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Citation for the original published paper (version of record):

Eriksson, S., Wallgren, P., Sandsjö, L. et al (2021). Genuine co-design: an activity theory analysis involving emergency nurses in an
interdisciplinary new product development project of a novel medical device. International Journal of Human Factors and Ergonomics, 8(4): 331-369. http://dx.doi.org/10.1504/IJHFE.2021.119054

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"Accepted for publication, post-review, pre-typesetting, Authors Manuscript" 1

Genuine Co-design: An activity theory analysis involving emergency nurses in an interdisciplinary new product development project of a novel medical device

Siw Eriksson[a], Pontus Wallgren[a], Leif Sandsjö[ab], and MariAnne Karlsson[a]

a) *Design & Human Factors, Chalmers University of Technology, Gothenburg, Sweden*
b) *Faculty of Caring Science, Work Life and Social Welfare, University of Borås, Sweden*

esiw@chalmers.se
pontus.wallgren@chalmers.se
Leif.Sandsjo@hb.se
mak@chalmers.se

Biographical notes: Siw Eriksson is a Ph.D. candidate at Chalmers University of Technology at Design and Human Factors division. Siw holds a Licentiate of Philosophy degree in Human-Technology-Design from Chalmers. Her research interest relates to how to facilitate interdisciplinary collaborations, specifically involvement of professional users in product development processes in complex sociotechnical systems such as the health care system. Central theme in her research concerns how users' and other stakeholders' specific knowledge of their needs can be elicited by means of representational artefacts, functioning as mediating tools in Co-design processes.

Pontus Wallgren is a senior lecturer at Chalmers University of Technology. He has a Ph.D. in Consumer Technology. His research focusses on how to involve users in product development, from methodological choices when engaging users as informants to Co-design methods. He also is interested in pre-requisites for user adoption of new technology, mainly focusing sustainable urban mobility.

Leif Sandsjö is a senior researcher at the Faculty of Caring Science, Working Life and Social Welfare at University of Borås. He has a Ph.D. in Human-Centered Technology and is affiliated to Chalmers University of Technology as an associated professor in Human Factors Engineering. He has contributed to about 50 scientific journal papers covering his research interests ranging from ambulatory monitoring, surface Electromyography, work-related musculoskeletal disorders to Biomedical Engineering applications of smart textiles, and, most recently, eHealth and Assistive Technology.

MariAnne Karlsson is professor (chair) in Human-Technology Systems at Chalmers University of Technology. Her research aims to develop in-depth knowledge on the multi-dimensional relationship between people and technical artifacts. Central themes include methodology for eliciting user requirements for new technical products and systems, prerequisites for individuals' adoption of new technology and its effects on everyday life, and development of new technical solutions to support sustainable behavior. She has been involved in a large number of R&D project, covering different application areas. She has published a considerable number of scientific reports as well as conference and journal papers. In 2015, she was elected member of the Royal Society of Arts and Sciences in Gothenburg

1 Cite as:
Eriksson, S., Wallgren, P., Sandsjö, L., & Karlsson, M. (2021). Genuine co-design: an activity theory analysis involving emergency nurses in an interdisciplinary new product development project of a novel medical device. *Int. J. Human Factors and Ergonomics, 8*(4), 331-369. dio: 10.1504/IJHFE.2021.10041817

Abstract

This study analysed a series of workshops and explored prerequisites for interdisciplinary co-design among industrial designers, design engineers and users in the development of a novel medical device. Presented as a case study, this paper focus on what affects participants' transformative processes towards genuine participation in co-design processes. Based on Activity Theory, we suggest that co-design activities have to support not only users, but all participants, shifting their perspectives beyond their own domain's rules, motives, objects and division of labour i.e. beyond their own activity system, to support users' participation as equal members in design teams. We propose that Genuine Co-design requires a holistic approach where a neutral arena, an impartial facilitator, clear rules of play, along with representational artefacts as mediating tools in the formation of a new collective activity system to foster equality, mutual value and long-term knowledge generation. Such approach requires a process over time.

Keywords: co-design; interdisciplinary collaboration; facilitating user involvement; power distribution; mediating tool; Activity Theory; activity system; healthcare; medical technology

1 Introduction

Medical devices are fundamental in healthcare systems and an absolute necessity in ambulance healthcare trauma situations. Ambulance nurses need to, sometimes within seconds, diagnose and take decisions towards the right treatments and actions to save a patient's life. This poses not only high demands on the professional knowledge and stress tolerance of the nurses, but complementary high demands on the medical devices used in such situations (Colldén Benneck and Bremer, 2019; Gunnarsson and Warrén Stomberg, 2009).

Today, medical technology is rapidly evolving and increasingly provides new possibilities for diagnoses and treatments of diseases with innovative, often technically complex, devices. Such devices must not only meet technical requirements, and requirements for cost and time efficiency, they must also meet the needs of heterogeneous groups of stakeholders (e.g. patients, nurses, physicians and medical engineers) and their specific relationships to the medical device in their particular use-contexts (Clarkson et al., 2004; Shah and Robinson, 2008).

Furthermore, these diverse needs are not only complex, but also often contradictory, which requires that those needs (i.e. goals to be achieved in non-solutions terms) and subsequent design requirements (i.e. requirements for e.g. significant functions and properties of the future solution) must be voiced and negotiated throughout the development process (De Ana et al., 2013). Failing to do so may lead to medical mistreatments, typically related to use error of equipment involved, causing unwanted side effects or even the death of the patient (Clarkson et al., 2004; Kohn et al., 2000; Stichler, 2016).

To address this complexity, there is a growing need for interdisciplinary collaboration in the design process of medical devices that includes users representing their own expertise (De Ana et al., 2013; Hoyer et al., 2010; Moody, 2015). Recognised benefits of such involvement include the fact that users can contribute to the design of the medical device with their specific expertise and knowledge of the use context (Karlsson et al., 2011; Moody, 2015; Shah and Robinson, 2007). It is recognised that users may: provide the design team with ideas for innovative products (Conway and McGuinness, 1986; von Hippel, 2005); identify conceptual deficiencies and potential problems in current and future devices; and propose design changes or solutions (Engelbrektsson, 2004; Wilkinson and De Angeli, 2014).

1.1 From participatory ergonomics to co-design

Various approaches for involving users (and other actors) in design processes have been described in literature and below we provide a brief in the areas of participatory ergonomics, participatory design and co-design.

Participatory Ergonomics (PE) has a long tradition of inviting users to participate in the design of their future workplace (Haines et al., 2002; Hendrick, 2008). The tradition includes collaboration among ergonomists, production engineers, and/or managers, where users are invited, typically by means of interviews or usability tests, to contribute their perspective for the design of a future workplace (Broberg et al., 2011; Hall-Andersen and Broberg, 2014; Money et al., 2011). This tradition corresponds to the notion of 'design for users' where the designer (or ergonomist) has an expert mindset and refers to the users as 'subjects' rather than partners in the design process (Eason, 1995; Sanders and Stappers, 2008).

Whereas PE focuses on improvements and new designs of users' work environment and its activities, Sundin et al. (2004) argue for the need to go beyond workplace and production change design to include the design of the products that will be used in the users' work environments and so coined the term Participatory Ergonomic Design (PED). Such participatory product design strategies are argued to benefit from more actively including methods and tools from the Participatory Design (PD) field (Broberg et al., 2011; Vagn et al., 2016). PD aims not only to invite users to provide information to the design team, but to involve and empower them as partners in a democratic design process that gives them and their user-expertise and knowledge an equal say and importance in the design of artefacts, processes, and environments that will affect their daily life (Bjögvinsson et al., 2012; Ehn and Kyng, 1987; Halskov and Hansen, 2015). This approach corresponds to the notion of 'designing with users'(Eason, 1995; Sanders and Stappers, 2014). i.e. moving from users being merely informants and evaluators to being legitimate and acknowledged partners in the design process (Eason (1995).

Gradually, the concept of PD has, over time, been disseminated into different fields such as citizen-led art contexts (McCarthy and Wright, 2015); urban planning (Toker, 2007); political processes (Johannesson and Holmlid, 2013); public organization (Holmlid and Malmberg, 2018) and, most relevant here, is increasingly accepted in the health care sector (Halskov and Hansen, 2015; Moody, 2015; Østergaard et al., 2018).

While the PD approach focuses particularly on the involvement of users in the design process (Ehn and Kyng, 1987) other approaches emphasise, not only to include, users, but also integrate other relevant stakeholders from diverse perspectives into the design process. Such approaches are referred to as co-creation. Sanders and Stappers (2008) (among others) define Co-creation as any collective activity that is shared by two or more people, for example designer(s) and people not trained in design. Co-design, instead, refers more specifically to the actual activity of designing together for knowledge generation and identifying potential solutions to complex problems, for instance medical devices. Importantly, both share tools, value and techniques with PD.

Still, bringing people together who represent diverse expert domains is not without its challenges. These challenges reach far beyond enactment (or not) of methods and tools to include more fundamental matters such as differences in knowledge, language and terminology, goals and motivations, perspectives, and power (Money et al., 2011; Moody, 2015; Pirinen, 2016; Simonsen and Robertson, 2012). Over time, an increasing number of researchers have sought to understand and balance these differences by focusing on how design games, probes, and prototypes may enable more equal participation (Brandt, 2006;

Cain, 2005; Druin, 2002; Sanders and Stappers, 2014). Moreover, aspects such as the importance of space (Binder and Brandt, 2008; Sanders and Westerlund, 2011), the degree of participation (Bossen et al., 2016 ; Frauenberger et al., 2015), and the empowerment of users as participants in the design process (Bratteteig and Wagner, 2014; Drain et al., 2019; Ertner et al., 2010) that may affect participants' contribution of their perspectives to the design have been scrutinized.

Despite this extensive research, an increasingly identified challenge for contemporary participatory design practices is that methods and tools of collaborative design practice are increasingly intersecting with other domains. As a result, the meaning and value of participation itself seems to lose its significance, and the degree of domain experts' (users') involvement is not always evident (Donetto et al., 2015; Pirinen, 2016).

Smith and Iversen (2018) emphasise that the value-driven dimensions of collective design approaches often get lost in the pursuit of rational, short-term gains providing pragmatic design solutions rather than the intangible production of knowledge and community transformation. Solutions to those transformative aspects have stressed the importance of bringing forward 'authentic user participation' (Went et al., 2009) or 'genuine participation' (Østergaard et al., 2018), two concepts that emphasise design processes where participants are truly participating.

1.2 Purpose and structure of the paper

The importance of actively integrating users from the health care domain in the development of medical devices has been emphasized by for example Bowen et al. (2013) and Moody (2015). However, evidence of these users' actual integration and empowerment is still scant, and studies focused on the matters from a more holistic perspective have not (yet) been undertaken. Accordingly, Donetto et al. (2015) invite studies that not only report the (positive) design outcome of the health-care co-design project, but rather examine what influences such processes and catalyses and fosters (or not) multi-directional communication and collaboration.

In this paper we unpack and discuss our insights from a co-design project that was carried out according to 'best practice', attempting to create conditions for genuine participation, hence considering factors such as: interaction space, mediating tools and empowerment. The project gathered industrial designers, design engineers and ambulance nurses in the early design phase of an industrial, cutting-edge, medical technology project to develop a novel device for diagnosing strokes (i.e. discriminating a brain haemorrhages from a blood clots) in patients by ambulance nurses at the emergency site. The project involved three factors which we argue make such interdisciplinary collaboration among professional users and the developing industry almost unavoidable: a complex and novel technology; a highly complex use context; and a use environment which was unfamiliar to the developing company.

In conjunction with the suggestion of Donetto et al. (2015), this paper does not primarily focus on the specific outcome of the design process or how the medical device may benefit from co-designing with professional users. Nor does it focus on any particular factor affecting the process. Rather, the paper takes a holistic stand. In this study we refer to 'holistic' from a systems thinking approach, recognized, by the non-linear interaction between diverse interdependent elements, which together form a system (von Bertalanffy, 1950). Such a system cannot be understood by studying the elements solely, as the elements' whole is more than the sum of its parts (Skyttner, 1996; von Bertalanffy, 1950).

A co-design process contains various elements (e.g. participating individuals, tools and methods used, contexts, problems to solve, etc.). We believe that the different elements must be understood, not only as the parts they constitute, but how they interact to form a whole, when seeking answers to our research question how various scenarios and set-ups in the co-design process may affect participants' transformative processes towards genuine participation — including democratic communication and collaboration among the participants. To take this comprehensive stand, subqueries related to the ingoing elements in the co-design process, such as: a) how participants' various perspectives and possible contributions were comprehended; b) how representational artefacts could be used as mediating tools; and c) how the context (space) affected the participants' interaction were formed. Altogether, the identified ingoing elements were critically explored, focusing on how they interacted and contributed to form a whole.

The search for responses to the questions required support by a theoretical framework that holistically addresses the dialectic gaps of human-artefact relationships, i.e. between individuals' diverse perspectives to the device that is to be designed. Activity Theory (AT) provides us with such a holistic framework. From a human-centric perspective, AT may support our understanding of individuals' skills; the experiences formed in their respective lives; the particular cultures of their disciplines; and their range of the motivations (i.e. for carrying out activities to meet their specific needs).

The paper is organised as follows: The Introduction and Purpose of paper are followed by the Theoretical framework. Thereafter, the organisation of the co-design project, including the clinical problem; the participants; the co-design process and the venue where the co-design project took place are presented. Within the section 'Data collection and Analysis' we describe methods used to collect data during the project activities and how we analysed the same. In the 'Workshop Series', events of importance are narrated. The article continues with 'The case revisited—through the lens of Activity Theory' where we discuss the outcome of the Activity Theoretical analysis and ends with 'Conclusion.

