The Role of Subjective Well-Being in Co-Designing Open-Design Assistive Devices

Lieven De Couvreur [1,*], Walter Dejonghe [1], Jan Detand [1] and Richard Goossens [2,3]

[1] *Industrial System & Product Design, Faculty of Engineering and Architecture, Ghent University, Belgium*
[2] *Applied Ergonomics and Design, Faculty of Industrial Design Engineering, Delft University of Technology , Delft, The Netherlands*
[3] *Department of Neuroscience, Erasmus Medical Center, Rotterdam, The Netherlands*

In this paper we explore the role of subjective well-being within the process of *making together* a personalized assistive device. Through a process of social product adaptation, assistive artifacts become part of occupational therapy and co-evolve with clients. Personal digital fabrication tools enable small user groups to make and share their one-of-a-kind products with the world. This approach opens up new possibilities for disabled people and their caregivers to actively engage with their own skills and challenges. The paper describes a case study of an inclusive participatory design approach, which leads to qualitative occupational experiences within the field of community-based practice. The aim is to show how the process of collaborative designing, making and using artifacts fosters several elements of subject well-being in itself. The starting point of this open design process is a threefold interaction involving industrial designers, patients and occupational therapists within their local product ecology. Co-experience driven design is an intersubjective process that enables all individual stakeholders to work on a common phenomenon in respect of each subjective experience. Participatory prototyping is applied as a mobilization medium that (a) coordinates and (b) motivates design actions towards collaborative well-being equilibriums. This form of artifact-mediated participatory design embodies simultaneously (1) a communication language between all stakeholders that identifies meaningful goals, (2) an explorative process to attain and challenge these goals, (3) a selection of meaningful and engaging prototyping activities and (4) an appropriateness process with local skills and technology. By implementing this creative process, disabled people and their carers become conscious actors in providing collaborative maintenance of their own physical, mental and social well-being.

Keywords – Assistive Technology, Co-experience Driven Design, Design for Subjective Well-being, 'Double loop' Learning, Flow, Participatory Prototyping.

Relevance to Design Practice – This paper suggests a process-oriented approach towards the role of subjective well-being within participatory design. What stakeholders' knowledge and skill set are required, how can they be engaged and how can they challenge and direct a creative process in a meaningful way? We discuss subjective well-being as a function of human adaptation within co-design activities.

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Introduction

Assistive technology enables people with disabilities to accomplish daily living tasks and helps them in communication, education, work or recreation activities. Despite all efforts and good intentions, the majority of assistive devices are often not a source of happiness (Hocking, 1999; Wessels, Dijcks, Soede, Gelderblom, & De Witte, 2003). Apparently, the language of acute medical conditions and universal design are ill-suited to maintaining well-being over a lifetime. In these frameworks, disabled people are perceived as medically not normal, and "being normal"—not better or worse—is the desired objective (Correia de Barros, Duarte, & Cruz, 2011). Based on unidirectional and standard interventions, rehabilitation engineering aims to reintegrate disabled people into society. As a result, the central strategy focuses more on the interdependency of primary activities than on the quality of life. On top of that, the variety of products and functions is rather limited compared with those that are mass-produced.

For this reason, disabled people and their caregivers are forced to adapt their goals and activities to the limited choice and static character of these products. When this adaptation process demands too much cognitive, physical or emotional effort new actions emerge on a local scale. At present, the authors recognize two main scenarios. (1) The most frequent scenario is that of non-use. In many cases, expensive devices are rejected and end up in the back of closets. The disabled client becomes resigned to the need to find another product variation of the device or has to fall back on an allied health professional to perform the activity. (2) The second scenario includes a more bottom-up and bi-directional process. In certain conditions, spontaneous design activities emerge between local agents, leading to the production of self-made assistive artifacts (De Couvreur & Goossens, 2011).

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Corresponding Author: lieven.decouvreur@ugent.be

Existing devices are adapted, or even reconstructed from scratch to create new possibilities around unique skills and meaningful activities of disabled people. Objectively, these self-made and humble artifacts cannot compete with the standards of mass production, but from the perspective of all engaging stakeholders they deliver profound happiness. In the course of several design activities, participants reveal themselves as proud ambassadors of their personal assistive devices and in some cases radically transform their self-image. A substantial part of the happiness itself stems from the physical and social experiences within the process of *making together* (Seravalli, 2013).

These experiences correspond with some main results coming out of happiness research (Lyubomirsky, Sheldon, & Schkade, 2005) and identity-driven design (Desmet, 2011; Zimmerman, 2009). Both lay the emphasis on the potential of our daily actions that are under our voluntary control and advocate for a possibility-driven approach (Desmet & Hassenzahl, 2012). In our opinion, this is exactly what caregivers and disabled people are spontaneously striving for when they start adapting their own activities and products. They create new possibilities with local technology, which unlock the potential of contributing to human flourishing. As an illustration, the case study shows a creative process of *making together* that has a positive impact on both interdependency and the quality of life. All stakeholders participate in meaningful activities that help them become the person they desire to be. At the same time, this pragmatic process is able to co-evolve beliefs and values with local skills and resources, but within the world of assistive technology the dynamic of these transformation processes is often unexplored.

In this paper, we define subjective well-being as a function of human adaptation, a state of mental health in which individuals challenges their own potential (see Ryan & Deci, 2001). We show how an inclusive participatory design approach, grounded in our experiences with self-organizing design activities, can affect the subjective well-being of the engaging participants in many different ways.

Lieven De Couvreur has a Masters degree in industrial design engineering. After graduation, he worked for several years as a professional designer in the front-end of innovation and has built up practical experience of participatory design and systematic innovation. Today, Lieven is active in the department of Industrial System & Product Design at the faculty of Engineering and Architecture, Ghent University. As a research and teaching assistant he organizes design practicums at the Industrial Design Center and has started a PhD in cooperation with the TuDelft Medisign group on participative prototyping within community-based rehabilitation. His research focuses on adaptive co-design behavior within self-organizing design activities built around open-design assistive devices. As co-founder of *design for (every)one* he organizes community-based practices between disabled clients, industrial design students, occupational therapy students and other stakeholders from the local rehabilitation contexts.

