacts like remote controls or mobile devices that need charging. Section IV discusses the competencies needed for users to use an artifact, as well as how such competencies are experienced and embodied. In Section V, we discuss how we can go from knowing about the difficulties people have in using an artifact to designing an artifact that is easy for them to use. Section VI concludes the paper.

II. PROBLEMS WHEN USING TECHNOLOGY

A close study of people using IT artifacts reveals that they often find technology difficult to use [5]. A classic study is Suchman's study of use of a Xerox copy machine [6][7] demonstrating how operating a copy machine was difficult due to the difference between the scripted "plan" in the copy machine and the users' (situated) understanding of copying. Another classic is Gasser's study of how people work around computer systems that do not fit the work they need to do, show that people carry out their jobs also with non-supporting artifacts [8]. Even when an IT system works well, it may not work well together with other systems [9][5].

A different set of studies shows that an artifact can be used in different ways, e.g., Barley's classic study [10] of a CT scanner: the same technology used differently in two radiology departments demonstrates that the same artifact can be part of very different socio-technical practices.

For designers, it is particularly interesting to study the non-users of an artifact. They are, however, very difficult to get hold of (unless they can be located in a particular place, e.g., an organization). Orlikowski [11] and Star and Ruhleder [12] describe how people are not using a computer system with good reasons, indicating that contextual matters (like reward systems) may offer good reasons for not using a system – irrespective of the usability aspects of the system itself. As a way to get access to non-users of the public service web pages of the tax authorities, Verne [13] studied people calling the authorities' call centre. She found that even if tax rules are complicated most of the questions concern relatively simple tax issues and that the callers' problems are concerned with interpreting and applying the rules to their own life.

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A number of studies concerning assistive technology in the homes of elderly people have been carried out, see e.g. [14]. Noting that much of the technology is not used, Greenhalgh et al [15] focus on the subjective opinions and experiences from the elderly's own technology use. They call for a different design approach in order to develop technology that supports the elderly in achieving what matters to them and enhances the quality of their life [15]. Many of the current solutions aimed at elderly users are imported from other application areas and not designed specifically for an elderly user group, e.g., touch screens [16].

We know a great deal about systems and artifacts that are not easy to use, but what is less clear is how to get from knowing what is difficult to designing a solution that is easy to use. In this paper, we have set out to do this: we analyse a set of studies of difficult-to-use-technologies in order to arrive at design ideas for easy-to-use solutions.

III. DIFFICULT-TO-USE

Investigating people's reasons for not using an artifact is very instructive for designers: there may be a range of logical and sensible reasons for not using an artifact or using it in "wrong" ways. In this section, we report from our studies of users and non-users of computer technology.

A. *Badly designed Systems and Artifacts*

Some artifacts are difficult to use because of the design. Verne's [17] study of citizens' calls to the tax information call centre showed that many callers had tried to use the online tax self-service without succeeding. Listening in to 474 telephone calls over a period of 22 months gave a basis for understanding the callers' problems. Examples of problems ranged from not finding their PIN-code to more specific questions like a woman receiving welfare benefits and had tax deducted from her pension, but being aware that welfare pension was tax free. The call centre advisors often walk the callers through the self-service web site, commenting that the online services were not user-friendly. To callers who do not know which numbers in their tax card they need to change, reporting online makes not much difference from filling out a paper form. But online tax self-services may introduce additional complexity for the citizens.

We also include a second set of examples from a study of IT technology for independent living in a home for elderly people [14], involving sensors, alarms and a tablet connected to the Internet. We have studied their use since 2012, documenting that several of the technologies do not function well in everyday use. The tablet, for example, has a wall-mounted charger station designed to charge while showing the time (Fig. 1 upper). However, the slot for positioning the charger in the right position is narrow and difficult to see, and many users do not manage to mount it right and do not discover this until the battery is empty. Also the very common stove alarm is difficult to use for people in wheel chairs or people who find it difficult to hold the turn-off-switch while stretching and bending over the stove to turn the alarm off (Fig. 1 lower).

B. *The Artifact in Use*

Some artifacts are difficult to use because of the use context and the use situation. Verne's [17] study of callers found that many people call because they need help with matching the rules and regulations with events and circumstances in their life, not because tax regulations and rules are complicated. Her data includes several examples of simple tax rules that may represent problems when applied to a person's life situation.

* When citizens move, they are required to send a notification of address to the Population Register. A citizen called to ask if he needed to send a notification to the tax authorities when he changed his job. (The answer is no.)