2 Theoretical framework

Activity Theory (AT) provides a multi-layered conceptual framework to support multi-faceted understandings of human activities. It originates from Soviet psychology in the 1920s and the work of Vygotsky (1978), who elaborated the cultural-historical perspective on human development (Kaptelinin and Nardi, 2006). Leontyev later expounded Vygotsky's work towards the theory we recognise today, a way to understand the relationships between individuals and their activities when interacting with the world. (For a more detailed overview see Leontyev (1981).

AT has been used as an analytical tool in various domains, such as HCI research (Bødker, 1996; Bødker and Klokmose, 2011; Kaptelinin and Nardi, 2006; Kuutti, 2009); education (Roth, 2004); organisational learning (Engeström, 1987); workplace design (Cobaleda-Cordero et al., 2020) as well as user-centred product development (Engelbrektsson, 2004; Eriksson, 2014; Hjort af Ornäs, 2010; Karlsson, 1996; Rexfelt, 2008) and sustainability design research (Goldsmith, 2018; Selvefors, 2017) to understand the interrelationships between human, culture (i.e. the life they live) and the mediating role artefacts have in human activity. However, understanding interdisciplinary co-design activities and processes by means of AT has not yet (to the authors' knowledge) been undertaken.

The fundamental concept in AT is 'activity' which is understood as a subject's purposeful activity directed towards an object. The activity derivates from the individual's needs and motives (tacit or explicit) and is mediated by tools to accomplish the object of the activity in a dialectic transformative relationship between the subject and the object (Figure 1) (Bødker, 1996; Kaptelinin and Nardi, 2006; Kuutti, 2009).

Insert Figure 1 here

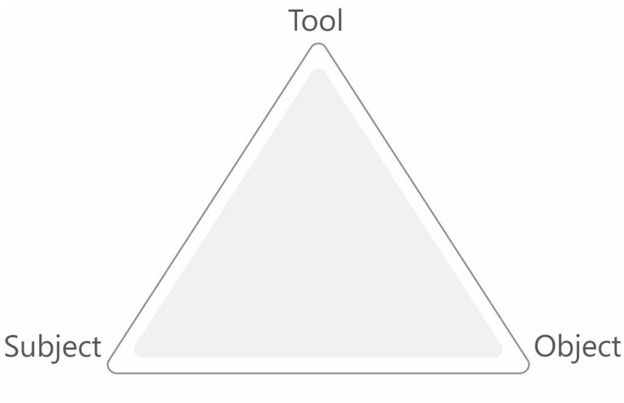


Figure 1. AT foundation unit for human activity analysis.

Engeström (1987) followed the legacy of Leontyev (1978), seeing human activities as ingrained within and defined by socio-cultural contexts which depict the individual as a part of a collective activity system. According to Engeström, an activity system is characterized as a social collective, artefact-mediated, object-orientated system. This includes that humans are part of specific activity systems in which their beliefs, tools and objects are influenced and steered by mechanisms such as 'community', 'rules' and 'division of labour' (Engeström et al., 1999). Engeström identifies the notion of 'community' in the activity system as groups in which an individual belongs and has the same or similar objectives and social contexts. 'Rules' refer to the subject-community interaction, e.g. regulations, norms or conventions that constrain an activity. 'Division of labour' signifies the community-object interaction that relates to the subjects' hierarchical structure of activities among actors with the same or different tasks within their activity system (Engeström, 1987; Engeström, 1999). Engeström includes the 'outcome' of the activity system as the transformation of the object produced by the activity into a result that can be utilized by other activity systems (Figure 2) (Engeström, 2000)Insert Figure 2. here

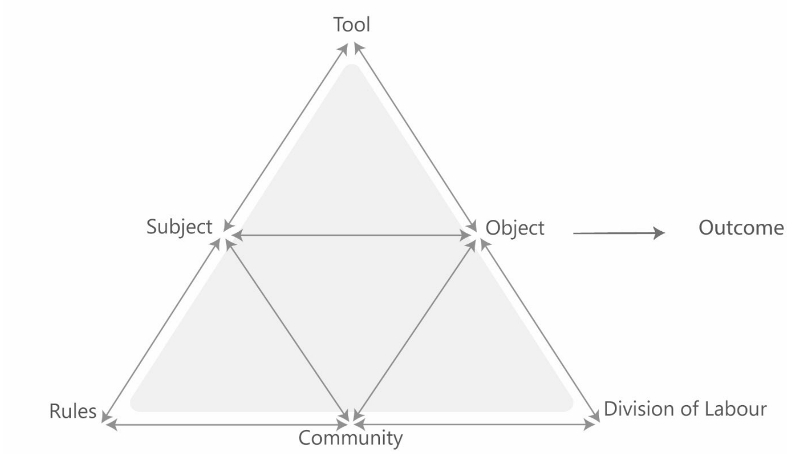


Figure 2. *Engeström's expanded activity system.*

Information sharing and mutual learning among the participants are core concepts in collective design approaches to overcome mentioned barriers and bridge disparate perspectives (Béguin, 2003; Robertson and Simonsen, 2012). These are ongoing processes and traditionally indicate bidirectional knowledge building. On the one hand, designers seek to understand users' contexts and needs, and, on the other, the user gains knowledge from the designers of the design process and proposed potential design options (Eriksson et al., 2020; Simonsen and Robertson, 2012).

However, Østergaard et al. (2018) argue that to create prerequisites for genuine participation, the traditional view of mutual learning needs to be expanded from the bidirectional (user versus designer) towards interpersonal collective reflection where conditions for collective learning among the entire group of stakeholders can emerge. This perspective of participation correlates well with the socio-cultural approach of AT, but such a process requires mediation. In AT the notion of mediation is central. AT emphasises that human beings seldom interact with the world directly, that is, without mediating tools. Thus, human activity is purposefully mediated by one or several physical and/or psychological tools. Such mediating tools can be language, methods, techniques, or artefacts such as hand-tools or computers, which shape the interactions between humans and their environments to achieve their goals. Tools are fashioned by the way human beings interact with the world. They reflect the social experience and cultural knowledge of other humans who have tried (successfully or not) solving similar problems in the past, and are modified to make them more efficient or invented to solve a problem in a totally new way (Kaptelinin and Nardi, 2006). While a well-working mediating tool allows users to focus on the object of interest in the activity, a mediating tool that does not fulfil users' expectations causes breakdowns and, potentially negatively, draws users' attention towards the tool instead of the object of the activity (Bødker and Klokmose, 2011; Kaptelinin and Nardi, 2006).

Many researchers have recognized that representational artefacts (i.e. artefacts such as sketches; material samples; mock-ups or prototypes that can illustrate 'anything' in the forthcoming design of the product) can have a significant role in facilitating communications and collaboration between heterogeneous stakeholders in a team. Star and Griesemer (1989) coined the commonly used term 'boundary objects' to mean objects that may work as interpretative gateways to make cooperation possible (Brandt, 2007; Broberg et al., 2011; Carlile, 1997; Carlile, 2002). However, the concept of boundary objects does not distinguish between the tool and its inherent mediating means and the object towards which the mediated activity is directed. This makes the concept of boundary objects a challenge to AT (Engeström et al., 2015). In AT, an artefact's inherently transformative, dynamic ability is what constitutes the mediating role that is of primary importance (Bødker and Klokmose, 2011; Kaptelinin and Nardi, 2006). Bødker (1987) emphasizes the importance of moving away from studying an artefact as something the user acts on or communicates with towards accepting that the artefact is something the user acts through — thus the artefact becomes a *mediator* for the activity.

3 The co-design project organisation

3.1 The clinical problem

Stroke, in medical terms cerebrovascular accident (CVA), is a brain injury caused either by a clot in the blood vessels (cerebral infarction) or a ruptured blood vessel (cerebral haemorrhage) that causes sudden inadequate oxygen supply (hypoxia) and cell death in the brain. Globally, someone has a stroke every two seconds, ending up with more than six million people dying from strokes each year. A critical issue for recovery from brain injuries is rapid, accurate detection so that successful treatment can be initiated as soon as possible (WHO, 2013).

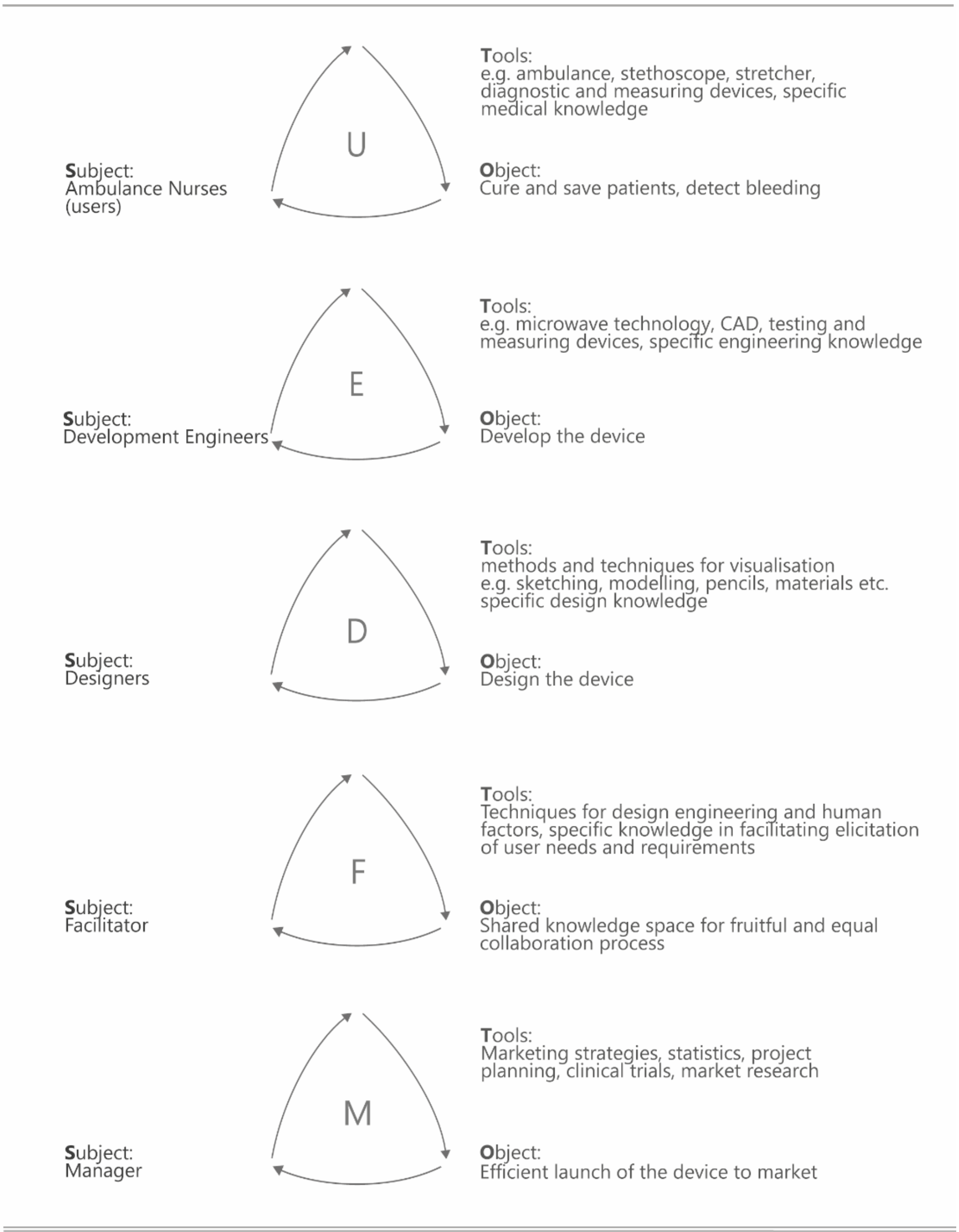
Mere minutes of delay between the diagnosis of stroke and proper treatment can mean the difference between an independent life or lifelong impairment or death. The participating company had developed a stroke-detection and decision-support device based on microwave technology and successful clinical trials had been run with a prototype in hospital environments. However, to meet the critical need to reduce time from diagnostic to proper treatment, the company had initiated a new product development project (labelled 'Concept A' in this paper) to explore if and how the technology tested in trauma rooms at the hospitals could be transformed into a device that could be used in the acute trauma situation by ambulance healthcare professionals. The company additionally wanted to explore potentials for technology synergies for other trauma conditions, for instance detection of pneumothorax or truncal bleeding with the same technology (labelled 'Concept B' in this paper).

3.2 The participants

The case involved ten participants: professional engineers/product developers, industrial designers, a business manager, ambulance nurses, and a facilitator. From an AT viewpoint, the participants came from various activity systems which, respectively, define and shape their daily work (Figure 3).

The ambulance nurses, identified as *professional users* of the forthcoming device, will onward in this paper, be called 'users'. These users were experienced nurses with expertise in emergency ambulance service (EMS), including both road ambulance (car) and air-ambulance (helicopter) services and brought from their use contexts skills with specific tools (for instance, measuring and diagnostic devices), their knowledge and their object of saving, treating, and transporting patients to hospitals. The product developers were biomedical engineers with expertise in microwave technology and signal processing. The engineers' object was to develop the technology and implement it in the device being readied for market. They brought tools including their specific engineering knowledge, skills, methods and techniques related to, for example, microwave technology, testing and measurement, and product development. The two industrial designers were contracted by the company (primarily) to design the concept for a head device (Concept A), but they were also engaged to contribute their specific expertise in product design. The designers brought their specific tools including design knowledge, and methods and tools for creating visualisations (such as modelling, sketching, pencils, CAD and so on) with the object to design the device. The manager brought tools such as knowledge of business, clinical trials and decision-making strategies with the object to launch the medical device to the market.

