Designing for other people's strengths and motivations: Three cases using context, visions, and experiential prototypes

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ABSTRACT

The front end of product development has seen a rapid growth in attention for the end-users. For radical innovation, as well as for redesign and optimization, design teams are looking to incorporate the experiential knowledge of users into the design solutions. By means of three cases, we describe participatory techniques in the early phases of design, and how they impact both the content and the methods of designing. Key elements in this are found in the establishing of needs, requirements, design visions, and early experience prototyping. But these different steps are no longer clearly separated, as iterative prototyping with user participation throughout the design process is becoming a more regular approach to designing.

1. Introduction

The focus in product design has in the past decades shifted to depend more and more on understanding users [7]. From the 1980s, focus groups and usability tests of products and concepts with users in laboratory situations became widespread practice; from the 1990s, perceptual and emotional factors became prominent for the success of new products and product-service combinations, and in the past decade, the participation of users as prime sources of information and as collaborators in the early phases of idea generation (co-creation) or throughout the design process (co-design) is on the rise [25,15].

A number of trends in product development have brought about this greater attention for research about, and *with*, users. Prominent among them are the emphasis on 'experience design', especially in highly competitive areas, and the increased complexity of products, especially in areas related to Information and Communication Technology (ICT). As in other technologically mature areas such as automobiles, in areas of ICT products, such as digital consumer electronics, competition on technological and cost factors has saturated: most competitors can also make a car that lasts long, is acceptably safe and economical. Moreover, in ICT specifically new types of functions are emerging, which go beyond replacing existing ones by digital equivalents. These new functions deeply impact our everyday lives. Mobile phones are not mere portable version of the old telephone. They have changed the way we keep in touch, make appointments, and structure our personal and professional lives in general. As a result, making a difference to the buyer of the product requires a tighter fit to, and understanding of, the user's need [6]. Next to manufacturing, hardware and software constraints, there is expertise on services, sales, infrastructure, environmental sustainability; on the user-centered side, specialisms from psychology, anthropology, ethnography, sociology, and theatre and cinema-related disciplines are finding their way in the design of both digital and traditional mechanical products. In the center of this process, tying together the inputs and requirements, solving conflicts in overlaps, spotting black spots in the available information, and coming up with new concepts to match those needs, stands the new design professional or, more often, the new design team. And to support the design team, new methods are needed to cope with the issues and complexities of modern product design [17].

Companies worldwide, and design educations, are struggling to find methods and approaches to cope with the new demands on the design process. Key difficulties are designing for other people's experiences, which involves dealing with complex, multifaceted problems. Moreover, design is addressing aspects of user worlds which are no longer easy to formalize in verbal lists of requirements. Especially affective and social issues, and interaction design aspects of timing interactions and transitions are difficult to conceive [3], develop, or communicate with traditional tools as the product sketch, the CAD-cross-section, or the software specification.

A range of new techniques have been developed (and are still in development) to cope with those issues. Approaches such as

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vision-based design, design-from-context, and iterative user-centered experience prototyping, are finding their place in the design toolbox. Most prominently, these techniques have been used by large international companies as Apple, Microsoft, and Philips, design research consultancies such as IDEO and Sonic Rim, and academic research centers in the USA, Europe and, recently, East-Asia. In the area of electronic devices, the branch of Interaction Design has already emphasized the focus on people and prototyping [9], and the need for design professionals to become proficient at visualizing experiences, rather than static product forms [3,26]. Small and medium enterprises, whose research budgets are much more limited, are recognizing the trend, and are currently beginning to pick up on the techniques, too [25].

In this paper we describe how these changes, which occur most rapidly in the high-tech product/service industries, are dealt with, using three cases of user-intensive concept design from the new Master programme Design for Interaction at TU Delft [23,24]. We explain, illustrate, and elaborate on a number of new elements in human-centered product design. At the end in the conclusions, we discuss how the deployment of these techniques challenges established understanding of the design process, the roles of its players (designer, user, researcher), and the way design research is conducted.

2. New approaches

The above described ingredients (the new possibilities of designing from context, continuous user involvement, and experience prototyping, how this approach fits in the spectrum of human-centered design research, and the importance of visions, i.e., positive statements of design intention in design thinking) get a place in the emerging approaches of design. These approaches are deployed with the following aims:

- Support radical innovation by designing from a contextual vision, rather than a pre-fixed product aim.
- Leveraging the wealth of design-relevant knowledge that is inside users.
- Enabling communication with all stakeholders, including users and the broad variety of other experts that are needed in the design of experiences, or of functionality in increasingly complex systems, as in ubiquitous computing.

The background ideas of these developments are described in Section 2; their use is illustrated in three design cases in Section 3.

2.1. Vision-based design

An important technique in designing new products is to postpone the focus on products. Increasingly, innovation projects start not from a single technological innovation, but from a set of possible technological (and other) ingredients. In order to achieve radical innovations, designers avoid focusing on possible products, but develop their ideas for products in a sequence of stages, beginning at a contextual level, through a user-product interaction level, down to the product level.

