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Using System Analysis and Personas for e-Health Interaction Design

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Abstract

Today, designers obtain more central roles in product and service development (Perks, Cooper, & Jones, 2005). They have to deal with increasingly complicated problems, like integrating the needs of various stakeholders while taking care about social, ethical and ecological consequences of their designs. To deal with this demanding design situation, they need to apply new methods to organize the available information and to negotiate the stakeholder's perspectives.

This paper describes how systems analysis supports the design process in a complex environment. In a case study, we demonstrate how this method enables designers to describe user requirements for complex design environments while considering the perspectives of various stakeholders. We present a design research project applying cybernetic systems analysis using the software "System-Tools" (Vester, 2002). Results from the analysis were taken to inform the design of an electronic patient record (EPR), considering the particularities of the German health care system. Based on the analysis, we developed a set of requirements for every stakeholder group, detailing the patients' perspective with persona descriptions. We then picked a main persona as reference for the EPR design. We describe the resulting design sketch and discuss the value of cybernetic systems analysis as a tool to deal with complex social environments. The result shows how the method helps designers to structure and organize information about the context and identify fruitful intervention opportunities for design.

Keywords

E-Health; System Analysis, Cybernetics; Personas.

The notion of design as dealing with "complex" tasks is not entirely new (see for example Alexander (1964)). Taking place in social and cultural space, the consequences of design interventions in society are difficult to anticipate. As to refer to Rittel (1973), the design of products that can cause radical social change is a "wicked problem". Established design methods consider partial aspects of the design context, but neglect the interconnection of different phenomena. With designers obtaining more responsible roles in innovation development, they require a holistic view on the problem situation (Perks et al., 2005) that an analysis on the "system level" can offer. As one way to deal with the nonlinear, interconnected nature of „complex" design environments, Jonas (2002; 2005) proposes a systemic approach, using cybernetic systems analysis tools like Vester's sensitivity model (Vester, 2002).

Cybernetics is initially referred to as the "science of control and communication in the animal and the machine" (Wiener, 1963). Nowadays the term is broadened to describe "an interdisciplinary approach to organization, irrespective of a system's material realization" ("Web Dicitionary of Cybernetics and Systems,"). It focuses on the organization of a structure (or system) and the mutual impact of its relevant variables on each other. One basic feature of cybernetic systems is feedback, the impact of a variable on itself through a causal chain of interrelations. The understanding of feedback among a set of variables helps to estimate if a planned intervention results in the desired effect.

Cybernetic system analysis itself has been used in city and traffic planning, ecology and business strategy, which include domains that can be considered as design activities in a broader sense (for examples, see (Frederic Vester GmbH)). However, the use of software-supported cybernetic systems analysis is not widespread in service and product design. The method assembles first-order causal relations to reveal interrelations of higher order. It depicts possible short-term as well as long-term developments and acknowledges opposing assumptions about the regarded system (as one can occur in the long term, while the other appears immediately). It is therefore appropriate to synthesize the opinions and approaches of stakeholders with divergent interests. In this respect, it is a promising approach to represent multiple stakeholder perspectives as the background of a new product throughout the whole design process.

The approach

Our project inquiry consists of two parts: A sensitivity system model of the situation and the definition of requirements for different user types. We used the system analysis to structure the information gathering process and to examine the system dynamics. In the next step, these results are used to identify the interests of different stakeholders, and also to differentiate the patients into a set of personas. A list of requirements was set up based on the main persona.

The resulting software and hardware interface gives an idea how cybernetic systems analysis can inform the design process and broaden the designer's perspective on the situation. However, it should not be considered as a market-ready prototype, but rather give a direction of how the interests of different stakeholders could be incorporated into the design of a coherent product.

Case Study: EPRs in Germany

In our case study, we demonstrate how cybernetic systems analysis enables designers to describe user requirements while considering the perspectives of various stakeholders. The result shows how the method helps designers to structure and organize information about the context and identify fruitful intervention opportunities for design.

We take the introduction of Electronic Patient Records (EPRs) in Germany as an example of a complex environment that benefits from design interventions. As an e-health service, the EPR setup involves many and different stakeholders, like the government, health insurances, medical professionals, the health-related industries and the patients. E-health applications are expected to have a considerable impact on political, social, economical and psychological aspects of health care (Coiera, 2004). Developments within the public health system can have extremely long-term effects, but are hard to predict and highly interdependent.