The facilitator was engaged to prepare and run the co-design process. That assignment included planning the co-design process, preparing collaborative events according to an anticipated outcome and supporting the participants throughout the co-design process. The researchers cooperated with the facilitator in the planning of the activities but did not engage in the actual workshops. The choice of facilitator was based on the person's knowledge of design and technology, bringing tools such as specific knowledge of design processes and technology, facilitating elicitation of users' needs and requirements, along with considerable expertise in facilitating similar situations. The facilitator was impartial in the sense that he did not come from any of the collaborating organisations. The facilitator's object was to enable the participants' involvement, foster an equal say among the participants, and support them to express themselves throughout the process of cultivating knowledge sharing and equitable collaboration.



Insert Figure 3 here.

Figure 3. Illustrating the participants different activity system, i.e. affiliations, tools brought to the co-design process and the various perspectives objects.

3.3 The co-design process

The participants gathered in a series of three workshops (WSs) to iteratively explore and develop concepts for the company's product ideas for head (A) and chest (B) devices. Each WS lasted between two to three hours and were spaced over a 14-week period. The users, industrial designers and facilitator attended all the WSs, while attendance by the company representatives varied over time (Figure 4).

Insert Figure 4 here.

WS Participants	Professional affiliation	WS1	WS2	WS3
User representative				
User 1 (U1)	Ambulance Nurse (car ambulance)	X	X	X
User 2 (U2)	Ambulance Nurse (car ambulance)	X	X	X
User 3 (U3)	Ambulance Nurse (helicopter ambulance)	X	X	X
Company representative				
Engineer (E1)	Engineering Design (concept design, clinical studies)	X	X	X
Engineer (E2)	Engineering Design (product development, clinical studies)		X	X
Engineer (E3)	Engineering Design (product development)	X		
Business Manager (BM)	Business Developer (business development, clinical studies, business strategy)			x
Designer 1 (D1)	Industrial Design	X	X	X
Designer 2 (D2)	Industrial Design	X	X	X
Facilitator				
Facilitator (F)	Senior Researcher in Design & Human Factors	X	X	X

Figure 4. The participants' professional occupations, their participation in different WSs and the coding acronyms when describing the different participants' contributions in the study, where X indicates full participation in the WS and x partial participation in the WS.

The industrial designers participated in all planning meetings to provide them with a greater understanding of their contribution and clarify their roles in each WS. In addition, as the designers were appointed on a consultancy basis by the company, they could communicate relevant input from the company in addition to the more general information the company had initially communicated to the research team.

The progression throughout the three WSs was based on traditional design methods and processes. Methods for divergent idea generation, such as 'brain-writing', visualisation through sketching, quick prototyping and CAD models, along with activities such as creative group sessions, group discussions and sessions for collective reflection were all intended to promote converging evaluations of the design concepts.

After each WS, the designers (representing the competences in visualisation, conceptualization and materialising ideas) brought the proposed ideas from each WS to their own design environment, i.e. their own activity system, to refine and combine ideas from the WS contributors to then be presented and discussed in the following WS.

It is often emphasized that use context must be present when users are involved in the design process as to be recognised and understood by all participants as well as counteracting biased hierarchy among users and designers (and other stakeholders) (Buur and Bødker, 2000; Vagn et al., 2016). In this case, we needed to adapt the circumstances that the users' workplaces are actual emergency sites and ambulance vehicles (car and helicopter), leaving minor opportunities to innovate and/or co-design something within the users' work environment.

Considering this and the crucial need for equality among participants for a desired outcome of the co-design process, the collaborative activities were organised so that prerequisites, as far as possible, could counteract the built-in (subconscious or not) hierarchy among the company, designers and users (Binder and Brandt, 2008; Buur and Bødker, 2000; Hess et al., 2008). To this end, the WSs were held at a neutral arena, a suitable meeting room at a Swedish university, away from any of the decision-making participants' 'home arenas'. The particular room was designed to serve as a collaborative space flexible enough to allow experimental activities and interaction between participants (Sanders and Westerlund, 2011).

To further enhance the recognition of the users' context in the collaborative venue specific representations from the users' activity system were installed in the collaboration space. These included, for instance, A3 size photographs (organised by the designers) representing images of important attributes in the users' work environment such as different kinds of stretchers, monitoring devices, along with images of ambulance interiors. The users were additionally given special tasks as 'homework' to sensitize their contribution for the WSs (Sleeswijk Visser et al., 2005). For example, they were requested to identify artefacts which may, positively or negatively, influence their use context and take photos of and/or bring such artefacts to the following WS. The purpose of these arrangements was to support the interaction between the users, designers and company engineers, but even more so to make the users' daily workplace (i.e. their activity system) explicit to the other participants. These arrangements were also to facilitate the exchange of experiences, knowledges, and perspectives among the participants and create a joint arena where the participants could move back and forth between their own activity systems and the joint collaborative venue where the WSs took place (Figure 5).

Insert Figure 5 here.

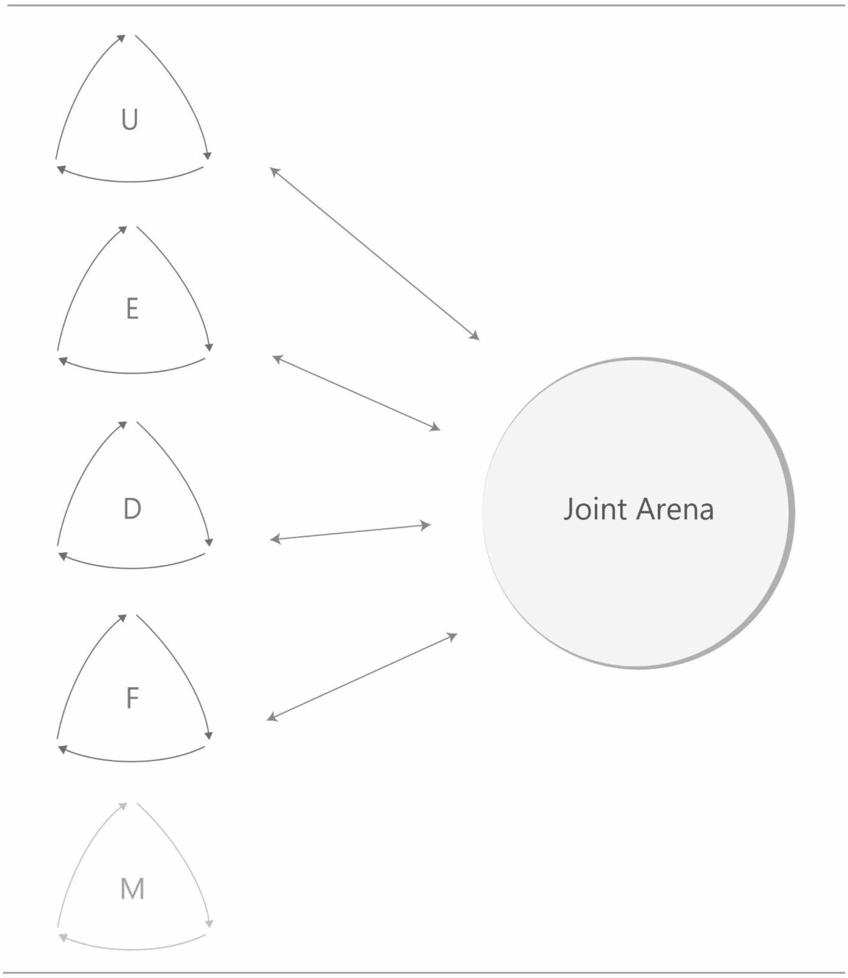


Figure 5. Illustrates the participants' constant movement back and forth between their own activity system and the common arena in the co-design process.

3.4 Data collection

The co-design process involved a series of preparation meetings, WSs, and follow up interviews with a subset of participants. All participants gave their consent to participate in the research project and being recorded throughout the process. As the project was use(r)-driven rather than technologically driven, the company freely shared necessary and relevant technical information which did not, according to the company, affect their business secrecy.

Data for the analysis was gathered in various ways. Before each WS, meetings were held among the facilitator, the two researchers and the industrial designers to plan, organize and prepare the activities for the desired outcome in the various WSs. As those meetings were part of the co-design process, they were voice recorded and transcribed, which along with the researchers' meetings notes were included in the analysis. The prepared images illustrating the users' work environment together with drawings and physical concepts realised in the WSs were also included in the analysis.

All three WSs took place in a collaborative space (as described earlier) which had cameras and microphones installed, so that the interaction activities could be video and audio recorded. A major part of the audio data was transcribed, which together with the video data formed the basis for analysing the WSs. The collaborative space was also especially equipped for non-participatory observation allowing two researchers (the first and third authors) to observe the activities from behind a one-way mirror in a connecting room when their presence was not required by the project activities. An example of a situation where the researchers had to join was in the second WS when the participants, several times, spontaneously expanded the collaboration space outside the dedicated room. In such cases an external video camera was almost immediately installed so the recording could continue with only a brief interruption.

Once the WS series was concluded, complementary, individual semi-structured interviews of one user (an ambulance nurse), two company engineers, the designers and the facilitator were done by the first author. The aim was to capture their experiences of the co-design activities as such; the role of the facilitator; and if they perceived being listened to and felt they had a say in the concept development. The interviews lasted between forty minutes to one and a half hour. All interviews were voice recorded with a smart phone with an external microphone.

3.5 Analysis methods

The analysis consisted of two phases. The first took an inductive and explorative approach to scrutinize communication and collaboration among the participants. The second phase took a retrospective, deductive, Activity Theoretical approach to analyse the outcome from the first phase. In both phases, a qualitative content analysis was performed and gave importance to all the video and audio recordings, transcriptions, illustrations, photos, as well as the physically materialised concept ideas.

In compliance with the recommended process for performing a qualitative content analysis proposed by (Granskär and Höglund-Nielsen, 2008; Miles et al., 2014), the exploration of the empirical data was carried out in several steps and progressed back and forth between the parts and the whole, in both analysis phases. The transcriptions and videos were viewed several times, mainly by the first author, but in some cases in collaboration with the second author, to gain in depth understanding of the participants' contributions in the co-design activities as a whole, but also to identify specific contributing details of interest. Such contributions could, for instance, be the participants' personal interactions, behaviours including tone of voice and body language at different moments and activities in the WSs.

The qualitative content analysis process did not follow any predefined coding system. Rather it aligned with Hsieh's and Shannon's (2005) suggested 'conventional' approach where themes emerged from the data as the analysis proceeded. The research questions formed the basis of what to search for in the data (Kohlbacher, 2006; Riessman Kohler, 2000), and various themes concerning behaviour, collaboration, interaction and communication evolved. Questions that guided the creation of the themes included: How did the participants act in the WSs?; Did the users contribute with their specific knowledge, and if so, how?; How did the engineers and designers contribute their specific knowledge? Other questions of interest were: How did the dialogue between the participants evolve?; Was there a particular theme or tone in the dialogues?; Were there any particular situations where the dialogue needed support, and if so, what kind of support was given?; How were the representational artefacts used in the co-design process?

The second phase in the analysis had a retrospective, deductive Activity Theoretical approach to examine the findings from the first explorative phase of the analysis. This part of the analysis corresponded to Hsieh's and Shannon's (2005) proposed 'directed' approach to content analysis, and new themes of interest based on the first phase analysis emerged as the second phase AT analysis, proceeded.

Our research questions formed the foundation also for the second analysis. Themes concerning behaviour, collaboration, interaction, and communication were again explored, but this time from an AT perspective which focused on and highlighted the contributions of the different participants and their respective activity systems. This included examining what different actors brought into the process, including how their tools and objects were influenced by, for instance, rules and division of labour in their own activity system and how that affected (or not) the interpersonal and (in this case also interprofessional) relationships in the co-design process. Furthermore, as mediation is central in AT, the analysis also explored the human-artefact relationship, the mediating roles of representational artefacts, as well as the effects those artefacts had (or had not) in the collaborative process.

Finally, the subsequent interviews were transcribed, and the content analyses followed the interview guide used in the interviews and responded to questions pose. This included for instance questions such as: How did you register whether your skills were being requested and used?; Do you think that you were listened to?. Other questions referred to the choice and role of the facilitator. In addition, questions related to whether their participation and experience of the organization and activities in the WSs would bring any particular benefit to their 'daily work life' were posed and included in the analysis.

4 The Workshop series

In the following section, we narrate selected excerpts from activities and outcomes from the co-design process that were of particular interest to our research questions. The Workshop series section is further divided into three subsections where each WS is presented separately. Each subsection provides information about, for example, specific settings, how the activities turned out, along with how the participants interacted during the activities and what affected such interaction.

4.1 Workshop 1

The focus in WS 1, which ran for two hours, was, besides getting to know each other, intended to create ideas for the two predefined product concepts: Concept A— the stroke detection device, and Concept B— the device for detecting pneumothorax or truncal bleeding. The process in WS 1 had three parts. The first part was an exchange of information and discussion session about the company's intention with the potential medical devices and the users' initial response towards the same. This was followed by a more creative session for ideation of concepts and finished with a reflection and negotiation session regarding the produced ideas.

The information and discussion session was moderated by the facilitator, who also guided the WS, introduced what to do and how to do it, and distributed 'the floor' (speaking time) equally among participants. To familiarize the users with the problem and the company's intention with the devices on a more detailed level than had been stated in the invitation letter received by participants prior to the first WS, the WS started with an introduction to the company's organisation followed by a description of their current product portfolio and (most relevant to this projects) intention to further explore possible future products (Concepts A and B).

After the company's presentation, the participants were invited to comment or ask questions. However, not until after quite a while of silence did User 1 (U1) confirm his interest in the presented product ideas: 'The stroke concept is very interesting…to detect or exclude bleeding early…'. Then User 3 (U3) seemed to recognize other medical needs and asked the engineers: 'Can you measure the abdomen…bleeding…as well…?' Those users' comments and questions opened up discussion among the participants, but in fairly general terms.

