

2013

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Recommended Citation

El-Gayar, O., Sarnikar, S., & Wahbeh, A. (2013, January). On the design of IT-enabled self-care systems: a socio-technical perspective. In 2013 46th Hawaii International Conference on System Sciences (pp. 2484-2493). IEEE.

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On the Design of IT-enabled Self-care Systems: A Socio-technical Perspective

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Abstract

Advances in information technology (IT) have resulted in a proliferation of IT-based solution to support the self-care and management for healthy individuals as well as patients with chronic conditions. Despite these advances, the adoption and diffusion of these solutions into practice is limited.

The objective of this paper is to enhance adoption and diffusion by providing actionable recommendations for the design of IT systems for self-care. The recommendations are grounded in socio-technical design theory and in an extensive review of self-care literature. The findings indicate that despite the diversity of disease conditions, users, technologies, and implementation environments, IT-solutions for self-care often fail to encompass a holistic socio-technical view. The design of such systems will need to account for the intrinsic and interrelated characteristics of the underlying tasks, actors, technologies, and environment.

1. Introduction

Self-care and self-management, which refer to behaviors that individuals engage in to promote health or manage chronic health conditions [1] [2], is a key area of emphasis in healthcare to help improve patient health [3]. It is related to the concept of patient empowerment [4] and represents a paradigm shift with its individual/patient centric focus and the emphasis on enabling individuals to make autonomous yet informed decisions about their healthcare. In effect, empowering patients through education, data, and analytics has become an integral part of supporting self-care and self-management.

The last decade has seen the propagation of consumer health IT applications to support self-care and promote patient empowerment. Despite the success of some of these applications in supporting patient empowerment and self-management, the literature shows that the potential for IT has not yet been maximized. In an exhaustive review of

consumer health informatics (CHI) applications, Gibbons et al. [5] identify several system level and individual level barriers that prevent the adoption of consumer health IT applications. The barriers identified are not limited to technology but span issues across social and technical boundaries. The study also recognizes that CHI application development requires participation of consumers, their caregivers, clinicians, and developers. Accordingly, barriers and challenges to the development of successful applications will inevitably include barriers to the participation of any of the aforementioned groups. Aside from barriers directly related to IT, there are inherent challenges with the diffusion of concepts such as self-management and patient empowerment in healthcare.

In essence, leveraging IT for self-care, self-management and patient empowerment will require anchoring designs in relevant theories, and adopting a holistic socio-technical perspective. In this study, we aim at enhancing the adoption and diffusion by providing actionable recommendations for the design of IT systems for self-care. The recommendations are grounded in socio-technical design theory and principles and in an evaluation of existing approaches.

The outline of the paper is as follows: in the following two sections we briefly present common principles of socio-technical design and a brief review of IT-enabled systems for self-care. Next we present a comprehensive review and analysis of IT-enabled self-care with particular emphasis on the use of socio-technical principles followed by a set of actionable recommendations for the design of such systems. We conclude with a summary of major findings and recommendations for future research.

2. Principles for socio-technical systems

Baxter and Sommerville [6] (p. 4) refer to socio-technical systems design (STSD) methods as “an approach to design that consider human, social and organizational factors, as well as technical factors in the design of organizational systems”. In this context, organizational refers to company or business related

factors while social refers to factors related to the relationships between people who interact together within and across organizations [6]. In general, a fundamental premise of socio-technical work and system design approaches is the importance of ensuring the technical and human factors are (whenever possible) given equal weight in the design process, i.e., “the joint optimization of the social and technical systems” [7] (p. 321).

Towards this objective, Cherns [8], [9] identifies nine principles for socio-technical design (Table 1). Clegg [10] later presents a revised set of these sociotechnical principles to guide system design, and to consider the potential roles and contributions of such principles. The principles are intended to be applied to the design of new systems and they attempt to provide a more integrated perspective than is apparent in existing formulations. These principles falls into three types namely meta, content and process that are highly interrelated. As stated by the author, these principles are to be used by system managers, users, designers, technologists and social scientists. They provide inputs to who are engaged collaboratively in design.

