Context Sensitive Health Informatics: Human and Sociotechnical Approaches
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Sociotechnical Systems as Innovation Systems in the Medical and Health Domain

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Abstract. It is argued that a development of healthcare systems should emerge within a healthcare providing organization and as part of daily practice instead of something implemented by a third party, in order to become successful. This sociotechnical view on system development is shared with new methods developed in the end-user development field. However, is it possible to realize this in practice? This paper explores the obstacles and potentials in the realization, leading to a discussion about sociotechnical systems as innovation systems. We describe two examples of sociotechnical innovation systems, and discuss the results from an end user driven innovation process perspective.

Keywords. Sociotechnical systems, innovation systems, end-user development

Introduction

There is a common understanding that medical and health practices are fundamentally *sociotechnical*, in that daily work involves a range of professionals and technical devices where all contribute to and put constraints on the outcome of care [1]. Clinical practice is also highly *situated*, where decisions often must be made based on the available limited knowledge and resources [2]. This poses demands on the different phases of technology development for such use environment. It is argued that the sociotechnical perspective needs to be integrated from the early phases. It is emphasized that formative evaluation studies should put focus on the change of work routines and of the culture that may affect the use of systems, as well as on how the use of systems may affect and direct the development of work routines. It is also argued that development of health care systems should emerge within the organization and daily practice instead of something that is implemented by a third party into the daily work, for the system to become successful [3]. This perspective follows also the meta-design perspective [4], in which the end-users and stakeholders are an integral and influential part of a software development process. Moreover, this perspective is also shared with the cultural-historical activity theoretical model [5], where the tool-developing parallel process affects and interacts with the main activity, i.e., the targeted clinical practice. However, emergence of health care systems within daily practice requires that innovative ideas of the actors in the environment can be materialized.

The transformation of a traditional sociotechnical development process into an *innovation* process is highly dependent on the end-users and stakeholders' role as innovators and designers [6]. Moreover, in order to enable them to participate, they

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need *tools* for designing and developing their innovations [6]. The benefits are reduction of costly iterations and improved customizations of products leading to more satisfying solutions [6]. However, integrating the development of new technology into the existing sociotechnical systems in medical and health care is a complex task. One obstacle to allowing the technical innovations to emerge within the sociotechnical systems, is that the allocation of available resources to the ordinary production of health care is of highest priority. In addition, the tools that can be used for taking ideas about new technology into practice are typically lacking. So, what are the incentives and obstacles to moving towards *sociotechnical innovation systems* as an integral part of medical and health care? For the purpose to answer this question, we explore two differently organized sociotechnical innovation systems operating in the health domain. One is production-driven, while the other is research-driven. Another difference is that the former targets primarily an improved care delivery process supported by a new version of an electronic health record system (EHR), while the other targets primarily an improved client-centric care delivery. Common for the two is the medical and health care personnel's strong engagement in changing and improving their, and their clients' tools. In the following section a brief description is provided of an ongoing and participatory development process of a new version of an EHR. This is followed by a summary of the process and outcome of a meta-design endeavor for improving health in older adults. The feasibility of an end user driven development approach in health care is discussed, and the article ends with some conclusions.

1. Scenario I: Sociotechnical System Development within a Hospital Environment

The medical professionals at the particular hospital in focus for this study have formed strong opinions about the electronic health record (EHR) in use at the hospital based on their experiences. Obstacles to its use have been frequently discussed in daily work. This was evident in the ongoing development of a new version, where engaged individuals were enrolled to form a number of expert groups representing different sub-organizations. Other key actors were a project leader assigned by an ICT-company different from the ICT-business delivering the EHR, representatives from the EHR-providing ICT-company, a person functioning as the "system-owner", representing the county council, and an operative group of medical professionals representing different units of the hospital. Although a participatory approach to the development was applied, a general opinion among the staff was that they were not heard and their opinions and ideas were not taken into consideration to a satisfactory extent. In order to satisfy this need, a wiki was set up, where personnel outside of the working groups could participate in discussions and provide their ideas.

Important tasks in the process were to identify requirements and make well-motivated priorities among the possible solutions generated by the working groups. The groups needed to agree upon a workflow suitable for the organization in the care delivery process. In order to accomplish this, the scope for analysis and design needed to be highly contextual, while also targeting details in the care delivery process.

The desired outcome was an improved system with better modularity, usability, and support for work processes, which the staff could feel comfortable in using. The work was done within the resource limits assigned to the project, and following the requirement specifications that were set up for the work. Consequently, this was a comparable structured process.