However, the patients, being probably the biggest group of stakeholders, are rather under-represented in the public discussion and in the setup of the EPR in Germany. Not being as organized as professional lobbies, the patients' interests are mainly articulated by public officials in data security (i.e. the data protection officer, assigned by the government). First pilot studies mainly address medical staff as the main users (Bossen, 2006), although there has been some effort and awareness to involve patients as well (Hägele & Köhler, 2002; Leonard & Winkelmann, 2003).

Still, the impact of the EPR on the patient-doctor relationship and the patient's self-perception should influence the whole health care system considerably (Rindfleisch, 1997). In Germany, the planned introduction of the EPR coincided with a political discussion about fundamental changes in the structure of the healthcare system. Due to demographic changes, there is a need for more self-responsibility if a high medical standard should be retained within a tolerable charge for the patients. Here, designers should emphasize the patient's perspective while considering the situation as a whole in the design of an EPR.

Method: The sensitivity model

In the following, we give an overview about cybernetic systems analysis and describe its application in the respective case. The method is used to deal with situations where the system behavior eludes simple causal prediction. We used the sensitivity model software „System tools" developed by Frederic Vester to conduct the analysis. Below, we will describe the following important steps in detail:

1. definition of the relevant system variables and their relations in a dynamic system model,
2. evaluation of the role of each variable within the system and its significance for design interventions,
3. analysis of feedback loops within the system model and their consistency with research results in the field and experience reports (e.g., in press articles).

Our system model describes the relationship between doctors and patients. We expected this relationship and its sensitivity to external influences to be crucial for the EPR design, and likely to be influenced by an EPR (as a comparable example, see (Bardram, Bossen, & Thomsen, 2005)). As the analysis depends strongly on the organization of the health care system (Böcken, Betzlaff, & Esche, 2000), it is only the German system that we refer to.

System description

To describe the system variables and relations, we needed a broad basis of information from different domains related to the patient-doctor relationship. It should cover the current status, but also give an impression of the system's reaction to major changes. Press articles about the EPR introduction and literature about the functioning of the public healthcare system served as important sources; existing future health care scenarios (Mueschenich, 1998) and recent developments in e-services indicated potential changes in the patient-doctor-relationship. We also considered influences from the social welfare system and the patient's economic situation on his/her behaviour. To reveal the most relevant aspects of the treatment situation, we interviewed medical practitioners.

Based on our inquiry, we identified a set of system variables and their interrelations in several iterations (see Table 1). We then used the sensitivity model software to build a system model and to simulate its behavior. If the simulation revealed unrealistic behavior, the model was modified accordingly. The inquiry and the system setup happened in parallel, as the setup process revealed blank spots that required further inquiry. At the same time, we established the borders between the system and its environment and towards superordinate system levels.

Once we judged the system setup as a sufficiently realistic representation, we could analyze it in detail. This required a look at the role characteristics of each variable resulting from the sum of relations that every variable receives and emits, and the overview of the feedback loops emerging from the system.

Variable name	Variable description
Physical well-being	Amount of physical limitations due to pain and stress
Mental well-being	Amount of resistance against stress, fear, social problems, pressure to perform etc.
Individual financial interest	Individual additional payment for services beyond the basic healthcare service; indirect costs like taxes on goods harming the physical health
Preventive health care	Effort for a healthy lifestyle
Self-responsibility	The patient's decision-making authority concerning his health-related concerns; his interest and active cooperation
Health related knowledge	General knowledge about symptoms, nutrition, activity etc.
Patient's satisfaction	How satisfied is the patient with the doctor's performance
Health care utilization	Frequency and duration of the consultation for the patient

Trust	The patient's trust into the doctor's abilities
Effort per patient	Effort per patient that the doctor can afford to make a living. Contains working time beyond the actual consultation: clearing, documentation, laboratory
Quality of treatment	Quality of treatment for the patient: The doctor's abilities, technical equipment, atmosphere etc.
Doctor's abilities	Quality of the education and further trainings, social and emotional abilities
Accessible patient data	Patient data the doctor can access during the consultation: the patient record, discharge letters, immunization records etc.
Doctor's authority	Amount of authority of the doctor over the patient
Basic healthcare	Catalogue of benefits of the public health insurances, amount of money for the basic health insurance
Healthcare supply	Availability of doctors, hospitals, information sources
Financial situation of health insurances	Relation between expenses and revenues (can be critical or balanced)
Social environment	Character of family, friends, relationship, education level, neighbourhood
Industries' influence	Amount of political and/or economical influence of the medical industries
Employment situation	Current unemployment rate, job certainty, income level