Despite the considerable variation that exists surrounding the term ‘socio-technical system’ across various fields of study [6], in the context of information systems a socio-technical system can be modeled as a collection of four components and their connections as shown in Figure 1 [11-13]. The socio-technical system model identified by Lyytinen and Newman [13] consists of four main socio-technical components, namely tasks, actors, structure, and technology. Tasks describe the goals and purpose of the system and the way work/activities is accomplished. Actors refer to users and stakeholders who perform and influence the work/activities. Structure denotes the surrounding project and institutional arrangements while technology refers to tools and interventions used to perform the work/activities. Each of the components is identified at the work system level, the building system level, and the organizational environment. Gaps are identified for the combinations of the components, namely task-actor, task-structure, task-technology, actor-structure, actor-technology, and structure–technology.

In healthcare, socio-technical design approaches have also been advocated including [14-23]. Furthermore, Kaplan and Harris-Salamone [24] provide recommendation from the literature and from an American Medical Informatics Association workshop regarding health information technology (HIT) successes and failures. Their report recognizes that while technical issues still exist, the discussion

affirmed the emerging consensus that problems with HIT projects are largely sociological, which further emphasizes the relevance of socio-technical approaches.

Table 1. Cherns’s [8, 9] principles of STS design.

Principle	Description
Compatibility	The process of design must be compatible with its objectives. Clegg [10] has addressed this principle under the principle stated that ‘systems and their design should be owned by their managers and users’. Under this principle, Clegg [10] has emphasized on user ownership instead of focusing on user participation like Cherns’s (1976, 1987) principles. Cherns focused on the need for compatibility between process and outcome, and this highlighted the need to involve users in design. The emphasis by Clegg [10] is on the related “notions of ownership and appropriation, that is with who owns the new system and the processes through which it is designed and implemented”.
Minimal critical specifications	Only the minimal critical allocation of tasks to jobs, jobs to roles, and objectives and methods that is absolutely essential should be specified. Systems should allow for some flexibility in their operation [10]. This principle is addressed by Clegg [10] where the users should be allowed to solve their own problems and develop their own methods of working, thereby incorporating scope for learning and innovation. Such situation is very difficult to achieve in bureaucratic organizations where standard and common working practices may be the norm.
The socio-technical criterion	Variances, if they cannot be eliminated, must be controlled as near to their point of origin as possible. This principle is addressed in the same way by Clegg [10] under the principle called ‘problems should be controlled at source’ where variances (called un-programmed events) should be controlled at source.
The multi-functionality principle	Each element in an organism (such as people in a team) should possess more than one function, and the same function should be able to be performed in different ways by using different combinations of elements. Clegg [10] has extended this principle to incorporate consideration of task allocation between humans and machines. Sociotechnical systems consist of allocating tasks to and between humans and machines [10].
Boundary location	Locate responsibility for coordination without outside groups clearly and firmly

	with those whose efforts require coordination. This principle along with the information flow principle were addressed by Clegg [10] under the 'Core processes should be integrated' principle as shown next.
Information flow	Information systems should be designed to provide information in the first place to the point where action on the basis of it will be needed. This principle was addressed by Clegg [10] under the 'Core processes should be integrated' by viewing the organization as comprising a number of core processes that typically cut laterally across different functions, not like the traditional, where it is comprise sets of expertise-based specialisms that are organized vertically.
Support congruence	Systems of social support should be designed so as to reinforce the behaviors that the organization structure is designed to elicit. Clegg [10] has extended this principle by considering that a new designs involve a set of working arrangements and these needs to be congruent with surrounding systems and practices. These new systems become integrated into existing ones, but such systems may require some accommodation by the systems into which it is being placed [10].
Design and human values	An objective of organizational design should be to provide a high quality of work.
Incompletion	Design is a reiterative process; as soon as design is implemented, its consequences indicate the need for redesign. Clegg [10] has addressed this principle under the principles of 'transitional organization and incompletion' where this principle states that systems that undertake design also need designing, and that sociotechnical thinking, ideas and principles are applicable to such systems.