To counteract bias from prior product experience (Cain, 2005; Engelbrektsson, 2004; Söderman, 2005), a decision was taken by the organisers not to show any images of the existing prototype of the device that the company had already developed for clinical trials at hospitals before ideating the two new concepts. Hence, only a verbal description was initially provided by the company engineers. However, it soon became apparent that the users needed something to help them comprehend the information provided by the engineers, that is, they needed to see the existing prototype to fully grasp the functions of the technology described by the engineers. For their part, the engineers needed something to visualise, demonstrate, and explicitly convey to the users how the technologies functioned as the verbal description alone did not seem to be enough to make their information fully explicit and envisioned by the users. Encouraged by the facilitator, the designers organised images on the fly of the existing prototype and made them visible on a computer and a smartphone so that the users could have a closer look.

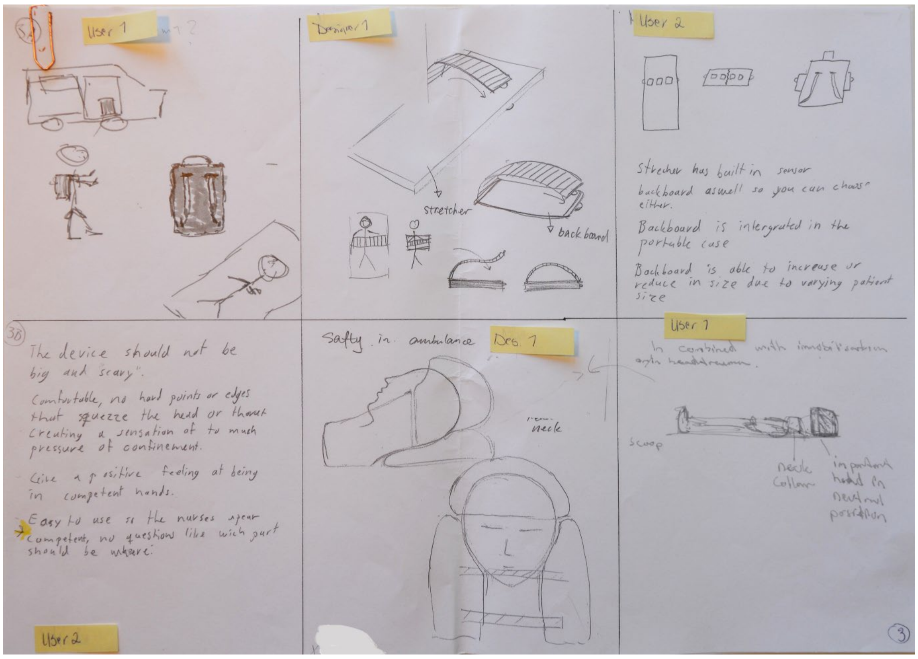
It was noticed that the images, i.e. representational artefacts, enabled the users to understand specific functions that the engineers described. The images mediated when words were not found, or terminology was not understood, by allowing multimodal communication, for example, by pointing to specific parts of the images when questions were posed and answered. The users could ask specific questions (U2): 'So this [pointing at a part of the device] is not attached to the head?' The designers used the images to aid the users' understanding, to demonstrate functions and verbalise answers to the users' questions (D1): 'You can touch this part [pointing] to attach [the device] to…' Hence, the images became mediating tools, enhancing cross-domain communication and understanding among the varied participants.

The representational artefacts seemed to help the participants focus on specific technical matters as well as potential usage activities, which also appeared to trigger the participants to 'dig deeper' into certain functionalities, technical opportunities or limitations in the device's design. Over time and mediated by the representational artefacts, the users seemed to grasp, in greater depth, how the devices might influence their work activities. This manifested itself as greater awareness of what contribution the users could and/or were expected to provide. This was illustrated, after a long explanation from the engineers concerning regulations from authorities (e.g. FAD[2] or EU-commission) regarding when to execute emergency diagnoses of stroke patients and the company's response to the regulations, when U2 clearly provided their expertise and questioned the company's solution to the problem:

> … I am just thinking…you were talking about measurements during transports in the car (ambulance) — how often do we have to do that? Consider if we take an ECG, we usually do that when we are stationary and often we need to stand still for a while to set a needle or so… so we could do that measurement then… to reduce [signal] noise— I'm thinking maybe we should do this before the transport…maybe we don't have to move during the measurement…

[2] United States Food and Drug Administration

The users’ contribution seemed to be valued by the designers and engineers, and the users showed enthusiastic interest in the presented concepts and confidence in not only supplying their knowledge of usage, but also in suggesting design solutions to certain problems. After the initial information elaboration session among the participants, the creative design session took place by means of a version of the brain-writing method (Wikberg-Nilsson et al., 2015) (Figure 6). The facilitator coached the participants to ideate from a healthcare personnel perspective by drawings, text, or a mixture of both on either of the two product concepts (A or B) in the upper left box of six boxes on a prepared A3 sheets of paper. Following the steps in the method, the sheets were passed on clockwise to the next person whose task was to refine, reject and/or add innovative ideas in the next box. In a second phase, the procedure was repeated, but this time focusing on solving the problem from the patient’s perspective. To counteract stagnation of individual’s ideation, the sheets were passed on counter-clockwise.



Insert Figure 6 here.

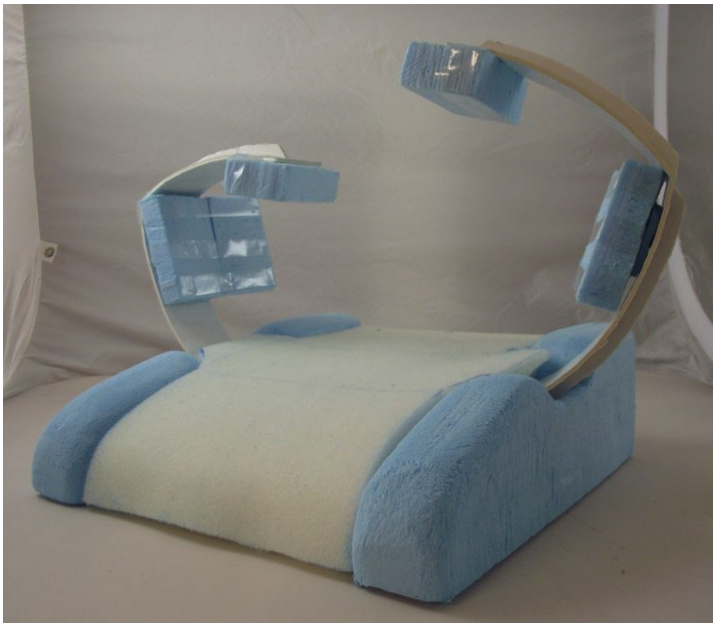
Figure 6. *One example of several on concept idea sketches from the brain-writing session.*

Following the notion of Vinck et al. (1996) of open and closed representations as mediators among collaborators in product design, the images of the device tested for hospital use served as a closed representation, with no possibility to change or redesign, while, for instance, the creative brain-writing activity served as an open representation in which one idea from one participant could be further elaborated by others. The creative activity with the open representations allowed the different perspectives to be negotiated into concept ideas in which the pros and cons of concepts could be embraced or dismissed immediately based on the various domain perspectives visualised in the drawings.

After the creative session, the facilitator arranged the A3 sheets on a wall for everyone to take a closer look. The participants were encouraged to select three preferred choices and mark them with Post-it notes. Guided by the facilitator, the most prevalent ideas were discussed from technological, healthcare personnel and patient perspectives respectively, but ideas showing less promise were also collectively reflected upon. At the end, the designers took the results of the WS to further elaborate the negotiated concept ideas and the revealed new information into representational artefacts, to be presented and discussed among the participants at the following WS.

4.2 Workshop 2

WS 2 ran for three hours, centring on hands-on collective making activities for design solutions appropriate for Concept B. The WS began however with the designers presenting their interpretations and further concretizations of concept A based on the participants' input in WS1. The designers had developed various representational artefacts of Concept A. One presented as a physical, full-scale, low-fidelity mock-up, illustrating the size of the device, its various external components and their positions (Figure 7) and one CAD model, simulating the devise's moving parts (i.e. rigid arms with antennas) and their functions when positioned on the head on a patient. An additional representational artefact contained a more flexible, textile-based, low-fidelity model, was presented as an alternative solution to the rigid 'antenna arms'.



Insert Figure 7 here.

Figure 7. *An example of a mock-up of design solution for the head device. (Photo loan from the designers in the study).*

Because the purpose of this session was to provide evidence that the designers had or had not understood and considered the needs communicated by the participants' perspectives, the solutions were presented and subject to open discussion, led by the facilitator. Everyone was given the floor to determine that their contribution to the design had been acknowledged or not, or if misunderstandings had emerged within the designers' materialisation of the concepts.

A reflective discussion followed in the second part of the WS that focused on Concept B (the chest device). In this phase, the participants were to ideate, design, and try out concepts by means of collective hands-on activities, per the facilitator's instructions that 'Things are going to be designed together'. The participants were divided into two groups (Group 1 and Group 2) with the aim to distribute, as equally as possible, disparate competences to the two group. Consequently, Group 1 consisted of one company engineer (E2), one designer (D2) and one user (U1), whereas Group 2 consisted of one company engineer (E1), one designer (D1) and two users (U2 and U3). The groups were free to take either the patient's or the health care personnel's viewpoints on the future product design, including but not limited to: designing for ease of use with the patient; storing the device when not in use; or exploring how the equipment would interact with its surroundings at different moments of use, such as when a patient is on a stretcher, or whether other equipment may interfere with particular actions.

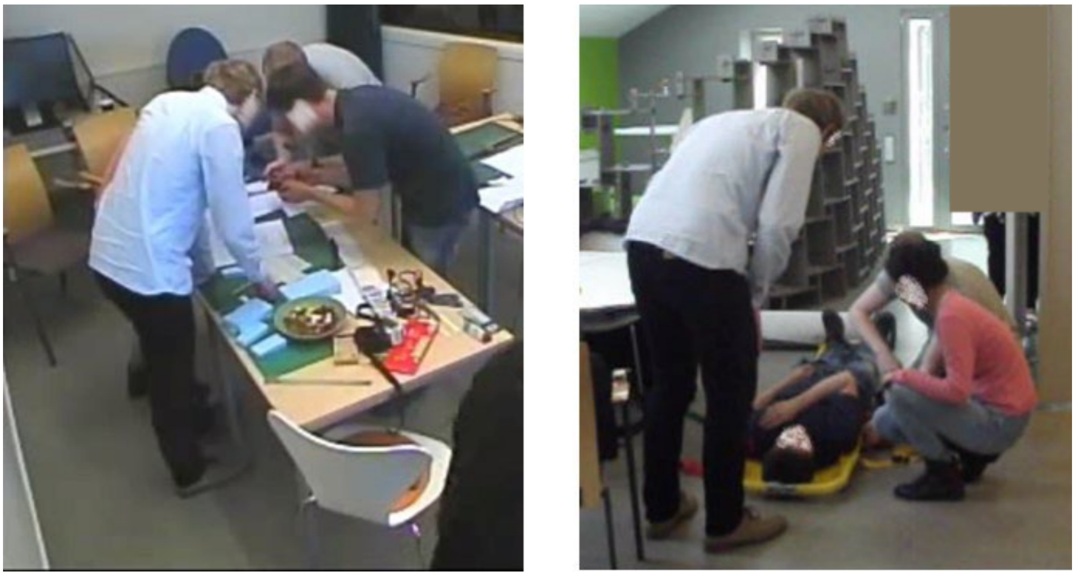
To facilitate the collective making activity, a well-stocked ‘materials table’ was prepared that offered stiff materials such as Kapa board, hard and soft foam, more soft materials such as various kinds of textiles (namely knitted and woven common fabrics as well as advanced so-called 3D and smart textiles), along with a range of various modelling and assembling materials.

Due to restrictions from the company, components such as antennas, batteries, switchboards and control units, were to be used ‘as is’, not to be changed in the design of the concepts. With those closed characteristic components (Vinck et al., 1996) in mind, they were to be included in the design of the device and the designers had prepared simple mock-ups of the components to increase efficiency in the collective making activity. The users had taken the initiative to bring a scoop stretcher to the WS, a special but common tool in trauma situations in the users’ work environment (and often mentioned by the users in WS1). These initiatives enabled the participants to test their concepts in a more realistic use context.

After the collective making activity, the facilitator guided the groups to present their concepts followed with a joint discussion regarding the respective concepts’ pros and cons. The groups presented their concept solutions which, though they visually appeared quite similar (such as a textile ribbon with simulated antennae in certain positions), they differed in sophistication.

The analysis revealed that the groups had undertook different approaches to ideating and materialising their solutions during the collective making. For instance, before Group 1 started to create anything, they focused on discussing diverse scenarios with proposed ideas, strongly influenced by technical impact of the device. When they started to create their concept, they used many of the prepared components, including the textile-based concept in which the designers previously had embodied and presented as potential solutions for the head device (Concept A). Rather than creating new mock-ups, Group 1 re-assembled, with minor iterations, the previously prepared representations to test and elaborate their design.

Group 2, on the other hand, had a short initial discussion that was strongly influenced by the use context (with minor attention on technical impact), and then concretized their ideas rapidly, mainly using the open materials provided. They also staged many iterations with a trial-and-error approach, often with participants acting as patients on the stretcher and thereby simulating the use context (Figure 8). This continued trialling contributed ideas to be evaluated from the various perspectives as each iteration revealed more detailed evidence regarding pros and cons of the proposed solution. This extracted information was collectively analysed within the group and refined in the next iteration.



Insert Figure 8 here.

Figure 8. Group 2 creating a design solution (left) and exploring use context with a scoop stretcher (right) in hands-on activity.