In the Vision in Product design (ViP) approach [5], three levels are distinguished: context, interaction, and product, and the design process proceeds in that order: the designer first create a vision of what a future context for the product use should be; within that context, a vision for the qualities of the user interaction is developed, which forms the framework for the development of a vision of the product (see Fig. 1).

The notion of a 'vision' in this is also different from the classical 'list of requirements': it is a positive statement-of-direction or pos-

sibilities, rather than a negative statement-of-constraint. One reason for that is that designers (as all humans) are better able to think in terms of a goal to reach, than in terms of forbidden zones to avoid. To avoid fixation on existing product solutions, the vision progresses from top to bottom, starting from contextual principles, and ending at the product level, by way of user interaction qualities.

2.2. Designing from context

Two forces of innovation are commonly distinguished: the technology push and the market pull (e.g., [18]. Product design relying exclusively on the former can lead to 'technological tricks in boxes with a button'. The latter, taken alone, caters only to the needs of people on the level of explicit needs. The competition on user qualities has created a third force, which can be called the 'contextual push', in which new products which address tacit and latent needs come about, not through a new technical possibility, or a visible demand from buyers, but through increased insight in the needs and dreams of possible future users. These insights can, of course pertain to existing products and their buyers, but more often lead to new products for which no buyers existed yet (Fig. 2).

Key lesson in this is that everyday people, if involved in an appropriate way, are a rich source of experiential knowledge, and are eager to participate in a design project if their expertise receives appropriate recognition.

Sanders [15] gives an overview of approaches to human-centered design, distinguishing two main directions of developments from the traditional human factors forms of user-centered design research. One direction concerns the role of the user, the second direction concerns the type of research. First, in participatory design, the user is not a passive respondent who gets to tick boxes on precisely-specified forms, but can have influence over the direction of the design process, by taking part in discussions, volunteering observations and ideas. Second, the new types of research, such as cultural probes [27] and generative tools [14,16] make use of designerly ways of research by creating expressive tools with which users can observe, remember, and reflect on their present, past, and future experiences. The value of the responses is often more in generating new questions and opportunities, than in answering old questions; this type of exploratory research can benefit from designerly ways of research, and more active role of users.

With the term 'contextmapping', we refer to techniques in which the user takes on the role of 'expert of their experience' [20], and is given tools and a process to express their tacit and latent knowledge. Fig. 3 shows an example of one such tool and technique, a self-observation and reflection exercise and a present-on-TV technique for helping shy people to take on the role of expert [10]. Besides supporting the participants to express themselves, these techniques help to motivate participants in several ways: by showing that their input is used by the design team, by explicitly (naming them) and implicitly (quoting them) giving credit to participants, these people feel co-owner and co-creator in the design process [12].

Through qualitative analysis and a variety of communication, expression, and idea development actions, the input from participants is either shared with the design teams, or applied by the design researchers (if they are designers) themselves (see Fig. 4). The information sources produced can be informing (and inspiring) for determining the functional and affective needs, and implemented in various activities in product design, including idea generation, concept development, concept testing, detailing, and marketing.