2. Scenario II: An Innovation Tool for Sociotechnical System Development

A generic ontological model of activity was developed based on studies of a broad range of use contexts and sociotechnical systems [7, 8]. The ontology serves as the data and terminology model of a platform for end-user development of knowledge-based health applications (ACKTUS) [9]. The purpose of ACKTUS is to provide a tool for medical and health professionals for developing tools, which are perceived as potentially useful in their daily work. In addition to the knowledge engineering tasks, the domain professional design the behavior of the knowledge system, for the purpose to improve the support provided by the system, and can test the outcome while editing [10]. We use ACKTUS as a means to explore how health and medical professionals, who are not familiar with design or system development, approach the task.

We take as example the development of an ambient assisted home environment, which aims to include a range of interacting software applications subjected to different purposes and regulations. Specific for an ambient assisted home environment is that the main purpose and desired outcome is to empower the individual as an autonomous citizen, who is in power of his or her home environment and daily life, and promote health and a satisfactory quality of life. This may be in a scenario where the individual is possibly subjected to tele-medical care activities [11]. We target individuals with cognitive deficiencies among other health-related issues. This holistic scope of an individual's situation is contextually rich and demanding from a design perspective.

Health professionals (physicians, nurses and occupational therapists) were enrolled as designers and knowledge engineers in the process working from a common use case scenario. As a result, three prototypes have emerged, one for the older adult and next-of-kin, one for physicians and one for rehabilitation professionals (nurses and occupational therapists). In our scenario of an older adult in her home environment, there is a range of potential daily obstacles to be handled, which also may change over time. The occupational therapist provides adjustments and equipment to the home as interventions, for the purpose to increase ability and autonomy. Consequently, since the assessments are based on the individual's needs and ability, the interventions e.g., in the form of an ambient assisted living environment, need to be tailored accordingly. When there is suspicion of a dementia disease, the physician and the team assess the presence of dementia based on information about daily activities in the home environment. In case the older adult suffers from a progressive dementia disease or depression, ability typically fluctuates, which needs to be taken into count when providing support in daily living. The professionals who designed the applications implemented also methods for the health and medical professionals to follow up on interventions.

3. Discussion

Contextual factors are acknowledged to an increasing extent in a design process of software to be integrated in a care process. The sociotechnical approaches and the latest developments of the human factors engineering methodology are examples of this [1-3, 12]. Researchers have suggested different approaches to managing contextual information in the design process, we have already mentioned a few [1-5]. Common between user-centered and sociotechnical design methodologies are that the social, organizational, technological and human factors (motives, needs, preferences, skills,

experiences, etc) are taken into account in the design process. However, to which extent end users and stakeholders are actually involved in the different steps differs between design methodologies, as well as between cultures.

There are typically clearly defined *roles* among people involved in a design process. The software professionals have their work division between engineers and designers, while the care providing organization has theirs, based on the daily work. A difference is that the ICT professionals keep their roles as part of their daily work when entering a new design process. When the health care personnel become involved, they shift roles and activity from acting as the healthcare professional using computer-based tools for treating a patient, to healthcare professional/designer designing an improved computer-based tool for their treatment activity. Their experience from the treatment activity including old tools is instrumental for informing the design of the new tool. It can be expected that the medical and health professionals, who become involved in a design process, are typically focussing the qualities of the care delivery production, rather than the *efficient production* of usable and secure software [13]. In their engagement in the design of their future tools, they are allowed to be *creative*, envisioning new better ways of doing their future work tasks. This creativity may become more or less influential, depending on how the design process is organized.

To what extent the end user representatives have influence on the design choices depends on which methodology and philosophy are applied. The traditional view is that designers interact with representatives from the clinical practice in the initial requirements phase, and allow end users, supervised by interaction designers or human factors engineers, test the next-to-finished prototypes in an environment similar to daily practice. However, designers make the design choices. By contrast, the participatory design methodology systematically integrates end users from early in the process, and they influence the design. A participatory action research methodology was applied in [14], where the design process continued as part of an authentic use of a prototype in clinical practice. The same idea is described in the meta-design approach [4], with an even larger emphasis on the merging of roles over time, and on the continuously ongoing development of computer systems while being in use, following the unavoidable changes in the environment.