One explanation of the differences in approach between the two groups could be the participants' distributed power balance in the activities. Group 1 comprised one individual from each profession i.e. one designer, one engineer and one user, whereas Group 2 comprised one designer, one engineer and *two* users. It was also observed that in Group 1 the one user was not as proactive as the two users in Group 2, and that the user in Group 1 got (or took on) more the role of an informant answering the engineer's questions. The engineer, on the other hand, took a firm grip of the process and focused the discussions on engineering and business aspects, dismissing ideas from both the user and designer which he deemed too expensive, or too far from the company's set strategy. Quite late in the process, the user seemed to become more confident and was able, or willing, to contribute more freely, suggesting solutions from a usage perspective.

In Group 2, the two users tended to be more successful in stating their views. They garnered more attention for their input as they supported each other in explaining and arguing proposed solution with their joint expertise, and they elaborated ideas from a usage perspective in a continuous, spiralling process based on each other's statements. Moreover, the designer took on a more supportive role in designing the concept, compared to Group 1. This allowed ideas to be quickly tested, which also noticeably encouraged the users and engineer to be active and engaged in the discussions while proposing ideas and joint elaborations of ideas, without the obligation (but with the opportunity) to visualise the designs.

Despite the discrepancies between the groups' approach to tackling the collective making, the designers played an important role in both groups as representing the competence to capture ideas and visualise proposed ideas and solutions rapidly and relatively accurately. The role of the designers in the co-design process was to support the participants in realising their group's ideas, rather than being the sole creative competence proposing new designs. This set-up ensured that ideas from the other (non-designer) participants were not lost due to their potential inability to materialise these ideas. In turn, it may indicate the importance of creating, new representations on the fly that can be evaluated and tested collectively in the moment they are created.

4.3 Workshop 3

The third WS, run for two and a half hours, was planned to follow a similar process as WS 2, but this time, the aim was to elaborate designs for Concept B (the chest device) altogether as one group rather than in break out groups.

The WS started with the designers presenting their refined designs of Concept A (i.e. the head device) and new designs of Concept B based on the outcome of hands-on activities and joint discussions in WS 2. The presentations were followed by open discussion and criticism, guided by the facilitator, regarding the design solutions. This setup allowed the participants to jointly recapture communicated user needs as the design solution emerged and support the designers by providing them with immediate feedback on whether their interpretation of users' (or other stakeholders') input, including concept design solutions from the engineers and the users, had been understood correctly.

An example illustrating the necessity of reconnecting with users as soon as a design solution is present became obvious when one of the latest concepts for Concept A was presented. It seems that even if the users emphasized, in both previous WSs, the importance of keeping the patient's head in a straight line to avoid any bending of the neck when using the device, the designers had not grasped or interpreted the information appropriately as the presented concept still included a head cushion. In the 'brain-writing' session in WS 1 none of the users illustrated any kind of pillow-like headrest. Rather, the illustrations showed patients with neutral head position in relation to the body, and U1 had specifically emphasised the matter in text next to the illustration. This matter was also emphasised by U3 in the second WS's discussion when the designers presented their design solution. However, during the presentation, it seemed that the designers began to comprehend the importance of the head position. Encouraged by the facilitator, the designers asked the users: 'How much can you actually lift the head?'

This event initiated an intensive discussion about the head position between the designer and the users. Although the designers seemed, over time, to realize the impact of this 'new' information on the design, they kept asking for details: 'but is there any set distance…?' (D2) and similar questions, and the users repeatedly argued the need for a neutral head position. The continued uncertainty from the designers' side seemed to push the users to find ways to express their stand. U2 (pragmatically) started to make use of the designers' images and tangible mock-ups to explicate their expertise arguments. In this way the users introduced design solutions for how the headrest should be redesigned based on their clinical proficiency. It seems (we can only speculate), that the designers were strongly influenced by the design of the existing (prototype) device for hospital environment which allows higher head positioning and did not abandon their mental representation of the head position design despite the users championing the necessary neutral head position in different ways, several times.

A significant occurrence in the third WS was that an additional company representative, a manager (M), joined the first half of the WS. Although keen to contribute to the discussions, the new participant tended to dominate the discussion and seemed biased regarding which participants should be heard and what the various participants' contributions could be. For example, the manager questioned the design concepts presented by the designers and instead turned to the engineers for answers and solutions. As design solutions were based on joint discussions and generated mutual knowledge embodied by the participants' collective efforts in previous WSs, the manager's actions seemed to result in both the designers and users feeling undermined.

Over time, the users' body language became more defensive (folding their arms across their chests; crossing their legs; avoiding eye contact), and we observed a decreased willingness to share their thoughts freely. The users' speech became more monosyllabic, using 'yes' or 'no' answers to posed questions instead of the freer and open-minded way of sharing their knowledge that was noted in previous WSs. To redirect this negative spiral among the participants, the facilitator intervened firmly to end the occurred situation and then invited the participants to move on to the second phase of the WS. The aim for this phase was, in a collective hands-on and joint discussion activity, to explore the device's 'peripheral details' (such as storage solutions or various specific connectors, and so on) from the users' perspective. To encourage commitment and support the elicitation of the users' knowledge of usage, the users had been asked to bring examples of good or bad solutions of any such part which might affect the use of the device (Figure 9).

Insert Figure 9 here.

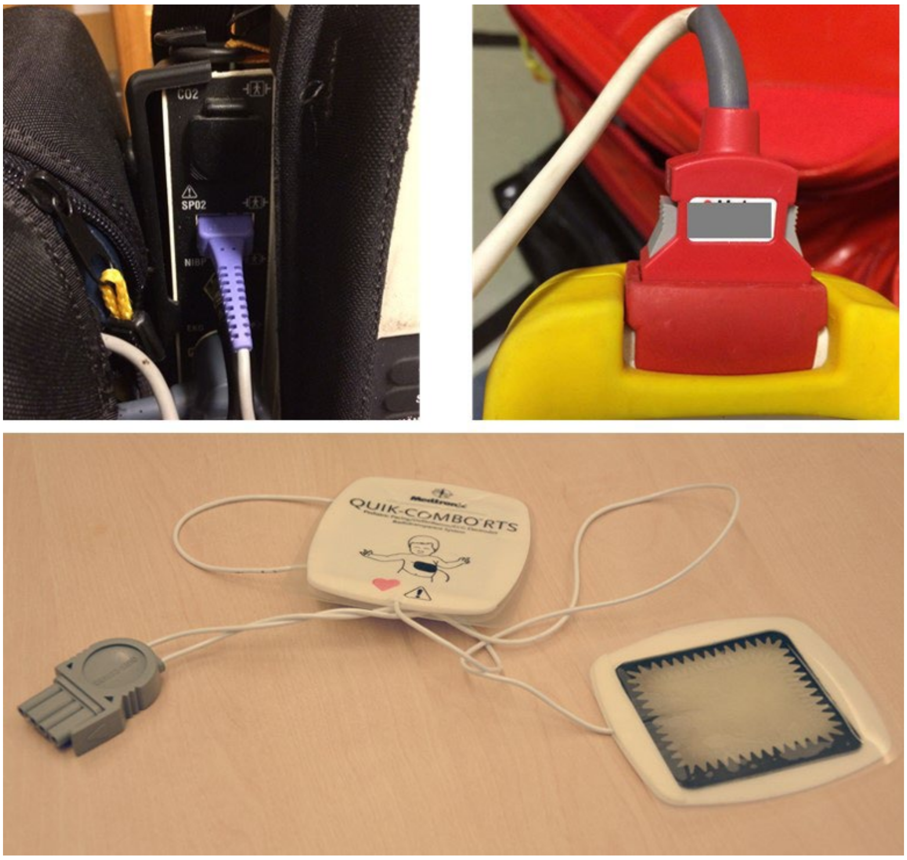


Figure 9. Specific details that users brought to the WS. Above left: a perceived bad example of connectors. Above right: a perceived good example of connectors. Bottom: electrode pads, representing a good design to teach positioning of electrodes on the body.

It appeared that the facilitator's strategy to change the object of discussion together with focusing on the specific 'peripheral details' mediated the communication among the participants. The users' experiences regarding the pros and cons of these details were noticed to be shared and discussed more freely again, moving back and forth from the users' and the engineers' perspectives, and contributing insights from each.

However, the stabilized intercommunication remained somewhat brittle, which was evident when the matter of storage of the device was to be elaborated. In line with the WS pre-instructions, the users had collected their experiences (positive and negative) of storage solutions as their needs for efficient storage solution were to be jointly discussed and designed. However, while U1 emphasised the importance of the device's carrier/bag being custom designed to work effectively at the emergency site (usage context), the manager (M) led the discussion to a dead end by declaring that the company bought their bags readymade from a supplier and that there was no room for customisation at this point in the project. Although the users jointly tried to argue, providing good examples based on their experience of the importance of customised carriers, the discussion closed as no one appeared willing to continue or contribute further.

After the manager left the WS, the communication among the participants slowly became more open and discussions about the design solutions and their impacts on usage recommenced. Still, the level of engagement that signified previous WSs did not fully recover and remained lacklustre.

5 The case revisited — through the lens of Activity Theory

A co-design process aiming to provide users an equal say in the design process is multifaceted, and as detailed earlier in the paper, contains several challenges that need to be considered if proposed benefits shall emerge.

Smith and Iversen (2018) emphasise the need to break the trend that focuses on pragmatic short-term design solutions and rather target the necessary value-driven dimension of users' participation, including community transformation for the democratic generation of long-term mutual knowledge generation among the participants in co-design processes. Implicitly, such meaningful transformation towards 'genuine participation' requires a redistribution of power, i.e. moving beyond involving users as informants or evaluators of design solutions, towards relationships between users, designers and other relevant stakeholders (such as patients, engineers etc.) that foster mutual learning and equal collective reflection in the co-design process (Halskov and Hansen, 2015; Pirinen, 2016; Simonsen and Robertson, 2012; Østergaard et al., 2018).

Analysing the case through AT illuminated the complex plurality of the participants who gather in the co-design process from a human activity centred perspective. The brief introduction of each participant (subject in Figure. 3) illustrates that everyone brings their own motivations, tools, and objects that are influenced by rules, communities and divisions of labour in their own activity system, into the collaborative design activities. But even more important, it illuminates the discrepancies of their respective needs and objects towards the device to be designed, as well as the disparate tools used to accomplish their respective object(s).

The analysis of the case support our belief that to reap the proposed benefits of co-design processes, it is imperative that the discrepancies are bridged, and participants come together as equals in a team. However, this process requires a shift of perspective and power (re)distribution that aims to enable users to communicate and contribute their specific knowledge and merge their viewpoints with those of, for example company representatives and designers. It is a process that must be carefully facilitated.

In the analysis, we identified four main mediators that we argue facilitated such transformative process in various ways:

- the interaction space,

- the specific mediating tools,
- the facilitator, and
- time.

In this section, 'The case revisited — Through the lens of AT', we first introduce the importance of creating a new, collective activity system and then introduce our findings of the different mediators' effect on the transformative process (the three first in said order) which are followed up with a reflection of balancing hierarchies in the co-design process, where also time as a mediator is considered.

5.1 Shifts of perspective — towards a new collective activity system

The generation of design solutions of forthcoming products that will function in the users' work environment requires a solid foundation shaped by the collective knowledge of users, designers and engineers. This is also a well-known challenge in the design process.

Acknowledging the challenge, Hasu and Engeström (2000) stress that if designers and engineers are to design technical devices functioning as tools that support users in their activity system, they need to be confronted with the complexity of the use context and expand their own domain spaces to include the users' perspective. Such transformation would include the need for opening up socio-cultural interaction among users and designers, and explicitly question existing standard practice. Furthermore, Kuutti (2009) discusses the consequences of if designers are not confronted with users' particular, timely and local knowledge of the temporal rules and practices of artefacts in their environment, the designers will only have access to general, timeless, and global knowledge of the use context. This means that the users' motivations for their activities has to become explicit for the designers to comprehend them, which, according to Kuutti (2009), may be the difference between a successful or unsuccessful design.

We argue however that it is not only the use context that needs to be tangible for the designers. Likewise, if users are to go beyond their role as informants or evaluators, contributing their particular, local and timely knowledge of usage and use context to the design process, they need to be confronted with the designer's perspective. Making this happen requires shifts in perspectives similar to what Brandt (2007) describes as translations between respective worlds, meaning that, on the one hand, designers and engineers do not belong to and may not fully understand the practice within which the new product is to function (Wenger, 1990). On the other hand, users understand usage but may be unfamiliar with the development context and have no (or limited) knowledge of design and its processes.

In line with Brandt (2007) and Wenger (1990) we recognise that a shift of perspective is essential. However, based on the case analysed, we emphasise the need to stretch this even further to achieve genuine participation in co-design processes, and from an AT perspective therefore underline the need to create a *new collective activity system*. This formation requires though not only enabling the users and the designers to contribute their knowledge and perspectives to design solutions, it necessitates something more — a meta-shift of perspectives.

We argue that such a meta-shift of perspectives must include embracement of the participants' externalisation (the transformation of individual internal activities into external activities that can be perceived by others) and internalisation (the transformation of external activities into internal activities) of others' differing viewpoints (cf. Kaptelinin and Nardi, 2006). This means that motives and objects from all the participants' respective activities (e.g. embedded practice, timely and future usage context, designing, methods, company's strategies, etc.) need to be transformed and acknowledged in an ongoing process so that an integrated and common perspective can be experienced, articulated, and adopted to cultivate mutual, long-term knowledge generation for future designs. This meta-shift of perspective can however only occur if and when participants are enabled to comprehend the co-design process and the active and the dynamic roles they have in it. This kind of process, transcending the specific domain activities, needs to be carefully facilitated as it requires the participants to attain greater understanding of why the activities, here the different co-design activities, take place and appreciate what the various contributions to the process might mean from a human interaction perspective.