Long-term user participation, from early exploration, through idea generation and concept development, detailing and marketing is an approach known as co-design [15]. Most often, for reasons of
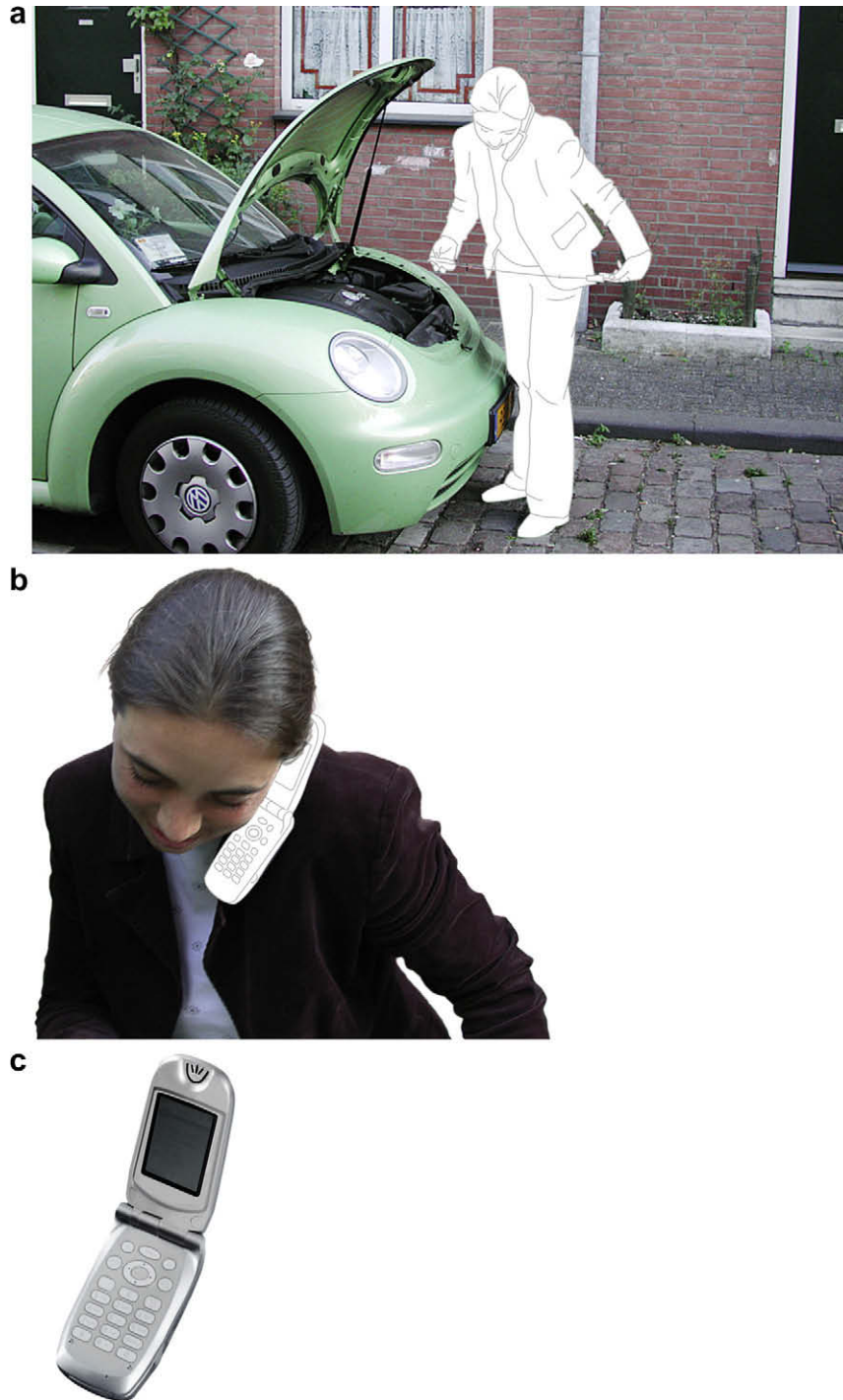
Fig. 1. Designing from context: an example of designing a product or service to synchronize business and personal activities.

practical organisation, different participants are involved in the different phases, rather than having the same users come back again and again. Another reason for bringing in 'fresh users' for concept evaluation is to avoid fixation on a small group of early participants, and thereby increase the validity of the evaluation process. On the other hand, Sleeswijk Visser and Visser [21] have shown that participants from explorative and idea generation sessions can fruitfully recall and apply their earlier insights later in a concept evaluation, and some have even deepened their insight, bringing in fresh views in the inbetween period. Users feel appreciated if they are asked again, and are highly motivated to contribute.

2.3. Prototyping for experience

A general lesson in engineering is that working prototypes and models are important for gaining confidence and providing proof-of-concept, also in early phases of a development project [19,9]. To help designers empathize with the user's condition, Buchenau and Fulton Suri [2] have advocated the use of 'experience prototypes': props or environments that can help the designer experience his environment as the user would do. Moreover, 'prototypes for experience', which are not necessarily technically complete or robust, but sufficiently worked out to support a convincing user experience, are important tools, not just for evaluating a concept, but also
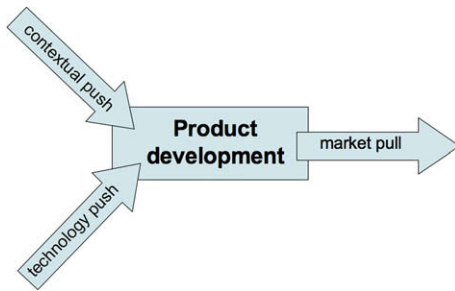
Fig. 2. Three forces on new product development.

for the preceding activities of discussing and exploring ideas. With prototypes, the design team can speak 'the language of everyday experience', which is the major shared channel of the team members. Moreover, making an experience prototype forces the designer to address issues which can remain hidden in sketches and technical designs, and interaction with those prototypes often shows up both problems and opportunities that were overlooked before [22,8]. Buxton [3] argues strongly in favour of continuous explorations with prototypes of different levels of complexity and refinement, starting very early: one can create and experience an interactive paper interface in two minutes with nothing more than, e.g., post-its and a pen.