Walter Dejonghe has Masters degrees in chemical engineering and general product development. He has broad experience in the development of high quality products with an essential user interface and has worked at a management level in industry for 25 years with high- and low-tech companies in an intercultural environment. Walter now lectures in design methodology and ergonomics at the undergraduate and postgraduate level, realizing a synergy between academic research and industry. He conducts novel research on a non-deterministic and dynamic approach for designing products realizing different potentials in different contexts, opening a new road for the development of more sustainable systems and providing a formalism to model the context dependency of experiences.

Jan Detand has a PhD and a Masters degree in mechanical engineering. He lectures in the domain of technological product development and production systems at undergraduate and postgraduate level. Jan is director of education at the Faculty of Engineering and Architecture Department of Industrial System & Product Design at Ghent University. His research focuses on changing the configuration and behavior of flexible production systems and the role of prototyping in product development.

Richard Goossens is a full professor of Physical Ergonomics in the department of Industrial Design Engineering within the section of Applied Ergonomics and Design at the Delft University of Technology. He is also a part time professor of Physical Ergonomics at Erasmus MC, department of Neuroscience. His 1994 PhD thesis investigated the biomechanics of body support. Since then, Richard has supervised research for the development of the 'Surgeons Cockpit' and coordinated the education of Medisign students, supervising them in serious design projects for medical specialists and companies.

Making Together within Participatory Design

One can argue that people are disabled by the context they live in and not directly by their impairment (Pullin, 2009). The WHO (2001) defines disability as *"a complex phenomenon, reflecting an interaction between features of a person's body and features of the society in which he or she lives"*. Individuals require a different approach to reach the goals based on their personal skills and disabilities. Multiple changes within social contexts and direct environments are emergent and not predictable in time. Making personalized assistive devices while coping with these dynamic aspects requires other situated methods than those applied in traditional participatory design. The latter is a familiar approach in which users and other stakeholders work with designers in the design process (Sanders, Brandt, & Binder, 2010) as a way to envision encounter *'use-before-use'* (Redström, 2008), that is, before the action takes place in people's life-worlds. As critics have accurately pointed out, *"Envisioned use is hardly the same as the actual use, no matter how much participation has been in the design process"* (Ehn, 2008, p.95). We argue that the same reason applies to happiness-driven design and advocate the use of open techniques that lead to reflection and learning on the spot.

In contrast to traditional participatory design, meta-design (Fischer, 2011; Fischer & Giaccardi, 2006) suggests deferring some design and participation until after the design activity, that is, design at use time or '*design-after-design'* (Redström, 2008). Within the design literature there are several attempts to deal with the challenge of meta-design on a pragmatic level. A similar approach is the idea of a continuing *design-in-use* (Henderson & King, 1991). In a broader design perspective, this also corresponds to visions and notions like *continuous design* and *redesign* (Jones, 1983). In such approaches there is also a strong focus on how users appropriate a given technology (Verbeek, 2005). Of particular interest here is what designers do and how this relates to unforeseen users' appreciation and appropriation of the object of design into their life-worlds. When conducting this approach within community-based practice, we noticed that more than just meaning emerged. Several elements of well-being (Seligman, 2011) such as sense of accomplishment, positive relationships and increasing engagement were noticed among the participants' behaviour. For this reason, the process of *making together* becomes a meaningful activity in itself, turning the negative notion of critiquing (Fischer, Lemke, Mastaglio, & Morch, 1990) into a more positive perspective.

Many of these original meta-design theories have their origins in the field of end-user development and HCI. Today, the maker movement is expanding this participatory prototyping vision with open hardware through a network of fabrication labs (Gershenfeld, 2008). In essence, inexpensive and powerful prototyping tools have become available for everyone in shared machine workshops (Seravalli, 2011). Due to the rise of the Internet and these direct digital manufacturing processes, we are capable of making niche products and adaptations on demand: the long tail of things (Anderson, 2008). With these tools and infrastructure, meta-design becomes a powerful engine for handling idiosyncratic aspects. Designers and occupational therapists can use these mediums to make custom-made solutions for individual clients within their own local context. Assistive devices become part of therapy and co-evolve with clients.

Our design for a well-being approach is grounded in this meta-design framework through the implementation of fabrication labs. Both makers and disabled users are seen as designers, much as in participatory design, but they are participating asynchronously in time and space, taking different roles and attitudes. Basically, this approach works in two ways; personalized assistive products are adapted to the skills of participants and participants adapt their values and beliefs through the making of their products (Figure 1). The power of this method lies in its highly iterative character and the acceptance of unexpected events, opening up new ways of thinking, feeling and acting.

The Dynamics of Co-experience-driven Design

Self-organizing design activities embody the opposite perspective of "disability", which is defined as "functioning" and denotes the positive aspects of the interaction between an individual (with a health condition) and the individual's contextual factors (environmental and personal factors) (WHO, 2001). Many of these phenomena can be considered as complex adaptive systems, consisting of different stakeholders, which cooperate while interacting with a shared physical environment. In most cases, the groups are rather small, up to 3 to 5 people. This implies that the complexity is not derived from the number of agents, but rather from the dynamic networks of interactions and relationships. The adaptive character is expressed in the fact that individual and collective behavioural changes as a result of personal and group experiences (Juarrero, 1999). Each agent finds meaning through a dialogue with the subjective experiences of his own actions and the interaction of other participating stakeholder experiences. It is important to notice that the creative process built around these artifacts directs the resulting user experience and vice versa. Meaning as such is created and re-created within a social-technical interaction, not prior to it. The output of such interactive systems is consequently unpredictable, yet exhibits a form of self-organization that emerges between the participating agents and their environment. To explain the dynamics of these situated activities (Suchman, 2007) between humans, we would like to bridge two concepts: co-experience and 'double-loop' learning.

Katja Battarbee (2004) first coined the term co-experience, which has origins within human computer interaction. As a design researcher, she noticed a missing perspective within the research field of user experience. Various existing approaches (for more extensive discussions, see Hassenzahl, 2010; Schifferstein & Hekkert 2008) only focused on the individual having the experience and neglected the kinds of experience created together with others. The research resulted in an expansion of the interactionist perspective on experience (Forlizzi & Ford, 2000). This pragmatist model explains the different dimensions of experiences (experience, an experience and co-experience) and how they arise out of different user-product interactions (fluent, cognitive, and expressive) (for an elaboration, see Battarbee, 2004). Co-experience is the process of learning, maintaining and modifying meaning in social interaction. Battarbee makes the distinction between three types of co-experience migrations: lifting up, reciprocating and rejecting experiences. These migrations, built around user-prototype interactions, allow participants to focus their attention on several sources of product emotions (Desmet, 2010), which could play a significant role in the process of designing for happiness.