5.1.1 The interaction space

If people are to collaborate, they need to meet. When bringing people together with the aim to make them interact as a team, we need to create space for cross-over activities between the respective activity systems (i.e. the users', the designers', and the company engineers' systems) that will aid in the formation of a new collective activity system.

Such an interaction space needs to be shared and experienced as both a physical and a mental landscape amongst the participants. If this is not factored in, co-design processes will probably not turn out as the intended collaboration activity, jeopardising that the participants' respective activity systems remain isolated islands, with few overlapping activities. This in turn may counteract the co-design intention, risking that users remain merely informants and evaluators to the design team, offering little contribution or commitment to the solutions (Donetto et al., 2015; Pirinen, 2016).

Therefore, the interaction space needs to be organised and facilitated so the participants' own motives, tools and objects also embrace the formation of shared motives, tools, and objects supporting a new shared activity system to emerge where the participants constitute a new community. This requires that rules and division of labour, based on the daily activities in the participants' own activity systems, needs to be renegotiated and redistributed (i.e. loosened up and reallocated inbuilt boundaries between different activity systems) to serve the motives and activities in the new collective activity system.

This is an ongoing learning process where each individual's knowledge and experience need to be externalized so that others can understand, redistribute and internalise the new information into knowledge that is meaningful in their own knowledge space (Engeström, 2000; Kaptelinin and Nardi, 2006). Such transformation depends on a collaboration space that supports the development of shared language and knowledge, and in a way that is understood and makes sense for each participant in the co-design process (Ehn, 1988; Reagans and McEvily, 2003; Stenmark, 2002; Thomas and McDonagh, 2013). However, the organisation of such a collaborative arena should not merely support interaction and knowledge sharing among the subjects; the psychological perspective of inviting users into an unfamiliar situation must also be considered (Binder and Brandt, 2008; Buur and Bødker, 2000).

In the case presented here we needed to consider the circumstances that the interaction space could not take place within the users' activity system where counteractions to suggested built-in hierarchies among the designers, engineers and users might take place (Bødker and Buur, 2002; Haines et al., 2002). To this end we applied the next best option and organised an arena that was as neutral as possible: a venue outside any of the participants' own activity system. One step taken to compensate the impossibility to interact within the users' activity system, was arranging images on the walls illustrating strategic artefacts from the users' work context (as described in WS1). The expectation was that the images representing the users' activity system would serve as mediating tools supporting and enabling further explorations of 'what if' matters. It was also anticipated that making the users' environment (more) explicit for the designers and engineers, less familiar with the use context, would serve to bridge the disparities of knowledge between the participants. However, the participants did not pay any attention to the prearranged images. Rather, it seems the images that were collectively exposed on the fly via the Internet on the participants' smartphones and computers were what supported the integration of the different perspectives. The users additionally spontaneously came up with the idea (far beyond what was asked for in their 'homework') to bring specific physical artefacts (e.g. the scoop stretcher brought to WS 2 and WS 3) to create a somewhat more authentic experience of their work environment, which also contributed to facilitating the integration of perspectives.

Those examples indicate that it is possible to reframe where the collaborative event takes place. Our analysis suggests that what the interaction space contains need to be a joint choice left in the hands of the participants so they can collectively configurate and self-generate what creates commitment for them in the new shared activity system. Though the neutrality of the interaction space seemed to be an important aspect for counteracting pre-existing hierarchies between participants in this case, the heart of creating fruitful co-design processes seems to lie, not particularly in the physical space. Rather, we suggest that it lies in mediating the mental landscape of the interactions, particularly in terms of supporting the redistribution of internalised knowledge to externalised and communicated knowledge. The examples illustrates that in this transformative process, the participants themselves initiated and provided the team with what was required (to use as mediating tools) to bridge the different perspectives. Those initiatives enabled individuals to expand their knowledge and concerns from their own segregated activity systems into the new integrated one.

5.1.2 Mediating tools

The importance of mediating tools to facilitate collaborative activities in general and co-design with users in particular has been emphasised in a number of studies (Brandt, 2007; Broberg et al., 2011; Engelbrektsson, 2004; Eriksson, 2014; Söderman, 2001).

Instead of simply functioning as milestones in the design process and providing evidence that requirements have been met or not, the analysis revealed that representational artefacts used in the WSs aided the participants in several activities. Firstly, they enabled the users communicating their knowledge and skills. The artefacts further helped the users to externalize and recall knowledge and experiences that were not immediately considered, and hence identify 'hidden' or emergent needs, a finding in line with, e.g., von Hippel (1994) and Karlsson (1996). Moreover, the representational artefacts did not merely mediate the dialogue from the users' perspective, rather they functioned as tools for merging the different perspectives.

Hence, the representational artefacts supported a shared understanding of users' needs and requirements for the device in a use context as well as brought forward explicit possibilities with the proposed technology. In particular, the representational artefacts mediated collaboration and knowledge-sharing as the participants transformed their own ideas into shared ideas representing design solutions that emerged from the multiple perspectives of the participants. This then, in the moment the new representations were created, also facilitated the generation of new and mutual knowledge. In the process of joint interactions with the representational artefacts, they became subjects for open discussions confirming whether ideas had been understood and whether needs had been correctly interpreted. Some representational artefacts emerged ‘on the fly’ in the WSs collective making activities, functioning as open representations (Vinck et al., 1996) in that they continuously facilitated ideas to be visualised and demonstrated by one person and allowed the other participants to evaluate, endorse or dismiss the idea more or less as soon as they were created. The representational artefacts also made ideas tangible and thus interactively explorable, with pros and cons becoming obvious as ideas were revealed.

Alongside these on-the-fly representations, there were also a few already prepared representations (e.g. switchboard, batteries and control unit) available, in the second and third WS. The prepared representations demonstrated parts of the device which, from the company’s perspective, could not be changed, i.e. closed representations (Vinck et al., 1996). Initially, those closed representations were considered a side issue by the company’s representatives as well as by the facilitator as they represented ‘dummies’ for components such as batteries and switches and proposed to be placed inside the headrest of the device by the company and the designers. However, in the hands-on activities, especially in WS 2, the dummies became as important as the open representations used. The dummies were in constant use by the users and contributed to important leaps in the design solutions as the users organised them as external components alongside the monitoring device rather than inside the device for the head as proposed from the company’s representatives. In addition, the stretcher brought to the WSs by the users supported the teams to test their solutions and thus identify synergies among the two concepts which revealed totally new design opportunities that could be beneficial for the company as well as for the users.

The joint manipulation of the representational artefacts confronted the designers with the users’ experiences of the use context and the users’ needs were challenged with the designers’ and engineers’ design solutions. This enabled not only the designers to access the users’ particular and local knowledge but also enabled the users to contribute to innovative design solutions. It also supported the process of making emergent (Karlsson, 1996), and hidden needs (von Hippel, 1994) of the novel device visible for the users from a usage perspective, so that they became explicit and tangible for the designers in the collective making.

The joint creation of new representational artefacts thus mediated not only the shift of perspectives but also the meta-shift of perspective (Figure 10) as they allowed the participants to go back and forth between their own activity systems with their respective tools, rules and divisions of labour and bring those elements into the new collective activity system to be shared, negotiated and redistributed among the participants.

Insert Figure 10 here.

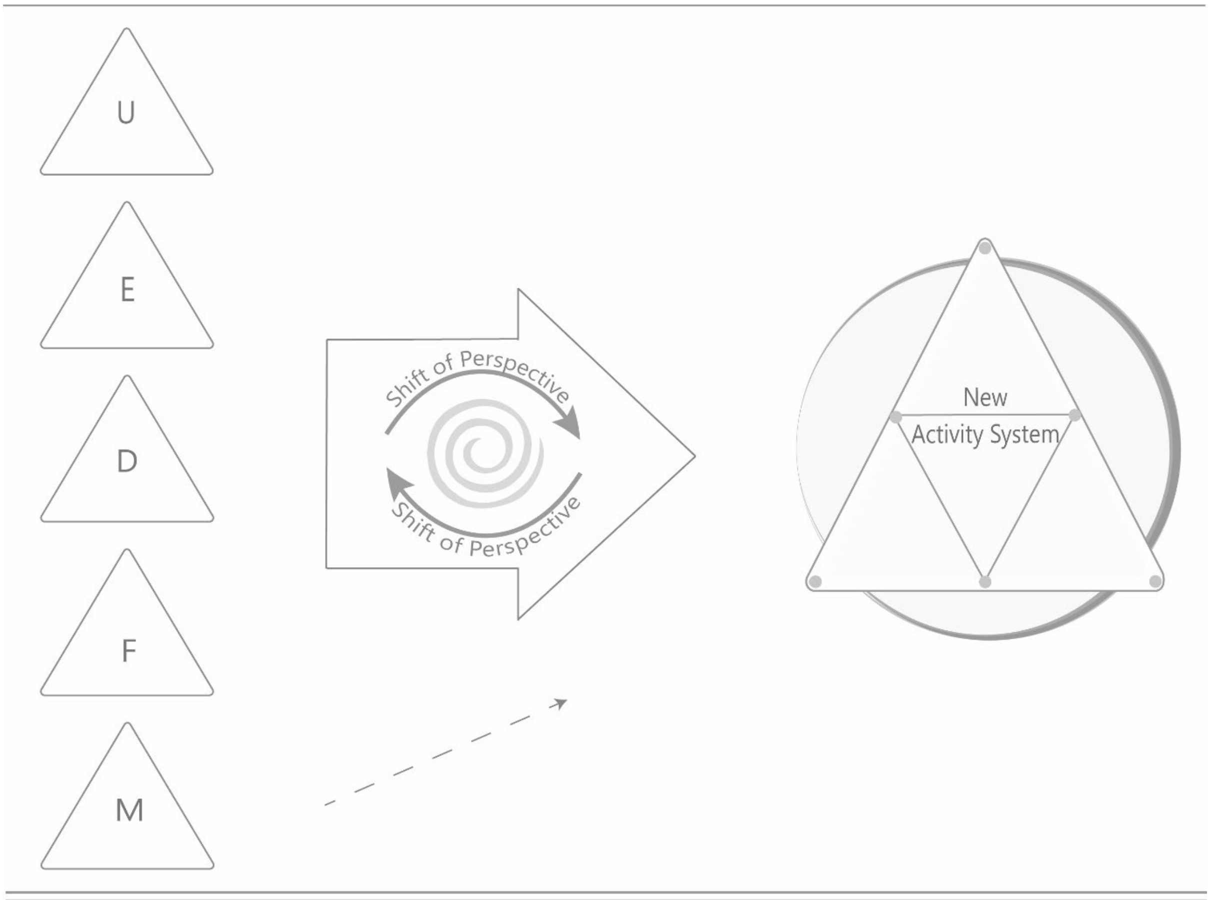


Figure 10. Illustrating the process of shift of perspective for the new shared activity system. Also illustrating that the manager was not part of the creation process and joined straight in with the new collective activity system

5.1.3 The facilitator's role

Unmanaged, power balance in co-design activities is argued to always be skewed in favour of the developing company. That is the company has the power to determine what to develop and produce and the designers decide what design solutions to bring forward in the design process (Bossen et al., 2016 ; Bowen et al., 2013; Hess et al., 2008). Inherently then user participation in new product development is not a democratic and equitable event per se, and the inclusion of a facilitator to counteract power imbalances is often argued for, albeit from different standpoints and different disciplines (Donetto et al., 2015; Hess et al., 2008; Vaajakallio et al., 2009).

For users to be able to participate, contribute their expertise and take active roles in the design process, their domain knowledge, the tools and rules employed in their activity system must be elicited, transferred and understood by the designers and engineers. Users, in turn, must understand the designers' and engineers' motivations and tools used to comprehend what specific knowledge they are expected to provide along with its significance to the overall project. This requires questioning the user — designers existing standard of socio-cultural interaction suggested by Engestöm and Hasu (2002) and include a shift of the power balance to empower users to contribute their perspectives and their objects. This process needs facilitation.

Reflecting on participants' various roles in co-design shows an emerging interest within design research, and Østergaard et al. (2018) emphasise the need to go beyond the 'user-designer' roles towards making the facilitator's contribution to the co-design process visible. This is in line with our understanding of necessities for genuine participation. A project-engaged designer taking the role of a facilitator for the collaborative activities is often stressed in co-design research with the argument that designers can contribute their domain expertise to the creative design practice and design solutions in co-design activities (Lee, 2008; Luck, 2007; Pommeranz et al., 2012; Sanders and Stappers, 2008). Østergaard et al. (2018) propose instead that a researcher who possesses a competence representing both the users' and the designers' activity systems takes the role of facilitator to bridge the disparities between users and designers. However, though we agree this could be a sophisticated way of facilitating genuine participation, we also see that such competence is rare.

Another approach argued in management research underlines that trust and commitment (as means for collaboration) must be cultivated by someone impartial. Such an approach implies that responsibility for organising, planning and running the collaborative activities should be in the hands of the impartial facilitator (Bens, 2012; Nelson and McFadzean, 1998; Wastchak, 2013). To discourage any bias of the participants and ensure that everyone could benefit from the facilitator's intentions, the facilitator should be designated, based on necessary skills, to monitor and support the project's progressing communication and collaboration, without having any conflict of interest or commitment to the participating organisations (Kaner et al., 2014).

In this case we took the latter approach and the facilitator 'was in charge' of the process, laying down the rules for activities in the WSs and planning for the desired outcome. We argue that continuously and over time, the facilitator not only created preconditions for new rules to evolve in the new collective activity system, but also served as a key player to ensure that the participants understood and complied with these rules, thereby creating conditions for the users to become equal members, as far as possible, in the co-design process.