Table 1: System variables

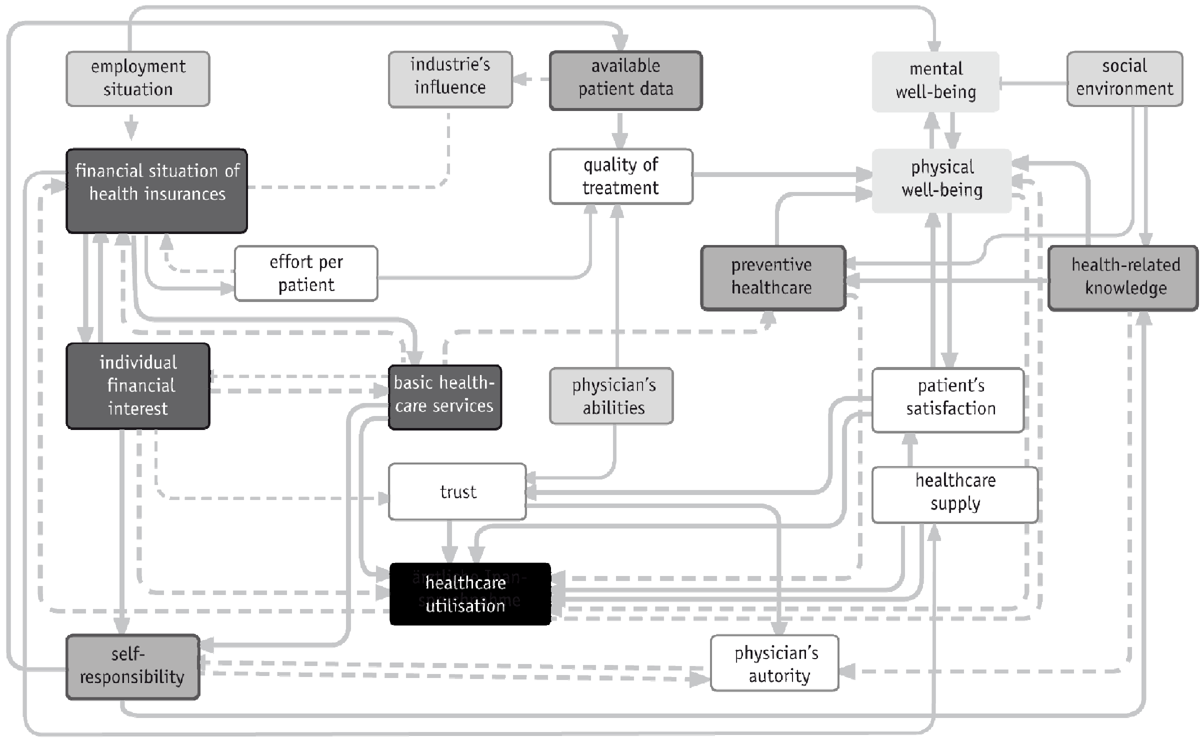

Figure 1: Sensitivity system model

Role characteristics of the variables

Identifying a variable's characteristic within the system sheds light on the possible reaction of the system once the variable is changed. The role characteristics derive from a cross-impact matrix that is part of the sensitivity system software. In the matrix, the impact (or its absence) of every variable on every other is weighted. The sum of these impacts (on other variables and from other variables) describes the role characteristics of the variable (see description in the glossary below).

We were especially interested in the variables that could cause positive system changes and that were amenable through design artefacts at the same time. "Basic health care service" and "patient's financial contribution", the active variables which were the most efficient to manipulate, all belonged to the domain of health care politics and were not accessible through design. "Health care offers", "patient's health knowledge" and "accessibility of the patient's data" were buffering variables that could be influenced by design artefacts.

Feedback loops

Feedback loops are an important source to test the system´s plausibility. If some of the appearing feedback loops don't make sense, the variables´ interrelations should be rethought. They also give a hint to unintentional developments: Amplifying loops can enforce a development, even an unintended one. Compensating loops may keep the system stable or accidentally even up a desired effect. In our case, we identified three domains where significant feedback loops appeared: Financial aspects, the patient's self-responsibility and the roles of doctors and patients.