3. Three design cases

In this section we present three design cases which followed the above-mentioned approach. The cases were graduation projects of students of Design for Interaction, a solo project conducted by the student in a period of approximately 6 months [24]. We chose for graduation projects, because these are conducted in situations close to, or in, industrial practice of product design (as opposed to academic research projects, which often have a much further horizon), and can be reported upon (as opposed to industrial projects, which are often confidential). Each of the cases followed a similar structure, illustrated in Fig. 5. Each case featured a user group requiring a distinctive effort for the designer to 'step into the user's shoes'. In each case, users participated first in a context-mapping study, and later used the experiential prototype in his or her home. The prototype was built on design vision formulated at contextual and interaction levels, and served a dual purpose: to validate earlier assumptions, but also to further explore the various situations of use. Also, in each of the cases, both affective and functional aspects were taken into account, and the design was aimed to work with current or just-around-the-corner technology. Table 1 gives an overview of the cases.

3.1. Family gallery

Families keep arrangements of cherished items, such as photos and souvenirs grouped together on the mantelpiece, which give meaning and a sense of personality to people's homes. This project started from the brief 'find new ways in which ICT media services can serve social and affective contact in families'. The process consisted of three main phases: exploration, conceptualization and refinement, each phase involving users, which were families living in the South-East England.

The initial field observations found that all four participating families kept clusters of cherished products. Initially we called these 'home altars' as these were at fixed locations, and treated with special care. But after the contextmapping study insight into the users' motivations led us to call it 'knick-knacks on display'. This name stresses the mundane character and ornamental value of the objects.
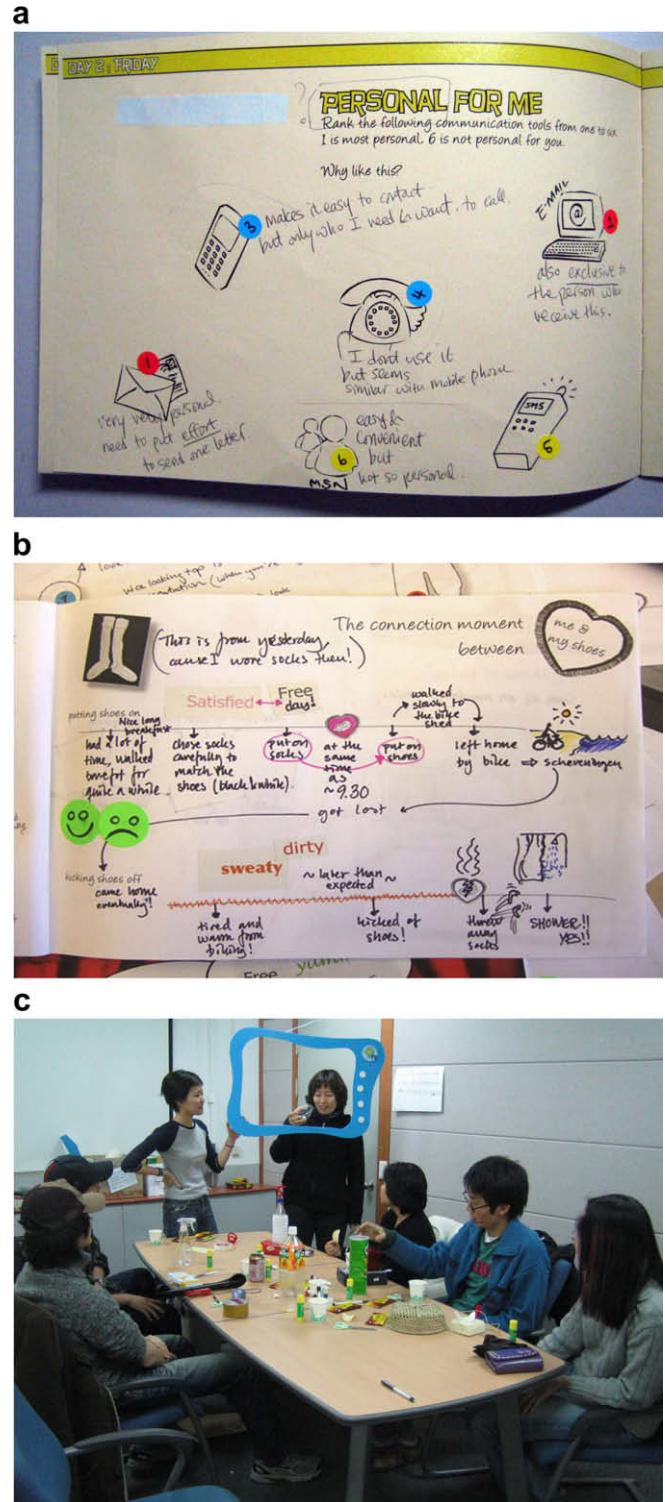

Fig. 3. Evocative techniques include homework books with expressive exercises, and techniques for easing the expression of private opinions.