The participants seemed to acknowledge and appreciate that the facilitator had no vested interest other than to create a progressive collaborative process in which everyone was supported to contribute their expertise and respect each other's perspectives. This was specifically noted in subsequent interviews with company representatives and users:

> U1: I thought it worked really well and it felt like he was part of the project actually...and he joined the whole time…he was great! It felt natural…he took the lead and started us and ended the discussions and said when we were going to break and so on...

> E2: The impartial facilitator raises the standards, and it is not only a scientist who wants to study something, it becomes more real for the project. He sets the rules for what to do and how to behave towards each other...

5.2 Challenges in the formation of the new collective activity system

In co-design, as in all collaborative design processes, power distribution between participants is an issue to be taken seriously. Based on the analysis of the case, we want to bring forth three particular challenges: changing the designer's role; the number of competences assigned to group activities; and when a new participant changes the hierarchy.

5.2.1. Changing the designer's role

Besides the general guidance provided throughout the co-design process, there were several occasions when the designers needed the facilitator's specific support to balance the participants contributions in design discussions or in the collective making activities, as well as to manage the inherent power inequality in decision-making in the design process. The designers seemed to experience difficulties contributing their design competence as the creative resource whilst simultaneously acting as coordinators of design ideas from other participants and struggled at times to support the collaborative activity in a democratic manner that allowed the users an equal say in the process.

In this case, the designers' tasks differed from those in their own activity systems. The designers seemed to embrace a more supportive approach in the co-design activities, enabling other participants by visualising and embodying ideas (e.g. sketching, prototyping etc.), rather than maintaining the roles of being the main creative contributors to design solutions. However, despite the facilitator's pre-instructions regarding their specific roles in the co-design process, it was observed that the designers occasionally strained to relinquish their roles in their own activity systems where their role contrasted with the new ones in the new collective activity system. The designers often seemed to regress into their classical role as experts in charge of solving the design problems. This was manifested by gravitating towards designing their own solutions and (at least to some extent) taking on the company's viewpoint of solutions, rather than, in discussions, arguing the value of users' contributions. In addition, the users were often treated by the designers as informants and evaluators, probing questions regarding design solutions close to their own ideas of solutions that had arisen between the WSs, rather than supporting a dialogue to make users' knowledge explicit for mutual learning toward future designs.

These observations support our stand that designers also need support to reframe their contribution in co-design processes, i.e. their roles in the formation of the new collective activity systems. Consequently, it seems that creating a new division of labour in the new collective activity system that is co-design is a fragile process that constantly needs a facilitator's attention.

5.2.2. Power distribution in group activity

Individuals in group activities differ in personality; some people are strong in their argumentation and others are not; some people take the lead, and some do not; some people are true team players, and some are not. In co-design activities, these realities are something the organiser needs to be aware of, though being aware of each participant's personalities in advance is unlikely. However, group composition is something that the facilitator can influence and need to consider. One way counteracting inbuilt inequality between company representatives (e.g. designers, engineers) and users in co-design processes is to consider overrepresenting users in group activities.

This approach became evidently fruitful as, in WS 2, the group consisting of two users, one designer and one engineer revealed differences in users' commitment and ability to contribute transforming their knowledge into design solutions compared to the group with equal numerical distribution of the disciplines. In the group with two users, the division of labour shifted as the users supported each other in the discussions and were proactive in ideation of potential design solutions. The users were also jointly active in the hands-on activities in creating and testing potential solutions, whereas the designer was seen to undertake a more supportive role, embodying the group's shared knowledge. This approach seemed to contribute to a shift of power in the users' favour and was manifested as they gained a stronger voice and more equal say than in the group with only one user.

5.2.3 Balancing hierarchy in the new collective activity system

Finally, a note regarding balancing hierarchies between disciplines. Managerial support is a central prerequisite for co-design activities regardless of who is to represent the organisation (Pirinen, 2016). One argument for managers participating in co-design activities is that managers contribute to effective decision-making in the collaborative activities. Another argument, considered an asset routine, is that managers gain an overview and take responsibility for the project results at the company (Binder and Brandt, 2008; Bowen et al., 2013; Brandt, 2007; Pirinen, 2016). Though we agree to the importance of managerial support, the set-up for this co-design project took another approach. The company representatives were engineers and industrial designers with responsibility to report and discuss steps taken in the co-design project with the company management, ensuring that design decisions applied in the co-design activities were anchored and supported from the company's management. The fact that the company's representatives were engineers and designers rather than managers was found to be of importance for balancing power distribution in the new shared activity system. This was revealed when a manager (M) from the company entered the last WS alongside the engineers and designers.

As the manager's participation was not announced in advance, the facilitator was unable to familiarise the new participant with what had been done in previous WSs or introduce the rules and the new division of labour that had been generated. This was demonstrated as the manager often implied or stated their own motives and objects, without adhering to the group's 'contract' i.e. the new rules and division of labour that had evolved during the joint activities — activities the manager had not been a part of. The manager's questioning of the design solutions which demonstrated the shared, emergent, and embodied knowledge from the different participant's perspectives, illustrated the business manager's unawareness. Indeed, the manager most often turned the attention to the engineers, requesting them to provide answers, rather than exploring the collective reasons and perspectives behind the presented solution. Hence the opportunity to learn about users' immediate as well as long-term needs and requirements remained unexploited for the manager.

The example illustrates that the manager, probably unconsciously, brought his own tools, rules and object which were shaped in his activity system, based on his role in the company, i.e. to provide efficient paths for new products to enter the market (Figure 10). Though it was obvious from the start that the company's representatives felt that they owned the co-design project, the manager's unexpected appearance drastically shifted the power balance among the participants. Even though the manager seemed keen to contribute to the discussions, it created an imbalance in the group that essentially silenced the users. These observations were supported in the subsequent interviews where one of the users confirmed their experience of the rapid shift of their roles from being equal participants in the design team to being 'customers' answering the manager's specific questions:

> U1…we were a homogeneous group and had a common story together...then he entered as a businessman, with a suit, from his company…it changed the dynamics in the group…not the discussion format we had before...more as…he came in with more business decisions…

It was noticed that the facilitator used his tools with the object to redistribute the power balance in the group again by, for instance, encouraging the users to have a voice and supporting the designers to contribute answers related to the embodied design solutions based on the collective work. However, the incidents were an obvious distraction and had a negative impact on the group dynamics as well as the planned process of the WS.

The episode exposes the inherent imbalance of power between users and participants who represent and own the power to make decisions. It also exposes the vulnerability of and difficulties in maintaining new rules and divisions of labour that are jointly created within the framework of the new collective activity system. All in all, it demonstrates the importance that participants and their operational competences as, in this case, designers, engineers and nurses are considered and situated on the same hierarchical level. It also demonstrates the importance of considering time spent together as a crucial factor for participant's contribution and commitment to the creation of new shared rules and redistribution of labour in the configuration of the new collective activity system. This further reveal that challenges in co-design processes are constantly present and that further research is needed to create greater understanding of how to foster mutual learning and users' equal say to ensure their and other stakeholders' genuine participation in co-design processes.

5.3. Limitations

Any co-design process will rely on the choice of participants. A question whether the 'appropriate' participants were represented in the co-design project or not can be posed. In this study we identified the complexity of getting, participants representing professional users, designers and developing engineers, to shift their perspectives towards mutual knowledge building and equal distribution of power in a co-design project. The inherent challenge in this transformative process lies in that each participant needs to move their viewpoint from their own domain space, i.e. their own activity system, towards the formation of a new collective activity system. Involving additional participants on different hierarchical levels (e.g. organisational management or health care device purchase representatives for instance) representing other activity systems (with other tools, needs and objects towards the device) would possibly contribute to a broader perspective in the development process. However, based on the analysis in this case, we argue that such arrangement, by having to handle participants with other competences representing other activity systems would further complicate achieving equality in the co-design process. However, it would be intriguing and probably beneficial to study such merging process of activity systems in future research.

While our case study may provide insights of interpersonal activities and events in a specific context, an inherent limitation lies is that conclusions presented in this paper cannot be generalised, as they rely on just one case. Another limitation may relate to the choice of qualitive research methodology and the natural characteristic of subjective interpretation when analysing collected data. We sought to counteract the subjectivity by debate and discussion, especially between the first and second author, of the analysis and its findings.

Although readers of this paper should keep this in mind, we hope that our insights can serve as a step for other co-design researchers to build on.

6 Conclusion

In this paper we have analysed a co-design project of a medical device involving three categories of participants: users, designers, and engineers, from an Activity Theory perspective. AT provides a human activity centred viewpoint, and through the analysis we have expanded our understanding of how various scenarios and arrangements in a co-design process may affect participants' transformative processes towards genuine participation — including democratic communication and collaboration among the participants. In particular, we explored how mediating tools, processes, participants, and settings as a whole may support the configurative process of genuine participation throughout a co-design process.

We emphasise that inviting users as team members to contribute their specific knowledge to interdisciplinary product design teams places considerable demands on those who invite them to ensure that users are as equally heard as those from disciplines that typically control the design process. To make this equity happen, a meta-shift of perspective, where all participants acknowledge that their contribution in the co-design process is not limited to proposing solutions, but rather that all need to comprehend why their contribution to the co-design activities is of value.

To this end, the respective participants' own activity systems, with its respective tools, motives, rules, object and division of labour need to be externalized, shared and embraced by the other participants. Through this process, a new collective activity system with its own and shared tools, motives, rules, object and division of labour, will emerge. This new collective activity system, we argue, is a pre-requisite for Genuine Co-design.

References

Béguin, P. 2003. Design as a mutual learning process between users and designers. *Interacting with Computers,* 15**,** 709-730.

Bens, I. 2012. *Facilitating with Ease! Core Skills for Facilitators, Team Leaders and Members, Managers, Consultants, and Trainers*, John Wiley & Sons, Incorporated.

Binder, T. & Brandt, E. 2008. The Design:Lab as platform in participatory design research. *CoDesign,* 4**,** 115-129.

Bjögvinsson, E., Ehn, P. & Hillgren, P.-A. 2012. Design Things and Design Thinking: Contemporary Participatory Design Challenges. *Design Issues,* 28**,** 101-116.

Bossen, C., Dindler, C. & Iversen, O. Evaluation in participatory design: a literature survey. The 14th Participatory Design Conference, 2016 ACM, 151-160.

Bowen, S., McSeveny, K., Lockley, E., Wolstenholme, D., Cobb, M. & Dearden, A. 2013. How was it for you? Experiences of participatory design in the UK health service. *CoDesign,* 9**,** 230-246.

Brandt, E. Designing exploratory design games: a framework for participation in participatory design? Proceedings of the ninth conference on Participatory design: Expanding boundaries in design-Volume 1, 2006. 57-66.

Brandt, E. 2007. How Tangible Mock-Ups Support Design Collaboration. *Knowledge, Technology & Policy,* 20**,** 179-192.

Bratteteig, T. & Wagner, I. Design decisions and the sharing of power in PD. Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts-Volume 2, 2014. 29-32.

Broberg, O., Andersen, V. & Seim, R. 2011. Participatory ergonomics in design processes: The role of boundary objects. *Applied Ergonomics,* 42**,** 464-472.

Buur, J. & Bødker, S. 2000. From usability lab to design collaboratorium reframing usability practice. *In:* BOYARSKI, D. & KELLOGG, W. A. (eds.) *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques.* USA, New York ACM.

Bødker, S. 1987. *Through the Interface - a Human Activity Approach to User Interface Design.* Diss., Aarhus University, Denmark.

Bødker, S. 1996. Creating Conditions for Participation: Conflicts and Resources in Systems Development. *Human - Computer Interaction,* 11**,** 215-236.

Bødker, S. & Buur, J. 2002. The design collaboratorium: a place for usability design. *ACM Trans. Comput.-Hum. Interact.,* 9**,** 152-169.

Bødker, S. & Klokmose, C. N. 2011. The human–artifact model: An activity theoretical approach to artifact ecologies. *Human–Computer Interaction,* 26**,** 315-371.

Cain, R. E. 2005. *Involving users in the design process: the role of product representations in co-designing.* U216679, Loughborough University (United Kingdom).

Carlile, P. R. 1997. *Understanding knowledge transformation in product development: Making knowledge manifest through boundary objects.* PhD PhD diss., The University of Michigan.

Carlile, P. R. 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science,* 13**,** 442-455.

Clarkson, P. J., Buckle, P., Coleman, R., Stubbs, D., Ward, J., Jarrett, J., Lane, R. & Bound, J. 2004. Design for patient safety: a review of the effectiveness of design in the UK health service. *Journal of Engineering Design,* 15**,** 123-140.

Cobaleda-Cordero, A., Babapour, M. & Karlsson, M. 2020. Flexible office, flexible working? A post-relocation study on how and why university employees use a combi-office for their activities at hand. *International Journal of Human Factors and Ergonomics,* 7**,** 26-54.

Colldén Benneck, J. & Bremer, A. 2019. Registered nurses' experiences of near misses in ambulance care – A critical incident technique study. *International Emergency Nursing,* 47**,** 100776.

Conway, H. A. & McGuinness, N. W. 1986. Idea generation in technology-based firms. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association,* 3**,** 276-291.

De Ana, F., Umstead, K., Phillips, G. & Conner, C. 2013. Value driven innovation in medical device design: a process for balancing stakeholder voices. *Annals of biomedical engineering,* 41**,** 1811-1821.

Donetto, S., Pierri, P., Tsianakas, V. & Robert, G. 2015. Experience-based Co-design and Healthcare Improvement: Realizing Participatory Design in the Public Sector. *The Design Journal,* 18**,** 227-248.

Drain, A., Shekar, A. & Grigg, N. 2019. 'Involve me and I'll understand': creative capacity building for participatory design with rural Cambodian farmers. *CoDesign,* 15**,** 110-127.