*A newly retired citizen needed guidance on how her new status affected her personal economy and on which of her different types of incomes are subject to which taxes.

*A house owner who earned money from renting her house asked if renovating costs could be deducted from her tax. She rented the apartment to her son, and wondered how the rules were applied in this case.

In all three examples, the life situation or circumstances of the citizen triggered the phone call. In the first example, the caller's life situation was irrelevant to the tax regulation in question, but in the two others the life situation needed to be matched with the rules and regulation by a tax expert.

Our second set of examples is from everyday technologies used by elderly people in their homes. We found that these types of difficulties arise when people use technologies that they do not have previous experience with. One example is an active woman, approximately 85 years old, who uses a hearing aid. She is well organised, educated, and has had an active work life, and she uses e.g. her TV effortlessly. Her occupational therapist has tried to teach her how to use an amplifier for her hearing aid: a wireless microphone that amplifies sounds and submits to her hearing aid.

Figure 1. Welfare technology: Tablet charging (above), stove alarm (below)

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The "accessory pen" is easy to use once fitted to the hearing aid: the manufacturer says that it is "zero hassle" because it is "completely simple to use, with one-click connection of receivers and fully automated settings" [18]. Using the pen involves pushing one small button in addition to charging it. However, the old woman finds the pen difficult to use. She does not remember how to use it from one therapist visit to the next. She wants to charge it before she uses it, but forgets. The occupational therapist (whose job it is to adapt support devices to individual users) has suggested that she instead charges it after she has used it, and that she keeps it in the charger until the next time she needs it. But in the "old days", keeping devices in the charger can be dangerous, and the old woman therefore does not want to do this – even if the therapist assures her that with this equipment there is no danger. The old woman often finds her hearing aid amplifier not charged when she needs it.

C. Other's Doings

Some technology problems are caused by factors outside the user's control, e.g., by actions or errors made by third parties. Some callers to the tax information call centre had a problem getting too little welfare support because the welfare agency "tidied up their systems" and deducted 50 % of the benefits because of a missing tax card. The tax authorities receive many calls from people who have not received a tax card in the mail, but it is often their own doing (or rather: not doing). However, in one case the street address had been changed by the municipality, without the caller being aware that she needed to send a notification of change of address – since in this case, she had not moved!

A more complicated case was a young man who had received a bill for penalty tax for underreporting income two years ago. His employer had gone bankrupt and his reported income was disputed. There was no employer who could confirm the callers' claims, and he had no documentation for his version of what had happened. In principle, he needed to document the non-event of not underreporting income. The advisor helped him by suggesting steps to take to retrieve documentation and proceed with his claims.

The smart home technologies in the apartment building for elderly people had electricity saving automation. However, the first winter everybody experienced that the apartments were very cold, and the elderly people (who normally need higher indoor temperatures because they do not move much) had to get help from the janitor service to correct the temperature. It took a long time to find out that some of the basic calculations for the electricity system were wrong resulting in faulty temperature regulation in the building [19]. We work in a smart building ourselves and have experienced similar difficulties when trying to identify the reasons for bad temperature regulation mechanisms. When using artifacts that are part of a larger complex system, the problems a user experiences may result from other people's activities or errors.

D. What is Difficult?

Difficulties that stem from the artifact or system itself pose different challenges than those stemming from the artifact-in-context or in-interaction. We sum up the kinds of difficulties in Table 1, and indicate what kinds of challenges they pose.

TABLE I. DIFFERENT KINDS OF DIFFICULTIES WITH ARTIFACTS AND SYSTEMS, AND THE CHALLENGES THEY POSE

What is difficult?	**Kinds of difficulties**		
	Artifact	***Context***	***Activities by others***
Examples:	Holding the turn-off switch. Positioning of the charger. Online tax self services	Personal economy when retiring. Tax deductions for renting out a house to family. Tax card when starting a new job	Bankrupcy by an employer. Welfare agency "tidies up their systems". Errors made by subcontractors.
Challenges:	Difficult to use, afraid to make errors	Matching artifact with own life situation or circumstances	Disentangling interactions and complexities

IV. COMPETENCE

Competence, as the ability to do something successfully or efficiently, is important for using technology. The examples in Section III show that competence can concern the design that makes the operation of the technology difficult (III.A) as well as the adaptation of the technology to the actual situation (III.B). In both cases, the users have to do fitting work [8] in order to use the technology

A. What we Know

A usability test of a video conferencing system showed that users who did not have the same technological experience as the designers: in this case: an iPhone, did not understand the interaction mechanisms and hence had problems operating the system [20]. Langdon et al [3] discuss this problem on a more general level, showing that "similarity of prior experience to the usage situation was the main determinant of performance, although there was also some evidence for a gradual, age-related capability decline." (p. 179). They conclude that in their test of driving a new car "there was … some clear evidence that experience may be more influential than age" (p. 189). Docampo [21] has identified four technology generations: electro-mechanical period, remote control era, use of displays, and use of layered menus, basically distinguishing between before and after 1960. The generations affect learning new technology visible in a discontinuity of errors and task timings between the generations.