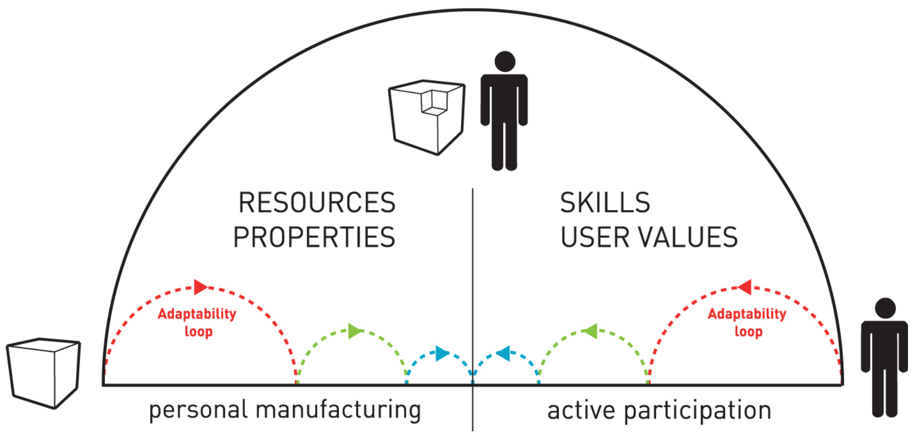

Figure 1. The co-evolution of user and assistive device.

Other than in professional product development, we do not recognize consecutive stages of gradual refinement within self-organizing design activities. The design behaviour principally builds on the patterns of reflection-in-action (Dewey, 1933; Schön, 1983). For Argyris and Schön (1978), learning generally involves the detection and correction of errors through feedback loops. When a situation is uncertain, vague or ambiguous, the main strategy of a participatory design group is to construct a lifelike prototype to see if their *theory-in-use* is congruent with their *espoused theory* (Schön, 1983). Decisions within a certain adaptation strategy are therefore always conditional, while critical decisions are based on insufficient information, but are taken according to the best of the group's intersubjective experience and common knowledge at that point.

A fundamental aspect within this form of inquiry remains openness to the discovery of unintended phenomena. What happens as a result of an interaction with a prototype can be perceived as both intended and unintended (Schön, 1983). The nature and intensity of these co-experiences will determine further action strategies or even change the belief system of all engaging stakeholders. To illustrate the impact of these processes, we have to make a distinction between *'single-loop'* and *'double-loop' learning.* Human actions are governed by a set of variables (Schön & Argyris, 1995). These *governing variables* are the 'shared truths' of the design collective constructed out of attitudes, be-goals and standards. As a rule for maintaining the viability of the social system, human agents steer their actions to keep these variables within acceptable limits. In other words, chosen goals are operationalized rather than questioned, which leads to a process of incremental change. According to Argyris and Schön (1974), this is *'single-loop' learning*. An alternative response is to subject the governing variables themselves, using feedback from past actions, to question assumptions. Both authors describe this as *'double-loop' learning*. These processes focus on transformational change and lead to an alteration in the governing variables.

In this section, the authors argue how Argyris and Schön's formalisms can be applied within the context of participatory design for subjective well-being. As already mentioned, we frame happiness as a function of human adaptation within self-organizing design activities. Conversely, a number of researchers and thinkers have argued that the ability to be happy and content with life is a central criterion of adaptation (e.g., Diener, 1984; Jahoda, 1958; Taylor & Brown, 1988). Findings from positive psychology illustrate the importance of intentional activities (Lyubomirsky, Sheldon & Schkade, 2005) that comprise a balance between skills and challenges (Csíkszentmihályi, 1990). Each participatory design activity (making, using or learning) can be perceived as a meaningful activity that challenges the skills of all engaging participants. Making products together can be framed as finding the edges of each other's physical, mental and emotional potential through incremental *'single-loop'* adaptations. As long as the *governing variables* stay within their limits, the same ingredients (attitudes, be-goals and standards) are challenged and optimized within a *'single-loop'*. However, once conflicts arise between the physiological edges and the *governing variables*, a *'double-loop'* learning cycle is triggered. As a result, one or more ingredients change, which results in new adaptation strategies. In practice, the group adapts or changes its belief system and perceives its goals, skills or values from a whole new perspective through the interaction with the environment.

This co-construction process (Oudshoorn & Pinch, 2003) therefore examines situated prototype adaptations as instigators of change. The use of lifelike prototype activities in a specific real-life context subsequently creates a shared language and common ground on the limitations and possibilities of each participant. Subtle product adaptations can provoke a lot of negative or positive emotions and steer our social design behaviour implicitly towards new insights into design for happiness. We believe that co-experiences evoked by unintended prototype consequences can play a key role as triggers for sustaining happiness in changing environments. Through a *reflective conversation* with

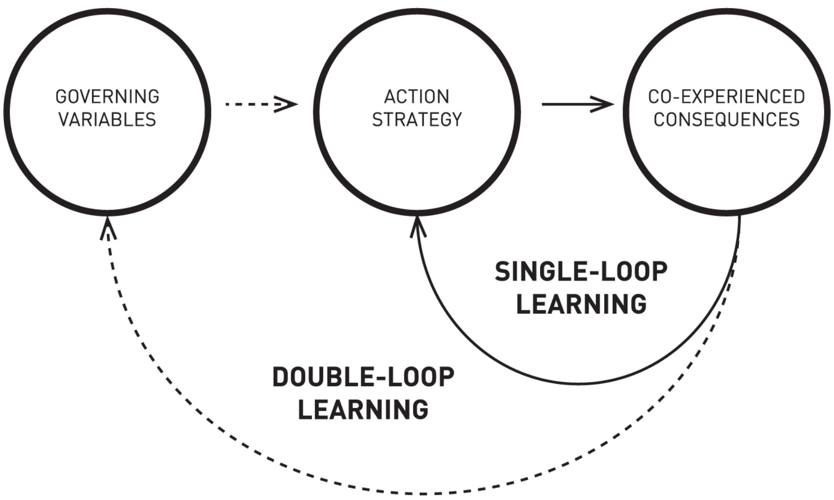

Figure 2. 'Double-loop' learning, adopted from Argyris and Schön (1974).

the situation, the design collective reciprocates (or rejects) spontaneous co-experiences that have the capacity to shift their attention from a problem-driven approach to a possibility-driven approach. It is important to notice that co-experiences cannot be predicted or orchestrated; they have a spontaneous and emergent character. The openness of the situated context and the empathic skills of all participants can have an impact on both single and 'double-loop' learning.