Druin, A. 2002. The role of children in the design of new technology. *Behaviour & Information Technology* 21**,** 1-25.

Eason, K. D. 1995. User-centred design: for users or by users? *Ergonomics,* 38**,** 1667-1673.

Ehn, P. 1988. *Work-oriented design of computer artifacts.* PhD. PhD. diss., Arbetslivscentrum.

Ehn, P. & Kyng, M. 1987. The collective resource approach to systems design. *In:* BJERKNES, G., EHN, PELLE., KYNG, MORTEN (ed.) *Computers and democracy.* Gower Publishing.

Engelbrektsson, P. 2004. *Enabling the user: exploring methodological effects on user requirements elicitation.* PhD, Chalmers University of Technology.

Engeström, Y. 1987. *Learning by expanding: An activity-theoretical approach to developmental research,* Helsinki, Orienta-Konsultit Oy.

Engeström, Y. 1999. Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. *In:* ENGESTRÖM, Y., MIETTINEN, R. & PUNAMÄKI, R.-L. (eds.) *Perspectives on activity theory.* Cambridge: Cambridge University Press.

Engeström, Y. 2000. Activity theory as a framework for analyzing and redesigning work. *Ergonomics,* 43**,** 960-974.

Engeström, Y., Kajamaa, A., Lahtinen, P. & Sannino, A. 2015. Toward a Grammar of Collaboration. *Mind, Culture, and Activity,* 22**,** 92-111.

Engeström, Y., Miettinen, R. & Punamäki, R.-L. (eds.) 1999. *Perspectives on Activity Theory,* Cambridge: Cambridge University Press.

Eriksson, S. 2014. *The Mediating Role of Product Representations; A Study with Three-Dimensional Textiles in Early Phases of Innovation.* Licentiate thesis, monograph, Chalmers University of Technology.

Eriksson, S., Wallgren, P. & Karlsson, M. Facilitating Users and Designers Towards a Shift of Perspective for True Participation in Co-creation in Health Care: A Holistic Activity Theoretical Approach. *In:* CHRISTER K., C., C. CHAMBERLAIN, P., ed. The 6th European Conference on Design4Health, 1st-3rd July 2020, 2020 Amsterdam. Sheffield, UK: Sheffield Hallam University, 128-135.

Ertner, M., Kragelund, A. & Malmborg, L. Five enunciations of empowerment in participatory design. Proceedings of the 11th Biennial Participatory Design Conference 2010 Sidney, Australia. ACM, 191-194.

Frauenberger, C., Good, J., Fitzpatrick, G. & Iversen, O. S. 2015. In pursuit of rigour and accountability in participatory design. *International journal of human-computer studies,* 74**,** 93-106.

Goldsmith, D. 2018. *Women Weave Daily: "Artisan Fashion" as "Slow and Sustainable Fashion".* PhD Dissertation, Univerity of Borås.

Granskär, M. & Höglund-Nielsen, B. 2008. *Tillämpad kvalitativ forskning inom hälso- och sjukvård* Lund, Studentlitteratur.
Gunnarsson, B. M. & Warrén Stomberg, M. 2009. Factors influencing decision making among ambulance nurses in emergency care situations. *International Emergency Nursing,* 17**,** 83-89.
Haines, H., Wilson, J. R., Vink, P. & Koningsveld, E. 2002. Validating a framework for participatory ergonomics (the PEF). *Ergonomics,* 45**,** 309-327.
Hall-Andersen, L. B. & Broberg, O. 2014. Integrating ergonomics into engineering design: The role of objects. *Applied Ergonomics,* 45**,** 647-654.
Halskov, K. & Hansen, N. B. 2015. The diversity of participatory design research practice at PDC 2002–2012. *International Journal of Human-Computer Studies,* 74**,** 81-92.
Hasu, M. & Engeström, Y. 2000. Measurement in action: an activity-theoretical perspective on producer–user interaction. *International Journal of Human-Computer Studies,* 53**,** 61-89.
Hendrick, H. W. 2008. Applying ergonomics to systems: Some documented "lessons learned". *Applied Ergonomics,* 39**,** 418-426.
Hess, J., Offenberg, S. & Pipek, V. Community driven development as participation?: involving user communities in a software design process. Proceedings of the Tenth Anniversary Conference on Participatory Design 2008, 2008. Indiana University, 31-40.
Hjort af Ornäs, V. 2010. *The significance of things: Affective user-artefact relations*, Chalmers University of Technology.
Holmlid, S. & Malmberg, L. Learning to design in public sector organisations: A critique towards effectiveness of design integration. ServDes2018. Service Design Proof of Concept, Proceedings of the ServDes. 2018 Conference, 18-20 June, Milano, Italy, 2018. Linköping University Electronic Press, 37-48.
Hoyer, W. D., Chandy, R., Dorotic, M., Krafft, M. & Singh, S. S. 2010. Consumer Cocreation in New Product Development. *Journal of Service Research,* 13**,** 283-296.
Johannesson, C. & Holmlid, S. 2013. Design av offentliga tjänster-En förstudie av designbaserade ansatser. *VINNOVA Rapport VR 2013: 11*.
Kaner, S., Doyle, M., Kerney, K., Berger, D., Lind, L. & Ebook, C. 2014. *Facilitator's guide to participatory decision-making,* San Francisco, California, Jossey-Bass.
Kaptelinin, V. & Nardi, A. B. 2006. *Acting with Technology; Activity Theory and Interaction Design,* United states of America, MIT Press.
Karlsson, I. C. M., Engelbrektsson, P., Larsson, L. E., Pareto, L., Snis, U., Berndtsson, B. & Svensson, L. 2011. Use-centred design of medical and healthcare technology: a pilot study of field tests as a development tool. *International Journal of Biomedical Engineering and Technology,* 5**,** 11-28.
Karlsson, M. 1996. *User Requirements elicitation A framework for the study of the relation between user and artefact.* PhD diss., Chalmers University of Technology.
Kohlbacher, F. The use of qualitative content analysis in case study research. Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 2006. Institut für Qualitative Forschung, 1-30.
Kohn, L. T., Corrigan, J. & Donaldson, M. S. 2000. *To err is human: building a safer health system*, National academy press Washington, DC.
Kuutti, K. 2009. Artifacts, Activities and Design Knowledge. *In:* POGGENPOHL, S., SATO, KEIICHI (ed.) *Design Integrations : Research and Collaboration.* Bristol, GBR: Intellect Ltd.
Lee, Y. 2008. Design participation tactics: the challenges and new roles for designers in the co-design process. *CoDesign,* 4**,** 31-50.
Leontyev, A. N. 1978. *Activity and Consciousness and personality,* New Jersey, USA, Prentice-Hall
Leontyev, A. N. 1981. *The Development of Mind* Pacifica, CA 94044; USA., Marxists Internet Archive.
Luck, R. 2007. Learning to talk to users in participatory design situations. *Design Studies,* 28**,** 217-242.
McCarthy, J. & Wright, P. 2015. *Taking [a] part: the politics and aesthetics of participation in experience-centered design*, MIT Press.
Miles, M. B., Huberman, A. M. & Saldaña, J. 2014. *Qualitative data analysis : a methods sourcebook*, Sage.
Money, A. G., Barnett, J., Kuljis, J., Craven, M. P., Martin, J. L. & Young, T. 2011. The role of the user within the medical device design and development process: medical device manufacturers' perspectives. *BMC Medical Informatics and Decision Making,* 11**,** 15.
Moody, L. 2015. User-centred health design: reflections on D4D's experiences and challenges. *Journal of Medical Engineering & Technology,* 39**,** 395-403.
Nelson, T. & McFadzean, E. 1998. Facilitating problem-solving groups: facilitator competences. *Leadership & Organization Development Journal,* 19**,** 72-82.
Pirinen, A. 2016. The barriers and enablers of co-design for services. *International Journal of Design,* 10.

Pommeranz, A., Ulgen, U. & Jonker, C. M. 2012. Exploration of facilitation, materials and group composition in participatory design sessions. *Proceedings of the 30th European Conference on Cognitive Ergonomics.* Edinburgh, United Kingdom: ACM.

Reagans, R. & McEvily, B. 2003. Network structure and knowledge transfer: The effects of cohesion and range. *Administrative science quarterly,* 48**,** 240-267.

Rexfelt, O. 2008. *User-centred design and technology-mediated services-identifying and addressing challenges by analysing activities*, Chalmers University of Technology.

Riessman Kohler, C. 2000. Analysis of personal narratives. *Qualitative research in social work,* 2000**,** 168-191.

Robertson, T. & Simonsen, J. 2012. Challenges and Opportunities in Contemporary Participatory Design. *Design Issues,* 28**,** 3-9.

Roth, W.-M. 2004. INTRODUCTION:" Activity Theory and Education: An Introduction". *Mind, Culture, and Activity,* 11**,** 1-8.

Sanders, E. B.-N. & Westerlund, B. 2011. Experiencing, exploring and experimenting in and with co-design spaces. *Nordes.*

Sanders, E. B. N. & Stappers, P. J. 2008. Co-creation and the new landscapes of design. *CoDesign,* 4**,** 5-18.

Sanders, E. B. N. & Stappers, P. J. 2014. Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign,* 10**,** 5-14.

Selvefors, A. 2017. *Design beyond interventions–supporting less energy-reliant activities in the everyday.* PhD, Chalmers University of Technology.

Shah, S. G. S. & Robinson, I. 2007. Benefits of and barriers to involving users in medical device technology development and evaluation. *International Journal of Technology Assessment in Health Care,* 23**,** 131-137.

Shah, S. G. S. & Robinson, I. 2008. Medical device technologies: who is the user? *International Journal of Healthcare Technology and Management,* 9**,** 181-197.

Simonsen, J. & Robertson, T. (eds.) 2012. *Routledge International Handbook of Participatory Design*: Routledge.

Skyttner, L. 1996. The Emergence of Holistic Thinking. *General Systems Theory: An Introduction.* London: Macmillan Education UK.

Sleeswijk Visser, F., Stappers, P. J., van der Lugt, R. & Sanders, E. B. N. 2005. Contextmapping: experiences from practice. *CoDesign,* 1**,** 119-149.

Smith, R. C. & Iversen, O. S. 2018. Participatory design for sustainable social change. *Design Studies,* 59**,** 9-36.

Star, S. L. & Griesemer, J. R. 1989. Institutional Ecology, `Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science,* 19**,** 387-420.

Stenmark, D. Information vs. knowledge: the role of intranets in knowledge management. 2002 2002. IEEE, 928-937.

Stichler, J. F. 2016. Patient safety: A priority for healthcare and for healthcare design. SAGE Publications Sage CA: Los Angeles, CA.

Sundin, A., Christmansson, M. & Larsson, M. 2004. A different perspective in participatory ergonomics in product development improves assembly work in the automotive industry. *International Journal of Industrial Ergonomics,* 33**,** 1-14.

Söderman, M. 2001. *Product representations: Exploring computer-based technologies and customers' understanding of product concepts.* PhD, Chalmers University of Technology.

Söderman, M. 2005. Virtual reality in product evaluations with potential customers: An exploratory study comparing virtual reality with conventional product representations. *Journal of Engineering Design,* 16**,** 311-328.

Thomas, J. & McDonagh, D. 2013. Shared language: Towards more effective communication. *Australasian Medical Journal,* 6.

Toker, Z. 2007. Recent trends in community design: the eminence of participation. *Design Studies,* 28**,** 309-323.

Vaajakallio, K., Lee, J.-J. & Mattelmäki, T. 2009. "It has to be a group work!": co-design with children. *Proceedings of the 8th International Conference on Interaction Design and Children.* Como, Italy: ACM.

Vagn, A. R., Jensen, C. S. & Broberg, O. Participatory methods for initiating manufacturing employees' involvement in product innovation. ISPIM Conference Proceedings, 2016. The International Society for Professional Innovation Management (ISPIM), 1.

Vinck, D., Jeantet, A. & Laureillard, P. 1996. Objects and Other Intermediaries in the Sociotechnical Process of Product Design: an exploratory approach. *The role of design in the shaping of technology,* 5**,** 297-320.

von Bertalanffy, L. 1950. An outline of general system theory. *British Journal for the Philosophy of Science,* 1**,** 134-165.
von Hippel, E. 1994. "Sticky information" and the locus of problem solving: Implications for innovation. *Management Science,* 40**,** 429.
von Hippel, E. 2005. *Democratizing innovation,* Cambridge, Mass, MIT Press.
Vygotsky, L. S. 1978. *Mind in Society: The Development of Higher Psychological Processes,* Cambridge, Mass., Harvard University Press (Original work [1934])
Wastchak, D. R. 2013. *Public Participation and the Impact of Third-Party Facilitators.* Dissertation, Arizona State University.
Wenger, E. C. 1990. *Toward a theory of cultural transparency: elements of a social discourse of the visible and the invisible.* Dissertation/Thesis PhD diss., University of California.
Went, K. L., Gregor, P. & Ricketts, I. W. Designing a Safer Interactive Healthcare System - The Impact of Authentic User Participation. 2009 Berlin, Heidelberg. Springer Berlin Heidelberg, 718-730.
WHO. 2013. *Cardiovascular Diseases Fact Sheet No. 317* [Online]. WHO. Available: http/www.who.int/mediacentre/factsheets/fs317/en/ [Accessed 2017].
Wikberg-Nilsson, A., Törlind, P. & Ericsson, A. 2015. *Design - process och metod,* Lund, Studentlitteratur.
Wilkinson, C. R. & De Angeli, A. 2014. Applying user centred and participatory design approaches to commercial product development. *Design Studies,* 35**,** 614-631.
Østergaard, K. L., Simonsen, J. & Karasti, H. 2018. Examining situated design practices: Nurses' transformations towards genuine participation. *Design Studies,* 59**,** 37-57.