It was found that knick-knacks clustered together often had a shared relationship, e.g., shared a meaning or aesthetics, but that these clusters become like wallpaper after a while. But after a time their familiarity breeds invisibility: the cherished items no longer act as memory cues nor as signs of social relationships. Findings from the participatory field study and the preceding literature study were translated into a design vision, which gave direction to the whole project, on how the designer wanted to react to these factors:

Fig. 4. Infographics and personal cards are tools that use words, images, and stories to consolidate insights and convey user experiences to design teams.
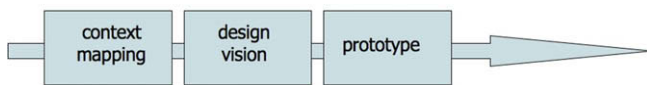

Fig. 5. Progression of user-centered design process, beginning with mapping the context of use, and proceeding by the combined exploration and evaluation with prototypes in real-life situations. The key direction-giver in the process is the design vision, and users are involved throughout the process.

the designer wanted to let people combine cherished stuff, both digital and physical, in dynamic clusters, to make them think more often about the memories and relationships these things denote and so keep memories vivid and contacts alive.

Ideas and concepts were developed based on this vision. Three concepts were developed into quick and dirty 3D sketches together with storyboards, which showed possible interactions with the concept. Three families from the original field study were asked to act out the interactions with the products and to make their own storyboards of how they saw the product fit into their lives. From this it was found that one of the concepts was completely off target. This one was discarded. The decision between the other two was proved more difficult. Participants liked them equally, although the concepts were quite different in spatial arrangement, and in social meaning (see Fig. 6). The concept with a vertical orientation invited social interactions, whereas the concept with a horizontal orientation invited more personal contemplation. The 'vertically oriented concept' was chosen because it matched the designer's vision best: more than the other concepts, it invited placing physical stuff on to it and combining it with digital media.

Insights from the concept evaluation, together with the vision made earlier, were also used to refine the chosen concept to the final design of 'the Family Gallery', shown on the right in Fig. 7. The Family Gallery can be used to display and cluster physical stuff together with digital items such as photos, movies and text messages. It consists of several open boxes that can be clicked together into different configurations. The box itself acts as a shelf on which physical items can be placed and a screen in the back can display digital files. The digital files can be sent to it by Bluetooth, SMS or e-mail.

A fully functional prototype was built to evoke the experience of having the Family Gallery in one's home. For practical reasons, the layout of screen-boxes was simulated by one large computer screen with boxes glued together and placed in front of it. Although in many aspects, such as size and material, this prototype differed from the real concept, the basic experience was evoked very well.

Table 1
The three cases.

	Primary user group	Connected users/ stakeholders	Type of user boundary to be crossed	'Task' or activity	Student designer	Product outcome
3.1	English families	Other family members	Cultural (Dutch– English)	Keeping family mementoes alive	Annet Hennink	'Family Gallery' digital media & physical things
3.2	Grandmothers	Grandchildren	Age	Keeping family contact	Sanne Kistemaker	'Piece of family', a weblog on TV
3.3	Children with autism	Parents and pedagogues	Severe autism	Children learning their first 500 words	Helma van Rijn	'LINKX', an interactive word block toy

Fig. 6. Two of the concepts, showing a horizontal (left) and vertical (right) arrangement of objects, which leads to private and shared displays, respectively.

Fig. 7. Left: a participant showing knick-knacks in the ethnographic exploration of contextmapping; right: the final prototype of the family gallery in participants' kitchen during evaluation.

This prototype was placed into the home of one family of four persons (which had participated the previous studies) for two weeks. During this trial they were asked to make pictures of the prototype every day to verify whether or not the clusters of cherished knick-knacks and digital items became dynamic, which was stated as in the vision. After the two weeks, the designer visited the family for a final interview and generative session. This gave insights in how the Family Gallery was used and experienced by the users. It underlined many of the findings from the concept evaluation study, but also gave new insights which were not anticipated by the designer on forehand. For example, the family members made extensive use of the different types of media for self-expression. Furthermore, every family member had much more editorial power than they had with the current knick-knack clusters in their homes. The fact knick-knacks can be meaningfully combined with digital media made the product different from any other digital product according to the participants.

The formulation of the context and design vision served as a crucial element in this design process: it gave direction in all subsequent stages. Consulting users throughout the whole process guided the designer, grounding her vision in the situation of use, yet making the final design innovative, appropriate, and appealing.

3.2. Grandma's weblog – no computer needed

Elderly people live in a shrinking social world; they tend to focus on their immediate environment and therefore contact with others, friends and acquaintances, decreases. At the same time they are in need of contact and often feel lonely. Besides this, the elderly are not adopting new trends and developments with respect to communication [1], such as mobile phones or the Internet, but their children and grandchildren do. For this reason the elderly often feel excluded from the new digital world. For many elderly, their family is their world, but their younger family members are often busy and have a life of their own. Because of all the new trends and developments in the area of contact, the younger generations tend to go faster and the older generations seem to go slower. This way, a 'contact gap' is created between the elderly and their younger family because of the difference of 'being online or not'.