Case Study

To exemplify concrete dynamics and emergent characters in design activities, we use a case study. We focus on events that steer product adaptation strategies and challenge stakeholders to explore new possibilities. From a meta-design perspective, we consider subjective well-being as a function of the adaptation process built from co-experiences around design, make and use activities. Taking into account the perspectives of all engaging stakeholders, generally we believe that this approach can contribute to the quality of design participation by making designers more aware of several subjective well-being elements enclosed within participatory design. In this case study, the design actions are mentioned in very descriptive manner. Our main purpose is to illustrate clearly how a variety of practical events can be linked to sources of happiness through direct contact. Simultaneously, we aim to make this approach accessible for both design researchers and practitioners in the field.

Method

This framework has been developed through action research (Brydon-Miller, Greenwood & Maguire, 2003; Swann, 2002) at the Industrial Design Center in Kortrijk. Over the last five years, several participatory design cases have been set up in real-life contexts built around meaningful activities of individual disabled people. Each participatory design team randomly consists of a disabled client, a caregiver, an industrial design student, an occupational therapy student and other stakeholders from the local rehabilitation context. The process takes approximately 12 weeks, during which the group alternates between several design activities within various locations. From day one, students are only allowed to communicate using tangible prototypes and report their findings on a self-reporting shared blog (Bellens & Stubbe, 2011).

Our notion of adaptive prototyping builds on the work of Ehn and Kyng (1991), who generally used mockups as tools for engaging with stakeholders rather than prototypes to be evaluated. Later on, this prototyping focus was further elaborated with the work of Buchenau and Fulton Suri's (2000) notion of *experience prototyping* and *prototyping for social action* (Kurvinen, 2007). All prototyping actions were executed in line with the following conditions required for studying social interaction for the purpose of subjective well-being: (1) create a social setting with more than one person, (2) use naturalistic research methods, (3) maintain openness for observing unexpected interactions, (4) observe the behaviour within a sufficient time span and (5) generally focus on the sequential unfolding of events (for an elaboration see Kurvinen, Koskinen, & Battarbee, 2008).

Analysis

We generally want to observe the impact of unintended consequences through user-prototype interactions. To measure consequences in relation to intention, we focus on the act of surprise. Surprise is right there on the fuzzy border between two related cognitive phenomena, emotion and attention (Ludden, Sheldon, & Schkade, 2006). A surprise reaction has its origin in encountering an unexpected event. This basic emotion elicits new reality constructions for all participating stakeholders and helps them focus on new possibly significant variables. We documented this principle in various co-experience driven design cases through a simple 4-channel matrix (Figure 3) that distinguishes four frames by the possible combinations of the following distinctions: surprise/no surprise and desirable/undesirable (for an elaboration see Schön, 1983).

	EXPECTED EVENT	UNEXPECTED EVENT
POSITIVELY EVALUATED	Make Design Use	Make Design Use
NEGATIVELY EVALUATED	Make Design Use	Make Design Use

Figure 3. Reflection on action—the Schön matrix (Schön, 1983).

For each use time encounter, the students were asked to fill in the matrix with their client. Observations were filmed and subsequently analysed with the Schön matrix from the perspective of the participatory design team. Design-time experiences are attached to the corresponding open-ended prototypes, which all have a unique number. Ideally each individual agent should fill its matrix from a first-person perspective and also observe the group from a third-person perspective. The combination of all matrices, linked to anterior and posterior tangible prototypes, illustrates how the co-experience patterns gradually emerge among the participants.

To illustrate the process, we discuss the co-experience driven approach through key incidents (Emerson, 2004). All the posts from the self-reporting blog have been coded in Fablab-time or Hospital-time categories (Figure 4), referring to the context where the action takes place in time. Both can contain make and use design activities. The starting point is a design brief (B_0) formulated by the occupational therapists. Insightful user quotes and notes on prototyping activities from each blog report were compiled (1-3 sentences) from the Schön matrices into thick descriptions.

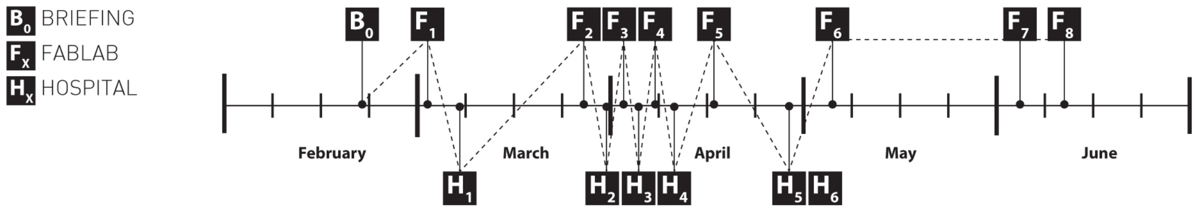

Figure 4. Oscillation between Fablab-time and Hospital-time reports.

Key Incidents

Initial context

The participating client was Fred, a middle-aged man who works in a hospital as head of the sanitary nurses. With his technical staff, he is responsible for keeping the hospital free of bacteria. At the age of 23, Fred was diagnosed with ankylosing spondylitis. This disease, also known as Bekhterev syndrome, mainly affects joints in the spine and causes rigidity. Fred cannot lift his head entirely upwards due to this disability. Each year, his field of view slowly decreases. At the start of the participatory design session, he was no longer able to see the top of a door. This state of dysfunction causes considerable friction with some daily activities and reduces the contribution he can make in his working environment. Some practical examples are replacing lamps, reaching for material from high cabinets, or setting up the beamers. In his quest to find a solution, the participant has not found any professional assistive device that can help him in his familiar surroundings.

Briefing

Fred initiated the start of the process. He was clearly unhappy with his current situation and had a rather negative attitude towards assistive devices. Apart from having many practical skills, he has not found a way around the negative interaction between him and his working environment. Fred changes his *personal values* to find a solution independently. He decides to change his action strategy and calls in the help of other stakeholders. This event is a distinct illustration of a '*double-loop'* adaptation. The consequences of multiple actions somehow exceed Fred's physiological limits and conflict with his current *governing variables.* This provokes a change in his belief system. By altering the perception of his values and skills, he takes a personal risk and opens up the way towards a *contributing* and a new *relationship* with other stakeholders.