- **Financial aspects**. The finance-related variables are highly interdependent. Not only do they have a strong active role towards the system, but also immediately affect each other. In Germany, individual payments for a treatment are uncommon because of a comprehensive basic health care service. With increasing individual health care costs, the amount of consultations is likely to decrease (Grabka, Schreyögg, & Busse, 2005).
- **Self-responsibility**. The German health care system used to be caring and did not provide much incentive or need for a self-responsible lifestyle. However, higher individual interests or limited basic health care supply could force people into a more self-responsible behaviour, or lead to higher individual health-related expenses.
- **The role of doctors and patients**. With medical information being available on the internet, the traditional high respect for physicians' decreases, as their competence and decisions can be doubted. A positive development would transform the physician into a medical consultant who supports the patient's understanding of her/his diseases. However, the increased responsibility patients have to take without the proper education may as well cause stress and refusal of medical treatment as such.

Concerning the involvement of design, the feedback loops in the latter two domains seem to be the most fruitful, because financial aspects can only be influenced through legal and political decision-making.

Requirement analysis

Based on the system analysis, we described the requirement of the professional stakeholder groups and, more detailed, the requirements of five different patient groups.

Considering the system dynamics, we identified five aims for an EPR that all stakeholders would be concerned with:

- **Device's activity**. Does the device alert the user a lot (e.g., asks for input)?
- **User's activity**: Does the user use the device for input, information retrieval, communication?
- **Openness to location-based information**: Does the device exchange data with the environment and receive location-based information?
- **Personalization**: Can the user personalize the device and, if so, to what extend? Does the adapt itself automatically to the user?
- **Abstraction level**: Does the device show medical "raw data" or a reduced and simplified version?

For the professional stakeholders, we sketched the divergent interests they would have in the different functions, and probable reasons, as far as the information gathered for the system model allowed a judgment. However, as the professional stakeholders were not our main target group, we did not detail their perspectives further.

For the patient's requirements, we could not refer to a comparable set of statements that professional associations articulate in public discourses. Besides, there was little precedence for the introduction of a comparable area-wide IT service. We basically drew on milieu studies (Sinus Sociovision GmbH, 2007), surveys dealing with leisure behaviour (Plath, 2003) and statements we derived from our own interviews with physicians. Based on this data, we created a set of personas and listed requirements for each of them.

Personas

Although the patient would likely benefit from an extensive use of the EPR, there is actually little incentive for people to do so. The group of "patients" contained a too big variety of characters and needed further differentiation. We decided to set up five prototypical user descriptions, known as personas (Pruitt & Adlin, 2005), to represent the different facets of the patient perspective.

A persona description gives a sufficient average impression of the addressed user group without restricting the designer to some status quo requirements derived from user interviews. The approach is particularly useful for experimental designs where the final purpose and context is not initially clear. For our purpose, we considered the persona approach more valuable than interviews: We were addressing an innovative technology, and user adaptation to new technologies evolves only slowly.

We identified the following five groups as our set of personas, as they differed considerably concerning their work and leisure activities, their attitude towards health and health problems, education and social affiliation:

- **Young hedonistic music lovers**: Rather low income, high interest in pop culture like movies, television and music. Live as single or childless couples. Invest a lot in clothing, music and entertainment electronics. Trendsetters that like to have fun.
- **Working middle-aged males**: Very engaged in their work, but only few leisure activities. Quite wealthy, but not especially interested in spending money. Tough or even reckless towards their health.
- **Homely silver generation women:** Retired elderly women with a low education level who like to be at home. Economical and not keen to experiment. Feel easily overstrained by technical devices.
- **Female cultural freaks**: Well-educated and very interested people. Extensive readers. Socially dedicated and demanding consumers, concerned with wellness. Low-key users of technological devices.
- **Teenage social sports aces**: Sociable, reasonable, young and very active. Very disciplined, skilled and extensive users of technical devices.

Besides their interest in health issues, the ability of different personas to deal with technical devices was especially important to us.

Among the five personas, we chose the working middle-aged men to be our main user group for the design concept. For the other groups, we would have to face so high demands on low-threshold usability (for the elderly women) and content presentation (for the young people) that these requirements would eclipse the main idea of finding a user-friendly interface for current EPR contents. Besides, this group covered a good part of the customers and would show a sufficient interest in healthcare issues, so that we could really focus on building an appropriate representation and interaction mode for medical data.