The remaining principles addressed by [10] are either not addressed completely by Cherns's (1976, 1987) principles of STS design or addressed implicitly under some of the Chern's principles. For example 'Design is systemic' is implicit in Cherns' principles and arguments. Also, the principle of 'values and mindsets are central to design is similar to the views presented by Cherns. The principle of 'design involves making choices' was briefly considered social options under his principle of minimal critical speciation. In addition, the principle of 'evaluation is an essential aspect of design' was mentioned briefly under Cherns' principle of incompletion. On the other hand the principles of

'design involves multidisciplinary education', 'design is contingent', 'resources and support are required for design', and 'system design involves political processes' were not included in Cherns' principles, but the notion of these principles were implicit in his ideas. Finally, the principles of 'design should reflect the needs of the business, its users and their managers', 'design is an extended social process', 'design is socially shaped', and 'systems should be simple in design and make problems visible' were not covered by Cherns.

While the aforementioned discussion referred to an organizational context, we hereby argue that socio-technical considerations are also applicable to pervasive and ubiquitous systems for self-care, self-management, and patient empowerment. Significant work has been done in various areas of pervasive computing application design including architectures and protocols [25], service compositions [26] and user interface design [27]. Nevertheless, with the exception of Crabtree et al. [28], most research in pervasive systems design is oriented towards technological aspects and is not people focused. The key challenge in pervasive technology design is to move the focus from pure technology to contexts of daily life [29]. According to Tang et al. [30] "The design of pervasive computing applications has emerged as a notable research area". Understanding user task goals, user interactions and capturing appropriate context are some of the open issues that remain in supporting the design of pervasive computing applications. In this study, we investigate the role of socio-technical principles and components in guiding the design of pervasive IT-enabled system for self-care and self-management.

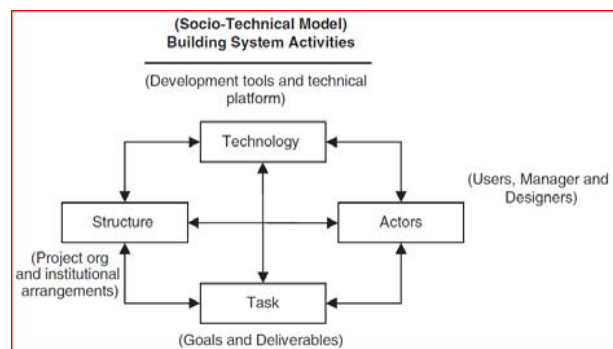


Figure 1. Components of a Socio-Technical System [13]

3. Review of socio-technical principles for IT enabled self-care

In order to identify the socio-technical dimensions of self-care process, we rely on Leavitt's model for organizational change and its adaptation as

a socio-technical (S-T) model for analyzing information systems implementation and change [11-13] and apply it to in the context of self-care processes. Given the large amount of literature on self-care process, we limited our literature base to review and survey articles on self-care published in English language journals. We searched the Pubmed search engine for reviews published within the last 10 years (2002-2012) with “self-care” in the title. Our search resulted in 84 articles. In order to prevent individual biases from influencing the generation of the model, two researchers independently coded and categorized findings and self-care related concepts discussed in the articles along the dimensions of

tasks, actors, structure and technology involved in the self-care processes. All three authors then compared the models and used an iterative process and consensus based approach to arrive at a common model. For each dimension, we identified factors relevant to self-care at three different levels including the work system, building system and environmental level. A summary of our analysis is presented in Table 2, which shows the different components of the socio-technical model for the IT enabled self-care systems. Example papers where the tasks, actors, structure and technology aspects of self-care are described are cited in the last column of the table.

Table 2. The Socio-Technical Model for IT Enabled Self-Care Systems.