Two families of three generations participated in the project. Throughout the design process there were several moments of contact. In an intensive process, the small group of end-users could be 're-used' several times. This way the users became real experts and felt valued when giving their opinion and telling their stories. When working with elderly, trust is very important. All users were selected via friends and acquaintances of the designer, which facilitated acceptance and communication. One of the families participating in the user-study was the designer's own family, which brought the advantage of rich background knowledge already present, but the risk of ego-design. The designer enjoyed to learn more about her own family, but it took extra effort to stay focused on the important information. To promote this critical attitude, and supply independent information, the second family participated. The users participated in interviews and a contextmapping study to map their experiences on keeping in contact (Fig. 8). They co-cre-

ated the concept by giving feedback on ideas presented to them in the form of storyboards, play-acting and low-profile prototypes and also generated new ideas themselves. Later in the project, they 'lived with' the working prototype over an extended period of time. Direct contact with the potential user is very important in order to understand them; who they are, what their activities are, to gain insight in their daily life and even their emotional and cognitive characteristics.

The context factors on which the design vision was built were derived from the findings of the contextmapping studies, literature research and current developments and trends. The key ingredients in the context vision were:

- Fast versus slow – there is a big difference in communication speed and frequency between the elderly and the youngsters. Visits to grandma can feel like an obligation; the youngsters are so used to fast contact and modern techniques, that their grandma can seem so slow and 'old'. For the same reason, elderly often feel excluded and more oldfashioned than they are.
- The need for social contact will always stay. Live and face to face contact will always stay important next to a communication tool.

These elements were integrated into a vision:

I want grandparents and grandchildren to invite each other to glance into one another's life, in order to learn from each other's life and stories, which are both so different, but so interesting.

With this goal in mind, a communication tool called 'Piece of Family' was designed for elderly people to communicate with their family, without using a computer (Fig. 9). It is a book with a scanner in the cover and a notebook inside on which stories can be written or photos can be placed. With one touch, the page is scanned and uploaded on the Family Weblog, so it becomes visible for the entire family. The family members can respond to the stories via Internet. The elderly can accordingly review the web-blog on their television and scroll through it by a special, but simple extension to the TV's remote control. (The design won first prize in the category Design for All at the Dutch Design Awards 2007, for including all ages in one simple concept and connecting three generations of one family).

The working prototype was tested by the three families. The elderly needed time to get used to a new product in their home environment, but after a few days started to use it naturally. Each of the participating families found they could readily work with it, and felt that it could strengthen family ties ("We think it's a fantastic thing, we really believe it strengthens family ties, we saw it this

Fig. 9. The working prototype consists of a notebook with a scanner in its cover, and a small extension to the television's remote control.

week. And we also loved to see how the other family members responded to each other, really nice.", said one couple, aged 75). We expect that the main reason for this success lies in the fast, but asynchronous, way of communicating, everyone using his or her own communication style, fitting the daily lives of all three generations. Especially reading about each other's daily lives and sharing pictures in a fast way was experienced as a valuable aspect of this product. Remarkably, all elderly appreciated receiving photographs: a photo of a flower felt like receiving a bouquet and photos of a grandson's home in Zürich felt like making a trip to Zürich. The elderly felt pressure of writing very neatly since the messages of their family members were so neatly typed and readable. This resulted in writing the messages slowly and carefully. A second remarkable observation was that all family members experienced grandma as being at the heart of the family and this way of communicating respects that family structure by letting grandma being the initiator of the weblog. The evaluation also pointed out the limits and deficiencies in the current implementation, e.g., that
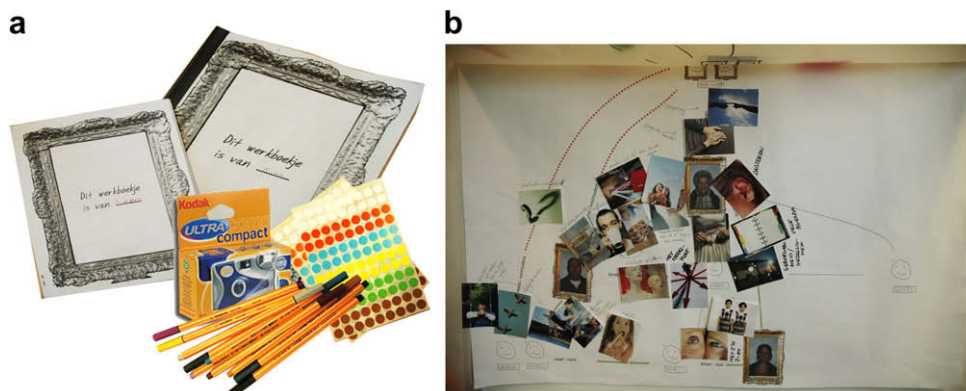
Fig. 8. With the help of generative toolkits (left), participants expressed their opinions and memories (right); the making of such artefacts generates awareness and provides a framework for expressing underlying needs, values and dreams.

grandma's messages currently should appear uncomfortably small on the TV-screen, making it difficult for the elderly to read back their own contributions.