Previous experience is a salient feature that builds self-efficacy [22]. According to self-efficacy theory for human agency, belief in one's own competence and mastery is an important factor for succeeding. In their study of the effects of training programs in computer use for older adults, Wild et al. [23] found that after one year of consistent computer use the participants reported reduced levels of anxiety and increased self-confidence in their abilities using computers. Participants with mild cognitive impairments were less likely to demonstrate increased efficacy and competence. This is in

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line with our own empirical findings. We interviewed an ergo-therapist, who had the experience that elderly people with mild cognitive impairments were able to learn new practices, but with much training and follow-up from her.

Langdon et al [3] suggest that "prior experience with similar products and product features is a strong predictor of the usability of products over the wider range of capabilities. This similarity results from experience with same brand, or functionally and perceptually differing products, provided that key functional features and visual appearances are maintained." (p. 190). Hurtienne and Langdon [24] suggest a continuum of knowledge sources starting with 1) innate knowledge like reflexes and 2) sensorimotor experiences like speed, gravity (early childhood learning), 3) culture (everyday life), and 4) expertise acquired in a profession or hobby. Knowledge about tools crosses these "levels" of knowledge. They suggest that knowledge residing on the sensorimotor level of the continuum is basic to most people and is acquired early in life.

B. How we Know

Langdon et al found that previous experience provided guidance on how to carry out their tests [3: 182], which explained why their older test-participants were not able to use the technology, rather than they having lower cognitive capability as a result of ageing.

Using technology is also a bodily experience. Höök [25] discusses bodily ways of knowing in her study of the challenges she experienced when learning the English style of horseback riding having experience from riding Icelandic style. The horses are trained to react differently to signals (from the legs, hands, body posture) from the rider in the different riding schools. Competence in and experience from horseback riding resides in the body and becomes more or less automatic.

Höök [25] describes how she needed to practice again and again with constant feedback from the instructor to be able to learn the new movements, positioning and interactions. Even though she cognitively knew and understood how she was supposed to move and position her body, it was difficult to *do*/*perform* the new movements at the right moments.

C. Learning and Un-learning

Höök [25] describes vividly how learning new movements and ways of communication implied unlearning the old ways. Unlearning bodily ways of knowing implies consciously and deliberately practicing *not* doing the usual activity and instead practice something new. Having learnt how and when to perform a new movement is different from practicing the old habits. Unlearning bodily knowledge requires conscious cognitive work before it becomes a habitual and automated practice.

A good example is modern hearing aids, where the wearer will need to train his or her brain to filter out noise from the sound that s/he wants to hear in order to get the most out of the hearing aid. The brain needs some years to re-adjust, and middle-aged people will benefit from using the hearing aids before it is strictly necessary. The brain needs time to allow for automation that enables the activity to take place outside of the conscious brain activity [26].

Changes in rules and regulations as well as in the technology for doing taxes introduce new tasks for the citizens. In 2008 was submitting the tax return form made optional in that Norwegian citizens could just accept the figures that was already gathered by the tax authorities and presented in a pre-completed form. Accepting was done by a non-action: by *not* making changes in the pre-completed form. Hence, learning to differentiate and understand when to report changes has become a task. Many of the callers were not aware that they did not have to send in a paper form, and that they could report online [13]. In practice it can be difficult to differentiate between learning new tasks and unlearning old tasks, but we argue that analytically they create different kinds of challenges.

Wu et al [27] present a participatory design project with people with anterograde amnesia, aimed at developing a "memory aid" for and with them. They base their design on the fact that "amnestics rely heavily on external memory aids, such as a calendar or an action item list." (p. 217) providing a "tool [that] will assist amnestics when they feel lost or disoriented by providing information as to their whereabouts and their *intent* for being where they are. A person having amnesia will typically follow familiar routines in their daily life, such as the same route home, because deviating from this path will often result in disorientation. Our tool enables an amnestic to grow increasingly confident and *independent* in exploring new locations and situations – a feat that is very difficult in current practice." [27:222, original emphasis].