	Work System	Building System	Environment	Main Properties
Tasks	Medical therapy, lifestyle changes, symptom monitoring etc.	Self-care processes such as self-glucose monitoring, diet and exercise control etc.	Health maintenance and improvement	Complexity (Cognitive), importance to health maintenance, difficulty (resistance to change, unpleasantness, etc.), frequency, and costs.
Actors	Patients and healthy persons	Family, care givers, clinicians, friends, and support groups.	Society and payers	Skills, knowledge, perceived health status, self-efficacy, expectations, beliefs. Social and family support, beliefs and motivation, cognitive function, experience, and knowledge.
Structure	Personal routines within which self-care is embedded	Family and health marketplace structure within which personal routines exists.	Societal and health system structure.	Communication processes, authority, workflows, economics, appropriate and knowledge sources.
Technology	Devices such as pedometers, glucose meters etc.	Home electronic devices and software such as smart phones and personal computers, and health organization IT infrastructure	Societal IT infrastructure	Functionality, interoperability and usability

The task dimension describes self-care tasks at three different levels. At the work system level, examples of self-care tasks include diet and lifestyle changes, symptoms monitoring such as self-glucose testing, and other specific self-care tasks conducted by a patient. The specific self-care tasks are embedded and conducted within a building system to achieve a certain goal. For example, self-glucose testing takes place within the context of a larger diabetes management self-care process of self-glucose monitoring that involves communication with health care providers and the support of family members. At the environment level, this process is a part of a health maintenance process for diabetics that involve coordination with other entities of a healthcare marketplace such as device vendors and insurance companies at the environment level. The actor

dimension of the S-T model includes patients who are the direct beneficiaries of the self-care tasks at the work-system level; family, friends, care givers and clinicians at the building system level who support the patient in self-care tasks such as self-glucose monitoring, and the larger healthcare system stakeholders such as policy makers and payers at the environment level that influence the processes and resources available to an individual to conduct a self-care process such as self-glucose monitoring. The structure dimension, at the work-system level, consists of personal routines within which self-care tasks are embedded. For example, in the case of self-glucose monitoring, glucose test task are often conducted in coordination or combination with dietary schedules. At the building system level, processes for self-glucose monitoring are often contained or coordinated with

routines for renewing prescriptions and supplies, and function within the family and marketplace structure. The technology dimension for glucose self-monitoring includes use of glucometers at the work system level, exchange of data between glucometer and the home computer at the building system level, and eventual transmission of this data to the provider through a telecommunication network at the environmental level.

The main properties of each of these dimensions need to be considered for the effective design of socio-technical systems. The properties of tasks that influence self-care processes include task complexity; which is related to cognition, importance to health maintenance, difficulty; like resistance to change and unpleasantness, frequency, and costs [31-36].

For actors, the main properties include skills, knowledge, perceived health status, self-efficacy,

expectations, beliefs, social and family support, beliefs and motivation, cognitive function, experience, and knowledge [31, 32, 34, 35, 37-40]. The properties for the structure dimension include communication processes, authority, workflows, economics, and the appropriate knowledge sources [41, 42]. Finally, interoperability and usability are the main properties for the technology component [33].

The major imbalances between socio-technical elements in the model are shown as gaps; these gaps are identified for the combinations of the four main socio-technical components. Several gaps have been identified from the literature and a summarization of the identified gaps is shown in Table 3.