Fabrication lab report 1

Before visiting the client, the students respond to the design brief and externalize their prior knowledge into three low-fi prototype variations (Figure 6). Each of these integrates mirrors into wearable glass concepts. We consider this a '*single-loop'* process in which the students find it *pleasant* to *engage* with their current *skills*. By doing so, they show Fred their *enthusiasm*. To reduce the design effort in time and energy, they decide to re-use old parts and waste material located in the workplace. This keeps them in a state of *flow* (Csíkszentmihályi, 1990). While using one of the artifacts themselves (Figure 7), they report being *surprised* at the fact that the relationship between the eye-mirror distance and the experience of controllability correlates so strongly and has a strong effect on performance. This event, which occurred within a prototype-use interaction, reciprocates their actual action strategy. The co-experience stimulates them to start an extra *'single-loop'* adaptation and make a fourth prototype, which refines the aspects. These *positive emotions* steer them concretely towards two reactions—dividing the mirror into two parts and moving it closer to the eyes—giving them a sense of *accomplishment* within this design iteration.

Figure 5. The participatory design team.

Figure 6. Fabrication lab report 1 prototypes (Bellens & Stubbe, 2011)**.**

Hospital report 1

The group first met together at the hospital. Fred evaluated all the prototypes within his working environment without being given any explanation about how they worked (Figure 7). The test with the *periscoop 2.0* revealed that Fred used the prototype in a completely different way to that anticipated. Instead of handling the two mirrors to correct his field of vision, he only manipulated the farthest mirror to gain an eyeshot of the space right above his head. He regarded the prototype as a useful solution to doing different odd jobs related to his ceiling at home, which lies within the scope of the original problem.

As mentioned in the Schön matrix, another latent goal emerged from the interaction with the *pentaprisma 1.1*. From the moment Fred used the prototype, he perceived a whole new range of vision that exceeded his current physiological limits. In response, Fred mentioned emotionally that he is *passionate* about photography. In his free-time, he takes pictures of large paintings by the Flemish Primitives and stained glass windows of old churches. His disability makes it increasingly harder to *engage* in this activity. This *'double-loop'* reaction changes Fred's assumptions; he suddenly experiences the possibility of engaging in his meaningful activity through the use of an assistive device and this reaction can be interpreted as an important cue.

The compact shape of the artifact evoked another unexpected positive reaction. The nature of this response was co-experienced as a *rightfulness* appraisal and focused on Fred's self-image. Fred is a very proud man with a high degree of self-reliance; the non-intrusive character of the *pentaprisma 1.1* embodies his attitude and standards towards assistive devices. The latter is a *'single-loop'* adaptation that explicates a *governable variable* awoken through the situation.

Of course, many unexpected negative aspects were raised too: the view size of the *pentaglass 1.0* was too small, the artifact blocked the view of the ground, the size of the prototype was too small and so on. But the students perceived the effort to overcome them manageable. The intensity of the positive co-experience prompted them to plan new actions that would integrate these new areas of focus. Both agents experienced a sense of *accomplishment,* which nurtured the *relationship*.

Fabrication lab report 2

In this phase, the students try to counter the unexpected negative aspects through creative prototyping and make new variations on the *pentaglass 1.1* and *periscoop 2.0* (Figure 8). They still work on both main design strategies as they still have the time, interest

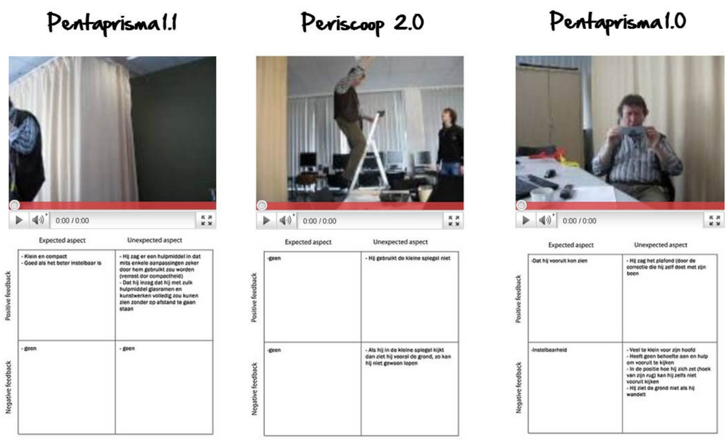

Figure 7. Hospital report 1 (Bellens & Stubbe, 2011)**.**

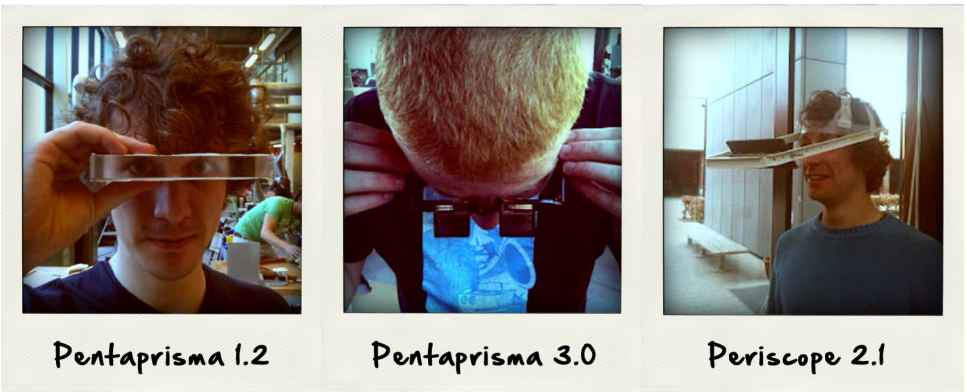

Figure 8. Fabrication lab report 2 prototypes (Bellens & Stubbe, 2011).

and resources to do so. Although both prototypes have evoked several cues, the students want to repeat the same behaviour and see if they can observe coherent patterns in Fred's appraisals and behaviour.

The occupational therapists had noticed that Fred spontaneously corrects his vision through a flexion of his hip joint. This behaviour makes him capable of self-adjusting his field of vision and eliminates the technical requirement on the level of the product by integrating this skill. As the distance and angle between both reflective mirrors is so crucial, the designers decided to make their own prism glasses out of PMMA or Plexi glass. Although they managed to calculate the exact angles and size, the students did not manage to reach the same optical performance. This is clearly an unexpected *negative* co-experience that disturbs the *flow* within their creative process. Somehow they have reached the physical limits although mentally they understand all the principles for designing the PMMA glasses. The group decides to alter their action strategy and change their position towards the value and pleasantness of making the prototypes by themselves. With the help of the occupational therapist, they manage to buy standard prism glasses for 34 euros. This object turns out to be *pentaglass 3.0*.