Selecting the *scope* of a design process is an important task, and may have to be adjusted during the process. To large extent it is the customer who defines the scope when enrolling a software producer for a task to be done, e.g., as a requirement specification as was the case in our EHR-example. In this case the customer was the healthcare providing organization. By contrast, our second example started in the assessments of eight older adult volunteers and their needs and wishes, the customers were individuals. The older adults actively evaluated prototypes and contributed to the design and re-design of their applications, thus they played also the role of designers besides stakeholders. The nurses and occupational therapists also acted as the innovators, creating their future envisioned software tools for the benefits of both themselves, their colleagues and their clients. Their roles became a mix of the stakeholder, domain professional, customer, user and designer.

The design and development process may follow an extremely *structured* procedure, typically in order to deliver a product within time and resource limits. With such restrictions, the priority to deliver a completed system possibly allows less attention to be paid to changing circumstances, which may urge for some less structured emergence of results during the development process. On the other hand,

design processes, which allows for *emergent development* in use, are typically less frequently seen in the medical and health domains, due to their safety requirements.

One of the particular challenges for medical and healthcare-related system development is the *regulations and legislation* of e.g., how patient data and interventions should be handled, which are explicitly included in models such as Engeström's activity system [5] and the model of Human Factors in [12]. Such regulations differ between countries as well as between different categories of end-users, and consequently, software needs to be validated towards regulations and legislation in a local context. A conflict arises for instance, when the treatment of a patient is stretched into their private home environments, where other legislations apply.

Different types of *outcomes* may be envisioned. A basic goal is to deliver an accurate, safe, usable and efficient system, which meets its purposes and user/organizational needs. Additional requirements may be an easily manageable knowledgebase, flexible to be adjusted to changing population of users and to changing work tasks. The conflicting expectations can be seen in the ambitions to support care flows bridging organisational borders, vs. keeping patient data secured. Moreover, the health professionals' obligation to document their work tasks may override their educational needs. A user may need to change their work routines when new software is introduced. Thus, there is a contradiction between behaviour change and a human's habitual system, seen in for instance, the resistance in physicians against following clinical practice guidelines [15]. A guideline-based decision support system is designed to *empower* the clinician, however, it can also *adapt* to a clinician's habits and way of reasoning. There is also a contradiction between empowering the older adult in an ambient assisted living scenario to become autonomous, while embedding adaptive systems in their home. How can the interaction with the ambient intelligent system be both adaptive, yet allowing the older adult to be in control?

Knowledge acquisition and management is known to be a bottleneck in knowledge engineering tasks when medical domain experts need to translate their medical knowledge into formal computer-interpretable formats. Although tools are developed especially for the purpose, the physician's switch of role from clinician to a knowledge engineer requires learning the relevant tools, in addition to time resources (e.g., [16]). By contrast, in our second example the domain professionals, previously unfamiliar with ACKTUS, were able to create prototypes within a few hours and test these in executable user cases while they were editing the content and interaction flows.

4. Conclusions

There are incentives and obstacles to transforming a sociotechnical system into a *sociotechnical innovation system* as an integral part of medical and health care, e.g., the laws and regulations that restrict the members of care providing organizations in how they can use information and systems. We identified challenging aspects of the design process in the literature and in analyses of two sociotechnical systems involved in system development. These aspects may serve as *facilitators* or *obstacles* for innovation in medical and health care: 1) *Scope and tools* (available toolkits for building innovations [6]); 2) *Resources*; 3) *Process* (creativity vs. production, emergent interaction vs. structured procedures [4]); 4) *Roles* (designer vs. stakeholder vs. user vs. developer [14, 4]); 5) *Rules and regulations* (laws, routines, clinical practice guidelines, etc. [5, 12]); and 6) *Targeted outcome* (behaviour change vs. habitual systems,

empowerment, autonomy vs. adaptivity). Their influence on the design process, when aiming at allowing the professionals design their tools to be used in, and as part of, their daily practice, has been discussed. A structured production environment has been contrasted with an unstructured, loosely coupled and emergent development process, where ACKTUS served as an innovation toolkit, allowing professionals compose knowledge-based applications according to their envisioned future practice.

To conclude, sociotechnical systems may become *sociotechnical innovation systems*, if members of the social sub-system are allowed to actively contribute to the emergence of new tools as part of their daily work. In addition, there has to be technical facilitators in the form of innovation toolkits available as part of the technical sub-system. When these two basic requirements are fulfilled, the additional identified aspects need to be explored. Since they are inherently present, they should be considered, not primarily as causes of unintended consequences of use, but as reliable and expected contributors to the evolvement of clinical practice and knowledge.

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