Table 3. Examples of Socio-Technical Imbalances in Self-Care

ST Imbalances	Examples in Self-Care
<p>Task-Actor: The actors do not understand or accept the task or cannot carry out the task.</p>	<p>The Task-Actor issues are the largest category of barriers to self-care. The barriers are further categorized related to patient capabilities, knowledge, attitudes and beliefs and resource issues.</p> <p><i>Capabilities</i> Patients find it difficult to learn self-care tasks due to problems in cognitive and physical functions [43], family structural variables [44], inability to recognize and interpret symptoms when they occur [45], lack of understanding about the discharge instructions [45], cognitive issues and trouble remembering how to perform related activities [46], do not possess required skill for self-care, and lack of requisite skill [47].</p> <p><i>Knowledge</i> Individuals suffer from self-care deficit because they does not possess the requisite knowledge, [47] [42], or lack relevant information [36, 37] to perform self-care tasks.</p> <p><i>Attitudes and Beliefs</i> Patient non-adherence to provider prescribed self-care tasks is due to worry about potential side effects [45], because they felt that these practices were a burden [48] or they fear taking the required actions [36]. Other issues include poor self-esteem [49], lack of motivation [47], when patients are not being convinced of the utility of the medication for self-care behaviors [45] and difficulty in adapting self-care recommendations to patients' particular way of life [50], lack of self-care agency [31], and incorrectly perceive that there is no reason to be adherent when symptoms are absent [39].</p> <p><i>Resources</i> Examples of resource related issues for non-adherence to self-care tasks include lack of time [37] , and cost [37, 45].</p>
<p>Task-Structure: The structure is not aligned with the task or no adequate structure is defined for a given task.</p>	<p>Advances in treatments and medical options for patients with heart failure (HF) make the management of this condition become increasingly complex for both patient and provider [43]. Implementing behavior change may be more difficult when patients living in certain circumstances have less access to relevant resources and face a greater number of perceived barriers to self-care [37]. Self-care have not adequately incorporated cultural values related to health and illness management [51]. Difficulty in developing services that strike the right balance between providing care, support and treatment for the individual when required and the autonomy of the individual, and the variable quality of the evidence available impede the widespread application of the self-care approach [41]. Individuals cannot provide other individuals with disabilities for assistance with basic self-care activities and instrumental activities of daily living because of lack of personal assistants, funding sources [52].</p>
<p>Task-Technology: The technology is not adequate to support the task or</p>	<p>The lack of a common medical record discourages self-care behaviors and activities [45]. Due to lack of appropriate technology, individuals cannot provide other individuals with disabilities assistance with basic self-care activities [52]. Modern medicine and health care systems suffers from limitations for improving the health status of the</p>

it is unreliable or inadequate in its support.	population [53]
Actor-Technology: Actors do not understand, cannot operate, or do not accept the technology.	Examples of issues identified in this category include problems due to technology self-efficacy [33][54]. and lack of trust [54] and access to technology resources due to socio-economic conditions [55].
Actor-Structure: Actors do not know the operating procedures, do not accept the structure, or are not aligned adequately with the structure.	Issues identified in this category include lack of cooperation and/or concern regarding the patients family [44], poor health literacy combined with complexity of the healthcare system, and one's ability to understand and act on essential health-related information [45]. Issues include barriers due to influence of philosophical reasoning, social theory, and socioeconomic factors [47].
Technology-Structure: The structure is not aligned with the technology and does not support technology operations and use. Structure does not take advantage of the capabilities of the technology.	Information and Communication Technologies (ICT) exceeds the boundaries of a health care organization and therefore it does not match with fragmented and disorganized health care [54]. Malfunctions with the wireless tele-rehabilitation technology based equipment occurred because electrical storms interfering with wireless transmission in the home and the remote station in the home and the base station at the hospital were set to different channels [56]. ICT-based care are faced by many problems because of the absence of adequate infrastructure or the logistical difficulties involved in organizing online consultations, with all parties having to agree on a suitable time [57].

The task-actor gaps exist when the identified actors in the model do not understand, do not accept, or cannot carry out any of the identified tasks. By reviewing the literature we have identified several gaps between the tasks and the actors. These gaps relate to the inability of the actor to perform the tasks due to lack of capabilities, lack of knowledge, attitudes and beliefs or lack of resources.

The task-structure gaps arise when the identified structures are not aligned with any of the identified task or there is no adequate structure that is defined for a given task. For example, self-care has not adequately incorporated cultural values related to health and illness management, and teaching patients self-care skills is not sufficient for effective self-care [51]. In addition, implementing behavior change may be more difficult when patients living in certain circumstances have less access to relevant resources and face a greater number of perceived barriers to self-care [37].

The task-technology gaps arise when the identified technology is not adequate to support any of the identified task or it is unreliable or inadequate in its support. For example, the lack of a common medical record discourage self-care are behaviors and activities [45]. Individuals cannot provide other individuals for assistance with basic self-care activities and instrumental activities of daily living because of lack of appropriate technology [52].