Considering the system analysis and the common criteria for all stakeholders, the user requirements for the EPR of our main persona were the following:

- it should encourage vital exchange of the user with the device, be it passively (automatically) or actively (with the initiative both from the device and the user). This supports the collection of the user's comprehensive medical data and its availability to the physician.
- be the access point to medical information, the personal record, but also inform about general health-related questions. This eases access to the user's medical data and strengthens his/her sense of self-responsibility.
- support the dialogue with the physician; serve as evidence about the personal condition, eventually also to support certain claims from the patient. The patient should experience considerable advantage from collecting medical data.
- provide a basis for a constructive collaboration with the physician without resigning to the feeling of control over the situation. This addresses the feeling of being committed to the physician (or guilty for their "misbehaviour") people might experience at a consultation, especially when releasing personal information.

We referred to these user requirements during the whole design process, constantly checking the appropriateness of our design decisions.

Interface Design

We developed a three-part system for an EPR and refined the hardware and software interface for its mobile component. Below, we describe the modular concept of the EPR and the hardware and software interface of the mobile component in detail and how the implementations meets the user requirements listed above.

Modular system

Our user requirements and an inquiry into healthcare-related technological innovation led us to a three-part system, composed of a mobile device, a software application and optionally an individual set of sensors to measure vital signs.

Woven into the clothes' fabric, non-invasive sensors can be worn comfortably and individually assembled. The mobile device component collects and stores the sensor data, and gives access to the patient's health record. As an acknowledgement to stressed working people with a neglecting attitude towards their health condition, the interface should gather data mostly automatically, allow quick and easy input and fasten medical consultations.

For extensive data entry and as a gateway to the data for professional users, the software application on the PC should be used for complex manipulation like uploading images and long text entries, changing preferences and linking related information within the patient record.

Product Interface

The EPR mobile device has a gesture-based product interface with an augmented reality lens display. Its movable shell can be rotated around the core. One quarter of the shell is lacking and gives access to the core that offers three functional sides: First, a wireless sensor and USB cable plug for data transfer; second, a small compartment containing the colored cursor cube; third, a lens with a camera on the opposite side (see Fig. 4-5). To access his patient record data, the user has to take the cursor cube out of the compartment and then look on it through the lens with one eye (like through a peephole, see Fig. 2-3). The camera displays the user's hand with the cursor cube inside and an overlay with the data structure. The cube's position and orientation is tracked. If it overlaps sensitive areas in the data structure, the user can press it between his fingers; overlapping works as a hover effect, while pressing the cube is "clicking" an overlapping data object. Thus, the product interface metaphor is consistent with the data structure of the software interface and provides an appropriate mapping of hardware and software interface.