The tool was based on the fact that amnestics' procedural memory to a large extent remains intact; therefore it was possible to train new routines and skills for using the tool. "Interestingly, the overall similarity of products that has been experienced before does not have to be high to allow effective learning" [3: 183].

Ergo-therapists working with elderly people tell that people often install electric water heaters in the homes of their old relatives in order to avoid starting a fire when forgetting the kettle on the stove. However, if the elderly person has a "bad day" and is particularly forgetful, s/he may put the water heater on the stove as a bodily habit, and this may cause fire.

D. What is difficult – seen from the user's perspective

Looking closer at what is difficult suggests a distinction between learning and un-learning tasks. We found that the sources for the difficulties were the tasks to learn and the old tasks to unlearn: the two different processes are experienced in different ways both in cases where the artifact is difficult itself and when it is the fitting of the technology to the situation that appears as difficult. We came across examples of actions and errors made by third parties, such as vendors, employers, other public agencies and other technologies. In these cases, the situation was experienced as unpredictable and confusing and not possible to explain by the user unless s/he had a deep knowledge of the complexity of the

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technology in its social environment. We sum up our analysis of what is difficult in Table II, expanding Table I with rows from this more detailed analysis of the nature of the difficulties.

V. DESIGNING FOR EASE-OF-USE

The three different kinds of difficulties can be a basis for approaching design of easy-to-use technology solutions. In this section, we report from some design experiments with elderly people [4][14][28][29] as well as our own design suggestions based on analysis of identified user problems [17].

Designing from the users' perspective starts with investigating their subjective experiences and competencies. Elderly users need much practice and repetition to establish new habits and unlearning old habits may be the hardest part. Unlearning may require trust to let old habits go to be sure that they are not necessary, e.g., for security. As unlearning old tasks is a challenge in itself, a design that builds on old, habitual tasks will be experienced as less challenging for the user. Using everyday technologies like radios, mobile phones, water heaters or remote controls is normally easy and often automated and habituated. Many of our memories and competencies sit in our bodies as automatic movements or perception (e.g., music, smells) and can be carried out without conscious deliberation. A design that incorporates that the user can rely on his/her old habits can make the changing of old practices more likely and the design more robust. However, designing for new habits in old age is possible, as the example of the memory aid for the amnestic people above showed [27].

TABLE II. WHAT IS DIFFICULT SEEN FROM THE USER'S PERSPECTIVE

What is difficult	**Kinds of difficulties**		
	Artifact	***Context***	***Activities by others***
New tasks to learn	Holding the turn-off switch. Positioning of the charger. Online tax services.	Personal economy after retiring. Charge device after use. Check pre-completed form	Check and act if something unusual
Old tasks to unlearn	Handling paper forms. Putting kettle on stove.	Charge device before use. *Not* pushing the horse. Changed tax rules.	Need trust to stop doing.
Basic knowledge for the task	Understand tax and web pages. Understand a water boiler.	When does the new apply?	Understanding the ecology of humans and technology
Challenges:	Difficult to use, afraid to make errors	Matching artifact with own life situation or circumstances. Differentiating between old and new.	Disentangling interactions and complexities.

We will exemplify the first design approach with the design of a digital radio that was co-designed with in total 25 elderly people [29]. Johnsen et al aimed to design interaction mechanisms that built on old and familiar bodily skills when designing a new way of operating a digital radio [29]. Using rotary controls for operating the radio – like in the old days – enabled them to make sense of the interface with their body even if they intellectually could not understand or remember how to turn on the radio. They easily recognized the button as a device for rotary movement. Several buttons were designed and tested for a good grip for old hands and recognizable positioning with different textures and shapes [29], see Fig. 2.

Figure 2. The prototypes for the knob (above) and the digital radio (below). Photo by Johnsen et al [29]

Figure 3. Testing several different induction chargers. Photo: Iversen [28]

In the second design approach, Iversen and Joshi [28][30] built on knowledge about earlier habits, e.g., the fact that in the old days telephones had wires and were usually located in a specific place, on a particular table by the entrance door. Maybe it would be easier to remember to charge the mobile phone if it was always put on a particular place like in the old days? As a way to provide easy charging of phones, Iversen and Joshi [28][30] collected seven different off-the-shelf induction chargers and had them tested by a group of elderly men (see Fig. 3). The trying out of different technologies was instructive to the elderly users as well as to us as designers.