As in the previous design case, contextual insights led to the design vision (connecting to the children's internet world, but at grandma's pace, and with a familiar interface integrated into her world), which guided the use of technology in the prototype.

3.3. Learning toy for children with autism

Whereas both the previous cases dealt with groups which were different from the designer, but with which the designers could have relatively straightforward spoken contact, the case of designing a language-learning tool for children with autism was different. Observation techniques, working with the children, and speaking with the parents and pedagogues formed the ways by which the designer/researcher learned about the experiential world of the children, which is fundamentally different from how most of us deal with the world (see, e.g., [13,4]. The used techniques are described in more detail elsewhere [10].

Three families volunteered to participate in the project, each consisting of a child and its parents. The generative techniques in the contextmapping study of creating artefacts (Fig. 10) and explaining them worked with the parents and pedagogues, bringing out many rich stories from the life of these families, and the difficulties of teaching language to these children. In several sessions with the parents and the children, the designer/researcher created an image of the way in which these children deal with the world, what motivates them and what disrupts their activities. This led to a design vision, consisting of several elements:

- The children need to feel in control. This means their environment should hold no surprises, be predictable, and, where possible, they should physically initiate the interactions. They enjoy repetition.
- The children sensory sensitivity is much higher than that of other people. They perceive little details, which can please or annoy them. They enjoy sensory stimulation from colors, sounds, and physical pressure.
- The children have difficulty generalizing and thereby applying what they learnt. By letting them learn words of objects in their home environment, the children can learn to meaningfully use language as well as understanding what a word means.

These insights were developed into a design vision, and into a set of guidelines [11], and a working prototype, named 'LINKX', was made that instantiates the guidelines. LINKX, shown in Fig. 11, consists of name-tags and linking blocks. The name-tags are fixed to objects in the home environment, such as the table, a chair, or a door. The parents can speak the name of the object into the tag, and each tag lights up in its distinctive color. When a block connects to a tag, it 'sucks up' the light from the tag, and the name is spoken aloud. Every time a block touches another block, or a tag, this name is repeated. The lights, sound, and weight of the blocks give sensory reward to the child's actions of making the blocks touch.

In several trial sessions, the concept was tried out with the children and parents. All of the children greatly enjoyed linking the blocks again and again, each time giving a sensory satisfaction of color, control, weight, and sound, and repeating the spoken word. With the help of their parents, some of the children learnt to associate the words with the objects, but the sessions also showed the limitations of the current model, strengthened and deepened the insights from the early part of the study, and served to direct further development and guidelines.

An important value of the prototype is that it showed the possibility of using tangible interaction in computer-supported language learning. Conventional approaches, which typically make use of on-screen applications where children click on pictures depicting generic objects in generic environments, do not work for these children, who have great difficulty in forming categories or recognizing symbolic representations. Bringing the computer into the everyday objects is a new approach, which suits the experience of these children much better.

In this case the direct contact and prototype were essential elements in exploring the concept. Whereas in the other two cases, a convincing argument might be made with the help of scenario evaluation techniques or storyboard evaluations, none of these techniques are applicable for this difficult-to-reach user group.