Fig. 2-3: Usage of the mobile EPR device

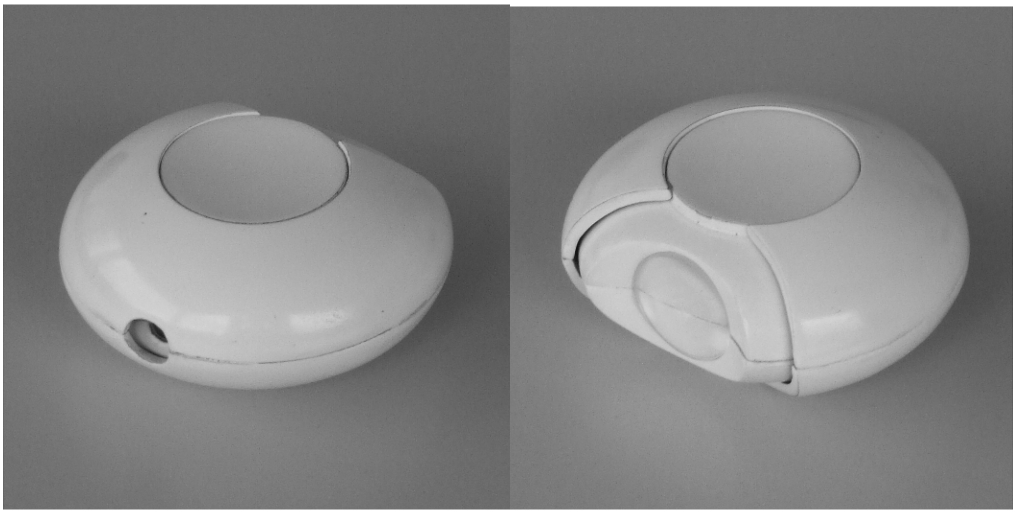

Fig. 4-5: Front- and backside of the mobile EPR device

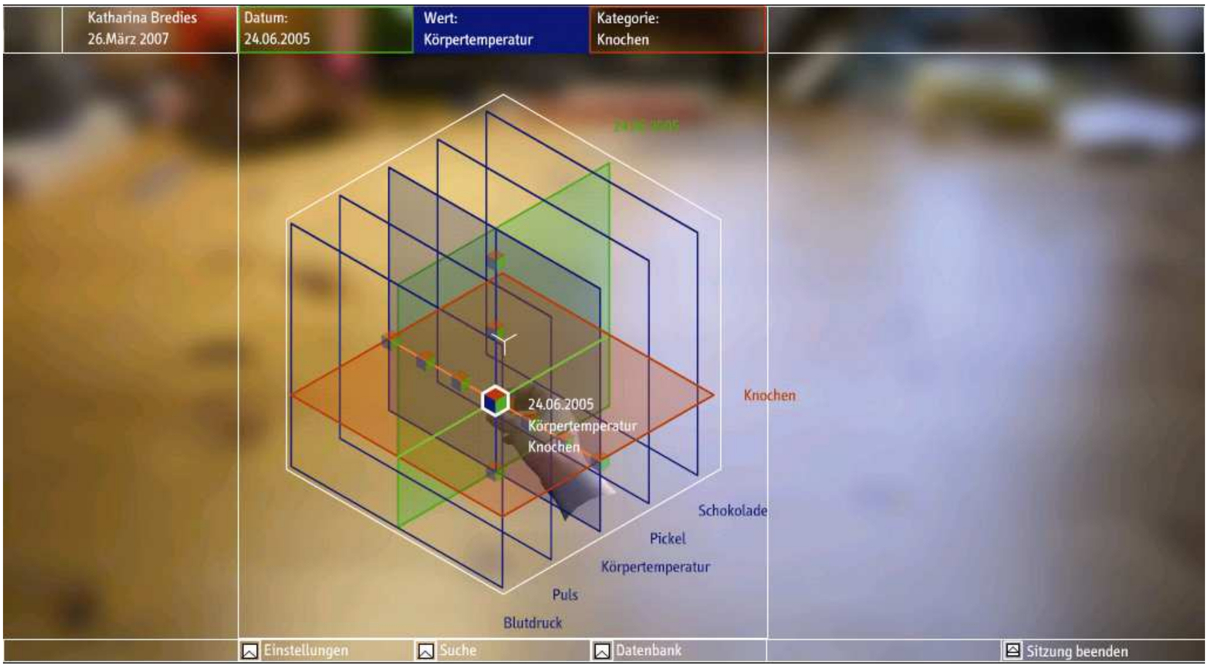

Fig. 6: 3D view on the EPR software interface

Digital Interface

In digital interface, patients and physicians could view and link different sorts of data. To organize the data, we displayed an isometric three-dimensional matrix, where each dimension (or axis) represented a certain filter criterion; a point in time, a category, or a value. This very abstract matrix allows relating each value to any category in any point in time. Every dimension is subdivided into planes, every plane representing one single value, or point in time, or category. Each intersection of three layers contains one single value at one particular date in one category (see Fig. 6).

Fig. 7: 2D view on the EPR software interface

The interface offers a navigation mode and a viewing mode: In the navigation mode, the user holds the cursor cube so more than one side is visible to her/him. Now s/he can browse the isometric matrix. Once s/he tilts the cube so that only one of the colored sides is flat visible to her/him, the interface displays the chosen plane according to the appearing color (I. e. red for the category plane). Additional windows appear on the display containing related information.

The overall proposed interface can be built with existing technology, provides a consistent and secure interaction and is able to represent all kinds of medical data.

Requirements

We describe how we met the requirements listed above in the actual design of the modular system and the mobile device in particular.

- **Encourage vital exchange**: The mobile EPR device collects data from the body sensors automatically (if the patient wears any of them) whenever it can establish a connection. It is small enough to be carried around in the pocket. To have a small device that serves as a viewer allows the user to be in control over her/his data, look up things s/he does not remember, and to automatically monitor basic vital signs.
- **Be the access point to medical information**: The mobile part is a data storage device that also works offline, but whose content can be synchronized with the local version of any treating physician or on a central web server (in case of loss).
- **Support the dialogue with the physician**: The PC software interface enables both the physician and the patient to add values for monitoring to the mobile device. The physician can make parts of the patient record accessible to advance the patient's medical

literacy. The patient can decide what information to reveal to the physician and actively complement his data. A successful consultation still depends on a confidential and trustful atmosphere and a good relationship between patient and physician to make sense of the data.