The *periscoop 2.1* consists of a mirror attached by means of a curved profile on the inside of a helmet suspension. The students expect that this hacked artifact will allow Fred to carry out tasks located above his head that demand a certain precision, such as turning a screw or replacing a lamp. The artifact makes it possible for Fred to keep both hands operational during a repair activity and thus enables him to *contribute* within his domestic living environment.

Hospital report 2

While testing the *periscoop 2.1*, Fred looks and behaves reasonably satisfied. He confirms the advantage of the hands-free aspects and considers the prototype to be useful when climbing a ladder as well. The space between the mirror and his eyes gives him the opportunity to look at his steps. He also repeats the spontaneous tendency to move the mirror closer to his eyes and emphasizes the compactness.

The purchased *pentaglass 3.0* is tested by flipping it 180° and placing it in front of Fred's current glasses. He still manages to self-adjust his vision and is able to perform activities while looking ahead more and examining the ceiling. Fred again expresses many *positive emotions*. Nevertheless, his global vision is distorted because the lenses do not align correctly to the position of Fred's eyes. Measuring and aligning both aspects are set as subsequent actions in Fablab time 3. After comparing both prototypes within this participatory design session it is clear that *pentaglass 3.0* evoked the strongest co-experiences, highlighting several meaningful ingredients. The group is happy and confirms its *accomplishments* within this iteration. As well as the *excitement* of the unexpected event, the designers perceive the next iteration as *challenging* too. There were no fundamental changes regarding the focus of the variables. The reciprocation of the co-experience characterizes a typical *'single-loop'* iteration for all stakeholders.

Fabrication lab report 3

The group has found an area of focus that strengthens the group's *relationship* and increases *expectations*. The design activities follow in quick succession, which illustrates the reciprocating tendency within the process (See figure 4). As previously mentioned, the designers concentrate on several performance-related aspects within a *'single-loop'* iterative process. Their action strategies focus on optimizing by making variations of the same aspects within their potential prototyping limits. In the first place, they want to investigate the distance between both prism glasses in relation to the position of Fred's eyes. Simultaneously, they are exploring the connection with the temples and the top bar. The resulting prototypes are all designed from an open and adaptive perspective. By using low-tech materials such as brass wires and double-sided tape, the prototypes can be easily transformed during the next encounter. These actions illustrate the *willingness* of the students to *engage* with Fred and the occupational therapist as equal participants in the participatory design process.

Figure 9. Hospital report 3, several prototype interactions within one context (Bellens & Stubbe, 2011)**.**

Hospital report 3

All three prototypes were brought into the context of Fred's working environment. Together the group adapt the prototypes and set up a real-life situation where Fred had to climb a ladder (Figure 9). The adaptive prototypes have a *positive effect* on Fred's co-design behaviour. Immediately, he starts adapting, using and suggesting new ideas. The students ask him to read the user interface of a projector that is mounted to the ceiling. By doing this they also find out by chance that Fred uses two types of glasses, one pair for close vision and the other for distances. Both frames are slightly different in shape and size. This unexpected '*single-loop'* aspect creates some new challenges regarding the final connection of the prism glasses. The students perceive it as *rightful* and *useful* that the prism glasses should fit both pairs of glasses. Only this will enable Fred to use the assistive devices properly within his working environment and during his photography activities. The students integrate the aspect, but do not change their design strategy, perceiving *the challenge* to be manageable.

An unexpected positive aspect is the *pleasantness* appraisal on the weight of the prototype, which Fred immediately shares with the group when he puts the *pentaprisma 3.1* on. The pressure on his nose is experienced as very light and makes the prototype look elegant. But as soon as he starts climbing the ladder, the construction tilts backwards and forwards. Apparently, the connection that is established by the brass wires is not rigid enough to deal with these types of movement. Once he stands on top of the ladder he proudly shouts: "Yes!" and raises his thumbs to the students, which embodies a sense of *accomplishment*. From this iteration, the team gained the exact distances of the lenses. They express the fact that both prism lenses should be fixed parallel to Fred's glasses within a rigid structure to avoid distortion of his vision. All of these unexpected co-experiences have a '*single-loop'* character as they only relate to the optimization of the current design solution. Again, the *positive* reaction of Fred and the experience of literally *making together* prototypes bring the team closer to each other, which results in the development of an open and shared language on relevant aspects for all agents.

Fabrication lab report 4

The proposed goals of "Fablab-time 3" have been *achieved* and as a result of the previous co-experience, the designers are focusing on the stability of structure in addition to efficiently connecting to the temples of the glasses. The designers use another prototyping technique from their skillset and make three variants from thick rigid cardboard (Figure 10) with dual lock Velcro. This *enables* the group to compare and discuss the impact of some design distinctions. For all of the prototypes, they use the measurements gained from the previous participatory design session. While making the prototypes, they explore the concepts themselves and share some experiences they found relevant. The design students

Figure 10. Hospital report 3, prototypes (Bellens & Stubbe, 2011)**.**

co-experience the support bridge of *pentaprism 4.2* as useful while mounting the artifact onto the glasses. At the same time, they assume that the length of the bridge itself will be too big and will make contact with Fred's nose. They appropriate the auditory feedback of the Velcro as a useful aspect. The *pentaprism 4.3* without a support bridge takes much longer to align and position.

Hospital report 4

The *pentaprisma 4.1* evokes, as expected, the most promising co-experiences within the team. This emphasizes the '*single-loop'* character of this iteration. The support bridge surprisingly does not touch or bother the Fred's nose; it is widened by another 5 mm. Together, they conclude that the prism lenses should be aligned with the top of the eye lenses. Fred feels more and more *confident* in his role as co-designer. He suggests many practical solutions and has noticed that the model fits perfectly in his spectacle case. The horizontal alignment of the lenses should be explored more thoroughly. The group's first impression is to make use of the top bar. These events show the *openness* and transparency of the decision-making process.