The actor-technology gaps occur when any of the identified actors do not understand, cannot operate, or do not accept the technology. For example, some people who use electronic devices such as a wheelchair, do not use the functions as prescribed and frequently come back to clinics to solve such problems [33]. Some patients are unable to master the home telemedicine due to a lack of fine eye - hand coordination [54]. Also, some of them have problems using ICT because they perceived the technology is very complex, time-consuming, led to information overload [54]. In addition, ICT-based care was thought to reduce the trusting and confidential relationship between patients and caregivers [54].

On the other hand, the actor-structure gaps occur when any of the identified actors do not know the operating procedures, do not accept the structure, or are not aligned adequately with the identified structures. For example, some patients do not take any actions when interventions are necessary because they lack cooperation and/or concern about causing worry among family members and cardiovascular patient [44]. Also, some of them have complexity negotiating complex healthcare system, as well as to understand and act on essential health-related information because of poor health literacy that impairs self-care in general [45]. In addition, the social context within which old adult patients attempt to manage their chronic illnesses

is important but not well understood [51]. Finally, some nurses did not apply a nursing theory because of the cumbersome nature of the theory itself [58].

The final gaps are the structure-technology gaps where the identified structure is not aligned with the identified technology and does not support technology operations and use. Also, these gaps occur because the identified structure does not take advantages of the capabilities of the available technology. For example, ICT exceeds the boundaries of a health care organization and therefore it does not match with fragmented and disorganized health care [54]. In addition, ICT-based care are faced by many problems because of the absence of adequate infrastructure or the logistical difficulties involved in organizing online

consultations, with all parties having to agree on a suitable time [57].

4. Actionable recommendations for the design of IT-enabled self-care systems

In this section, we formulate design directives for self-care systems based on the socio-technical gaps identified in the previous section and provide illustrative examples of how such directives can be implemented for the design of self-care systems for diabetes care. The design directives and illustrative examples are presented in Table 4.

Table 4. Design Directives for Self-Care Systems

Reference Gap	Design Directives	Illustrative Example
Task-Actor	System should help overcome user deficiencies in performing the self-care task	The self-efficacy of a user in performing a self-care task can be improved by incorporating interactive tutorials in the system for performing a self-care task.
Task-Structure	The system design should accommodate the supporting elements of the external structure in support of the Task and help overcome deficiencies in structural environment with which self-care processes are embedded.	Self-care processes such as self-glucose monitoring for example, interact with the larger structural environment through provider workflows and patient routines. Such interaction and the effects of such interaction can be supported by decision support systems and automation to handle communication and patient support workloads. In addition, ensuring data interoperability will help support provider processes that consume patient self-care data such as outcomes and meaningful use reporting.
Task-Technology	The system design should incorporate use of reliable technology to support all critical components of a self-care task.	This design directive can be implemented by incorporating accurate glucose monitoring and reporting technology, ensuring reliability of technology in typical use contexts, and support for interoperability for data transfer and reporting.
Actor-Technology	Actors should be provided training on appropriate use of technology when required	A user friendly and intuitive system can be designed using user centered design processes and usability testing. In addition context sensitive help functionality can be used to support user training.
Actor-Structure	The system design should accommodate the supporting elements of the external structure in support of the Actor	Use of privacy controls, data sharing and role-based access, and social software can help incorporate support for family and support network's role in self-care processes such as diet control, glucose monitoring, and exercise.
Technology-Structure	The system should fit well within the structure in which it is used	This directive can be implemented through integration of the system with care provisioning technology and processes of the healthcare system. For example, such integration can be achieved by integrating self-care systems with EMR tethered patient portals, and support for transmitting self-care data in the context of patient-provider communication or billable clinical appointments.

5. Conclusion

In this paper, we have presented an extensive review of self-care literature and have analyzed self-care

processes from a socio-technical perspective. Based on our review, we have identified several socio-technical imbalances in the self-care processes. We then present design directives for addressing the

socio-technical imbalances along with illustrative examples of how such design directives can be implemented in the case of self-care systems for diabetes care. The results of this study help provide a framework to understand the complexities of self-care processes through a socio-technical viewpoint. The identification of socio-technical imbalances in self-care and the corresponding design directives can help in the design of better information systems for supporting self-care processes.

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