- **Support collaboration without loss of control**: To protect the health record against the view of unauthorized persons, we designed the device in a way so that only one person at a time can access the data. Looking into the mobile EPR device like into a peephole emphasizes the private and intimate nature of the patient record, and gives the user the feeling of being the only one in control over her/his data. To avoid unintended data transfer, we designed the device so it would only transfer when the wireless sensor and USB plug are open, as we as we recognized data security as an important issue during our inquiry.

Conclusion

In this paper, we described the design process for a patient-centred EPR user interface design using a sensitivity system model and personas for analysis. To represent various points of view regarding the advantages and disadvantages of an electronic patient record, the systemic sensitivity analysis proved to be a useful tool. We especially appreciated the possibility to address the multiple perspectives of a complex environment like the presented one. Besides, system models include efficiency and technical feasibility concerns as well as psychological and social effects. They are therefore especially helpful to support a user-centred approach in the development of new technologies.

Limitations and Value

Users of the presented method have to be aware that the representation of data in a systemic model does not equal the "real world", but provides a perspective on what kind of dynamics may produce the observed effects in the world. There is a danger to stick with an incomplete or misrouted system representation if aspects or stakeholder viewpoints are missing. Additionally, systems analysis itself is a complicated process involving a considerable amount of work. The process of establishing the system's dynamics is labour-intensive, as they have to be modified until they are close enough to real world experiences. Besides, one should not confuse the simulation of the system's dynamic behaviour with a prognosis on future developments.

We see the value of cybernetic systems analysis in the following properties:

- It incorporates quantitative as well as qualitative data and "fuzzy" information that is often neglected as not being scientifically valid, despite its importance for the respective design environment. Thereby it is also possible to incorporate common sense knowledge and narrative data.
- It structures and guides the inquiry to cover all aspects of the design environment and results in a detailed, yet broad description. The designer can always refer to this in later stages of the process. In this

respect, system analysis helps to broaden the designers' view, while relying on existing data and knowledge from the field.

- It provides a dynamic representation of the design environment that may indicate possible directions of its development. It also allows estimating successful opportunities for design interventions and avoids sticking to obvious solutions lacking the desired effects.
- It can integrate the perspectives and opinions of various stakeholders and also makes the designer's point of view explicit. However, it should be clear that a system model does incorporate a particular point of view from a particular observer.
- It may ease the transition between analytic data and projective work, as it provides a valuable source for the setup of user requirements. The system model always provides the background information against which the expected consequences of a design artefact can be tested.

With our project, we hope to have made the value of cybernetics system analysis for design accessible. While differentiating the system to its subordinate and superordinate levels, the designer iteratively explores the design environment and his/her possibilities to intervene in the system. The simulation is not meant to be a reliable tool to predict the future; but it may point to directions that the designer would not have considered otherwise.

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Glossary

Environment	The system defines itself against the environment, towards which it can be open or closed. Open systems can interact with the environment. For closed systems, there can be structural couplings with the environment: If a variable in the environment changes, another variable within the closed system changes as well.
Feedback loop	If the change of a variable falls back on itself through a number of relations with other variables, it is part of a feedback loop.
Relation	A relation defines the effect that the change of one variable has on another. This effect can be reinforcing (variable A increases, variable B increases too) or balancing (variable A increases, variable B decreases).
Role characteristics	In our case, the role characteristics derive from a variant of cross-reference analysis and are described by the sum of all the relations that affect a certain variable. That means, if a variable is affected by many other variables in the system, it has a **passive** role and serves as an indicator of the system's state. If, on the other hand, a variable affects itself many others in the system, it is considered as

	an **active** variable and an effective lever to change the system's state. There are also variables that receive as well as emit a lot of relations, the so-called **critical** ones. Variables that neither effect nor are affected by many other variables are referred to as **buffering**.
System	The sum of variables and their limited interrelations. A system can contain smaller subsystems or be itself embedded in a larger system.
Variable	A variable is the smallest entity in a regarded system. A variable has to be quantifiable ("Web Dicitionary of Cybernetics and Systems,"). However, qualitative and subjective phenomena can also be expressed as quantified variables in a system (see (Vester, 2002), p. 213).

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