Fabrication lab report 5

The design team felt confident enough to integrate all their current knowledge into more high fidelity prototyping techniques. They chose 3D printing and laser cutting. The designers are *looking forward* to the result as it is the first time they are using the techniques. They express *positive emotions* as they know that the result will look professional, coupled with the fact that they expect Fred to be impressed as well. They explore both manufacturing processes and provide all prototypes with the Velcro connection. By chance, the structure of the 3D print makes it possible to fix the prism lenses through the friction generated by the ribbed surface. This was another unexpected *win-win* constructed within a '*single-loop'* iteration.

Hospital report 5 and 6

The printed model fits the reading glasses perfectly, but still shows some problems with Fred's glasses for distant vision. The Velcro works perfectly, but is not acceptable for the design students' finishing standards. They *challenge* themselves to explore more aesthetic solutions. These events illustrate a nice example of a *'single-loop'* correction based on the current belief system of both students.

Fabrication lab Report 6

They explore the use of small magnets and heat shrink tubes to attach the whole onto the temples of the glasses. The aesthetic effect looks promising and from a behavioural point of view they will guide Fred even more intuitively during the positioning activity.

The designers still need to cut out some material at the level of the nose bar. 6 mm seemed to be sufficient. This action illustrates a typical *'single-loop'* iteration that ends with quantitative measurements. Also, the small legs can be shortened to print less material. While wearing the assistive device, Fred noticed that two small screws from his glasses scratched the printed part. He was *afraid* of damaging his glasses. Technically this could not happen, but the designers respected Fred's concern and immediately made two small cuts. This again illustrates the mutual *relationship* between both agents. Although there were a few practical concerns, the team felt in control.

Fabrication lab report 7

The latest model was printed with an FDM printing technique. The students felt *confident* enough to send their file to Shapeways.com and print their frame with an SLS printer. This technique produced a much more detailed finish without losing its rigidity. The connection of the magnets onto the frame was solved with a small leather strip. With the help of an orange wire, they emphasised the aesthetic character of the connection. As the icing on the cake, they engraved Fred's name in the leather strip (Figure 11). Fred *trusts* the students, as they do not have to come over to the hospital the show their end-result. The actual product adaptations stop here; the students do not see any more challenges from their perspective. The product itself has reached a reliable stage of performance and reflects a nice balance between hedonic and pragmatic qualities. Fred, too, is not experiencing any problems that are serious enough to trigger a new iteration. As a result, they all are satisfied and *proud* of their *achievement*.

Figure 11. Reversed prism glasses—final result.

Fabrication lab report 8

Fred visits the students for one last time at the Fablab. They hand over the artifact and take some pictures of the group. Later on, Fred assists the students by taking part in their final presentation at an open-design fair for assistive devices. By framing this community-based practice within the context of open design, the participants *are contributing* to something bigger. On top of that, Fred *volunteered* to promote his assistive device for a local television crew. These events exemplify the *positive relationship* and *mutual engagement* that have been established between Fred and the students. To Fred, the glasses have become a *symbol* and memory to the positive aspects of his participatory design experience.

Results

In this case study, we already recognize some patterns (Table 1) between the unexpected co-experiences and subsequent adaptive design actions. Co-experiences of user-prototype interactions steer both 'single' and 'double-loop' adaptations and nudge engaging stakeholders into meaning-making. The prototyping actions act as a mobilization medium (Heylighen, Kostov, & Kiemen, in press) which (a) coordinates and (b) motivates design actions towards new collaborative solutions. From a practical perspective, coordinated adaptations lead the group to "*make the right things*" and motivational adaptations stimulate the team to *"make the things right*". Both adaptations have an impact on the subjective well-being of the participants.

Table 1. Dynamics within co-experience driven design.

	Unexpected within limits	Unexpected outside limits
Positively evaluated	• Adaptation through 'single-loop' learning. • Active reciprocation • Affects motivation	• Adaptation through 'double-loop' learning. • Passive reciprocation • Affects coordination
Negatively evaluated	• Adaptation through 'single-loop' learning. • Active rejection • Affects motivation	• Adaptation through 'double-loop' learning. • Passive rejection • Affects coordination

'Double-loop' adaptations coordinate the process in a compulsive way by integrating change at the level of be-goals, attitudes and standards. They literally transform the opinion and self-image of the engaging stakeholders. As a result, they start focusing on new activities, skills, engagements and relationships. These co-experiences have a compulsory character; once physiological aspects exceed their limits when operationalizing a certain goal, forcing the co-design team to intervene. This does not always have to be in a negative way. We would like to refer to the moment where Fred put on the *pentaprisma 1.1* and experienced a whole new field of vision. With this experience, his current physiological aspects exceed their upper limits. 'Double-loop' patterns are sometimes hard to describe from a first-person perspective. From the experience of the changing agent, they are manifested through a type of passive reciprocation or rejection. This stresses the importance of designing with multiple agents who can mutually observe behaviour and interact with each other from a first and third-person perspective.

'Single-loop' adaptations instigate motivation to explore and challenge certain elements within the boundaries of the group's current assumptions. Their starting point is the current set of activities, skills, engagements, relationships and contributions. Through a creative process, new combinations are made without questioning the initial scope. They compare a current state to a desired state, act to achieve the desired state with the resources at hand and measure progress toward the goal. 'Single-loop' prototype activities are strongly related to the concept of flow (Csíkszentmihályi, 1990), which puts the emphasis on the balance between skills and challenges. Participants who undergo these activities experience a type of active reciprocation or rejection. They have a sense of autonomy and control towards the actions within a certain environment. These design activities strengthen emotions towards relationships, accomplishments and contributions.

Discussion

We believe that based on our experiences with several participatory design cases, *making together* is a powerful method that provides pleasure and respects meaningful goals, leading engaging agents to new sources of profound happiness. Its incremental and experiential approach allows them to adapt their assumptions through the engagement with design activities within their own local environment. The case study illustrates some necessary and sufficient conditions that make this regeneration process possible. In all of these conditions, the co-experiences of prototyping actions play an essential role and have both social and technical aspects that we will discuss in greater depth.

> (1) The process of co-design serves as a common language between all stakeholders, which identifies meaningful goals and our personal limits in achieving them.