Matching the artifact with the personal use situation and context represents a challenge [17][31], in particular if the artifact is complex (like tax). Showing ways of matching, e.g., by using several examples, can help the user in the matching of her/his situation with the technology requirements: s/he may be lucky and find an example similar to her situation. FAQs and help texts can provide such examples in the artifact itself, while human helpers like call advisors and ergo-therapists will have to assist if the matching is too difficult to carry out by the user alone. Graphical illustrations and simulations can also help explain complex systems like the tax system.

Fig. 4 illustrates our view of how technology influences the tasks done by a human user. Fig. 4a illustrates a loosely defined set of tasks for a particular purpose (like doing taxes) as seen from the human's perspective. Fig. 4b illustrates how technology takes over some of the tasks: they become obsolete. Fig. 4c shows the automated task area as seen from the human user's point of you: s/he encounters some left-over tasks that are not automated and some new tasks.

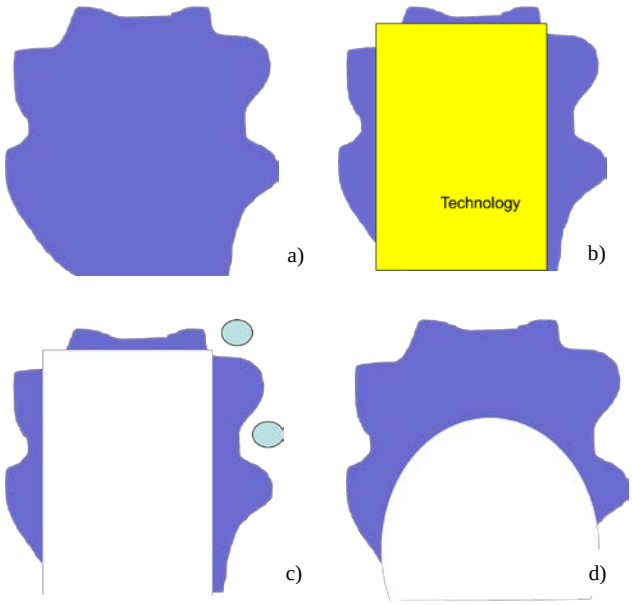

Figure 4. a) A set of tasks for a user - not clearly defined. b) Some of the tasks are made obsolete because of technology. c) Fragmented tasks left for the human user. d) A coherent set of tasks for a user.

The tasks left for the human interacting with the technology appear as fragmented and there may be no or little coherence between different subtasks. New tasks can be of a very different kind than the original set of tasks. Fig. 4d illustrates that in order to make the tasks left for the human user coherent and foreseeable, we should design a coherent set of tasks left for the user instead of let the technology decide what is automated [17][32].

Managing the boundaries between tasks made redundant by technology, tasks left for the user to do and emerging new tasks is a challenge in itself. Designing from the user's perspective aims to present the tasks for the human interacting with technology as a coherent whole and with connected subtasks. This will enable the user to disentangle the problems s/he encounters.

VI. CONCLUSIONS

Based on examples from our research on design with and for elderly people and on citizens doing taxes, we describe how artifacts and systems become difficult to use. We have reflected on how we can use knowledge about difficulties in a constructive way to suggest better designs. In the paper, we make an analytical distinction between types of difficulties according to where they appear: in the artifact / system itself or when used in its use situation / context. Our analysis also includes a discussion of the differences between learning new tasks and/or competences to benefit from the technology and un-learning old habits and practices. In addition, difficulties stemming from activities and errors made by others may occur, and in order to be able to disentangle the problem and sort out what can be done, the user needs to understand the larger ecology of the service / system.

We suggest that habits and bodily knowledge are used as resources for design where users benefit from familiarity and coherence. Building on and extending old habits instead of making them obsolete in a new design can be experienced as very simple for the user – independent of any usability assessment based on criteria that are external to and irrelevant for the particular user in the particular situation. Our aim has been to present a conceptual framework for design for the user's subjective perspective.

Our conclusion is that "easy to use" is difficult to design, and that the notion of "ease-of-use" hides the complexity that comes when artifacts are used in real life contexts. Both the identification of what makes things difficult and what turns out to be easy to use challenge a notion of "usability" that looks at the artifact as a de-contextualized object. Easy to use is a characteristic of the relation between a user, her/his activity and the technology that supports that activity. It is thus both situational and personal. This makes it even more challenging to go from what is difficult to use to designing easy to use artifacts.

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