4. Discussion and conclusions

These three design cases in this paper exemplify the recent trends in human-centered product design: the contextual push, the going together of affective and functional factors, long-term user participation, an importance of formulated visions to guide the product development, and a continuing learning process in which experiential prototypes are created not only to evaluate a concept, but to explore and refine it. In the tuning of the prototypes, new things are learned which gain in importance by viewing them in the perspective of the field study. This affects not just the
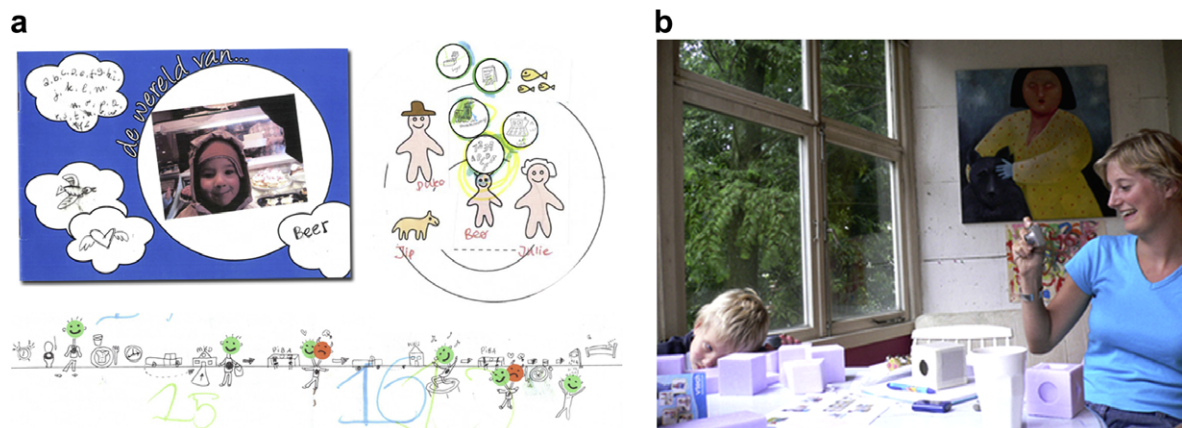
Fig. 10. Artifacts made by a mother of an autistic child explaining the needs, feelings and experiences of her child (left). A participating child playing with early prototypes of the concept design (right).
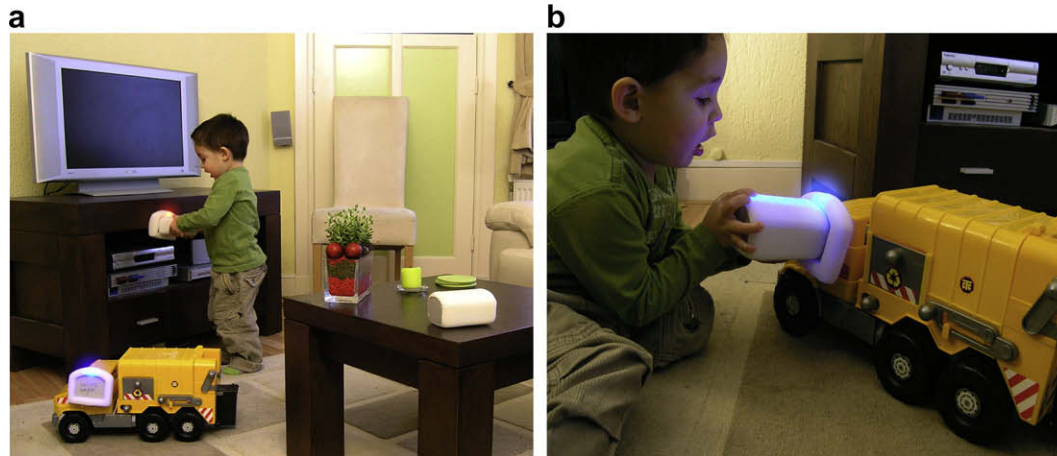
Fig. 11. The working prototype consists of name-tags and interactive blocks. By linking them together a child hears the word. (Left) The block says 'cabinet, (right) the block says 'garbage truck'.

process of designing, but also content of the design concepts generated, and the very goals that designs aim to realize.

The goals in the design brief of these projects did not mention a specific product or service. Rather, it defined an intention on the level of user's lives and experience. A thorough exploration of the user's context, including functional and affective aspects, formed the basis for the design vision, which provided a perspective and framework for the later development. It was the vision on user context and interaction which determined the selection from available technologies (contextual push). In the case of the Family Gallery, it was the basis or deciding between concepts that were equally appreciated in the user evaluation.

The projects also show that the steps of exploration and evaluation, of design and research, have merged. Making the prototype itself was used more to guide concept development, and its deployment in the user's lives a way to explore those lives more fully, than that it served as a 'physical hypothesis', to be proven or rejected, as it is seen in most rational models of design.

Similarly, the roles of user, designer and researcher are overlapping, maybe merging, although that is not so apparent in these cases, where the primary researcher was the designer herself. But the acts of designing and researching are highly interwoven, and difficult to separate.

In all these projects, user evaluation of the prototype was not a quick half-hour confrontation of an unprepared user with a finished concept design, as is still often the case in industrial practice. Instead, users had been prepared and sensitized to the meaning of the project for their lives in a longer period, and thus could contribute from their experience to a much deeper degree. Indeed, time and again the researchers in us were surprised at the eagerness and level of expertise that everyday people can bring to bear, when given the right tools.

The cases are representative of those conducted in high-end industrial practice, and indeed were carried out in collaboration with leading industrial and academic research laboratories. As student projects, however, they are not in all respects indicators of the emerging practice. On the one hand, the projects were conducted by a single designer-researcher; most industrial projects are more complex, because large teams are involved, greatly complicating issues of communication and coordination. On the other hand, the projects are highly research-intensive, and only affordable for the larger industries or academia. As Wakeford [25] mentioned, also small and medium enterprises are in need of the new design techniques. Further research should focus on and making them applicable and affordable to smaller companies, and to smaller projects.

Moreover, in this paper we have discussed almost exclusively the new force, the contextual push, and said very little about either the technology push or the market pull. This is not to say that those two forces are unimportant: indeed, the designers in these cases were very well aware of both the available technologies, and the (longer-term) market perspectives of their projects. But the latter two ingredients served as 'fields of opportunities', rather than giving direction to the design process. We expect that in the next decade, the field will learn better on how to integrate the three forces in understanding human-centered product design.

Acknowledgements

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