While using, designing and making artifacts, we are reminded by the environment of our physical, cognitive and emotional limits. All of these are a function of time and force us to adapt one way or another. We need to explore these edges while undertaking action and simultaneously creating a shared understanding of the common goal. Some disabled people do not realize what they really are capable of or what truly makes them happy. Others seek unrealistic challenges or are fixated on one particular way of reaching their goal. This process might take some time, typically a few weeks at least, depending the nature and relationship of the participants. 'Double-loop' adaptations in particular need a certain time span due to their passive character. If certain elements are not clear, the best thing the team can do is to re-iterate with several new variations, consisting of other prototypes, activities or environments. Make sure that at the start of the process especially that each concept is clearly distinctive from the others. Work preferably with extremes and use these as a spectrum for the participants to engage with. By sequentially asking why one prototype is better than another triggers the participants to examine their responses. Once the shared goal is clear, the process usually speeds up, driven by 'single-loop' co-experiences. The begin status should be clearly described in the start document to enable the group to compare its progress later on. For practically every iteration, the activities can be executed with both the initial and the adapted prototype. This method helps to highlight the accomplishments and lets the participants co-experience the progress or deterioration.

> (2) The process of co-design serves as an exploratory process to create new possibilities for achieving new goals.

From a 'single-loop' perspective, the most prominent question can be formulated as follows: "How many ways are there to accomplish a specific goal through well-balanced occupations?" We cannot stress the importance of this creative action as the strength of the method is based on repeat with variation. Designers are normally trained in this skill, but often focus too hard on product-oriented variations. A well-balanced occupation consists of three factors: the individual himself, his activity capital and the surrounding habitat that encloses both social and physical capital aspects. Morphological matrices, which underline these factors, force participants to explore in a much wider perspective and increase the number of ideas by making new combinations (for examples, see Desmet, 2011 and Pohlmeyer, 2012). Non-designers often have problems with the notion of creativity. We invite them to suggest new ideas through the process of copying, transforming and combining elements from the several user-prototype interactions. These activities increase the sense of engagement and slowly move the participant to the position of "expert of his/her experience" (Visser, Stappers, Van Der Lugt, & Sanders, 2005). From a 'double-loop' perspective, each creative process within a "design for well-being" context has the tendency to shift from a problem-driven approach to a possibility-driven approach. The instigators are often perceived as unexpected positive events. The Schön matrix is a useful tool for creating openness and joint attention towards these types of event. As mentioned in the results, critical co-experiences have a compulsory character and demand the group's attention through a creative reaction. Denying them will, in the end, stop the self-organization and split the participatory design collective.

> (3) The process of co-design nudges people to take action to progress the co-design activity.

The ability to bring ideas into practice is a third essential condition. Before the group can make errors and learn, they have to take experiential action within a certain environment. Despite the accessibility of digital manufacturing processes, we emphasise the importance of *underdesigned* artifacts (Fischer & Giaccardi, 2006). What makes these primitive prototypes so exceptionally useful is that some properties are explicitly given up in order to augment the engagement process and leave space for spontaneous behaviour. By framing prototyping actions as meaningful activities, we aim to make this process from a 'single-loop' perspective more fluent and self-organizing. The team should honour the fact that participants have different capabilities. Design for engagement has to resonate with the level of skills and interest, using just enough technology to get the prototyping activity going. Everyone is creative at a certain level. The work of Liz Sanders (2006) distinguishes four levels of experiencing creativity: doing, adapting, making and creating. Each level requires more interest and a higher skill set. From a pragmatic point of view, we always start at the level of doing and adapting. The use of a prototype by a disabled person can be considered as the lowest level, that is, doing. The case study illustrates a nice example of adaptive prototyping. At a certain stage, the students made adaptive prototypes that enabled Fred to adjust the location of the prism glasses so that they better fit his functional needs. These actions require a more facilitating role, but lead to positive emotions and a sense of accomplishment when properly tuned. A good adaptive prototype medium is robust to small technical details, making it easy to leave out details and does not require detailed skills, which makes it possible to focus on what you are doing rather than how you do it (Gedenryd, 1998). Materials such as Velcro, double-sided tape, brass wire and Plasticine are often used to give prototypes a more adaptive character.

> (4) The process of co-design stimulates habituation of new options in the design process, such as new technology and new human skills.

This fourth condition refers mainly to the process of flow within 'single-loop' adaptations. Csíkszentmihályi (1990) describes occupational emotions as the relationship between the perceived challenges of the task at hand and someone's perceived skills. Practically, when a co-experience of prototyping action leads to anxiety, the co-creation team can undertake two types of action. The first action could be to vary the characteristics of the challenge. Occupational therapists can break down activities into achievable components or they can teach new ways of approaching tasks. Within this approach, activity analysis is an often-applied technique. It is defined as a process of dissecting an activity into its component parts and a task sequence. It allows people to identify inherent properties and skills required for its performance. A second type of action can be found on the horizontal axis. It rests on augmenting the skills and ability of the patient through product and environmental adaptations. Factors like people can also be taken into account through the guidance of family members and caregivers. In the first approach, we admit that much of human behaviour can be thought of as an adaptation to the powers and limitations of technology (Norman, 2005). The second approach asserts, as a tenet, that technology adapts to human agents. Adapting technology to users increases prototyping effort. Adapting users to technology takes time. In reality there is no ideal standard approach. Design for well-being switches constantly from meaning to technology and vice versa.

Conclusion

In many more cases, disabled actors cannot act physically as designers, but somehow trigger caregivers from their direct environment into taking action and give birth to self-organizing design activities. This paper suggests a process-oriented approach that respects the subjective experiences of all participating stakeholders and highlights the meaningful aspects of the process itself. Prototyping activities (making, using and designing) are framed as sources of happiness, which lead to engagement, new challenges, fruitful relationships and sense of accomplishment. Product adaptations and stakeholders co-evolve towards balanced well-being equilibriums. The notion of single and double-loop helps us to explain the underlying transformation processes driven by the physical, cognitive and emotional potential of each stakeholder. Double-loop adaptations have a compulsive character and steer the creative process to new and disruptive possibilities that keep the participatory design team together. Single-loop adaptations strengthen emotions towards relationships, accomplishments and contributions. The process itself tries not to be prescriptive; rather, it attempts to build on the use of local knowledge and works with the situation that emerges from unexpected user-prototype interaction. Mismatches will lead to new understandings and identify challenging opportunities for new solutions. By balancing empathy and systematic observation, it tries to detect and make use of relevant skills and experiential knowledge. The participatory design method allows participants to understand the experience domain of the patient in relation to the product ecology. Design for adaptive capacity through participative systems is an optimistic and sustainable way of turning disabilities into new possibilities. Ideally, these structures help people find out for themselves the most effective way to act in a meaningful and challenging manner.

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