Evaluating Socio-Technical Systems with Heuristics – a Feasible Approach?

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Abstract. In the digital world, human centered technologies are becoming more and more complex socio-technical systems (STS) than in previous years thus challenging existing traditional design and evaluation methods. There are two new tendencies, a) STS-methods for design and development are complemented by methods for evaluation of existing STS, and b) the question arises on how to evaluate STS and their quality sufficiently. In this paper we illustrate a method to develop STS heuristics combining four differed areas of research: CSCW, job design, usability heuristic and socio-technical design principles. Initial results will be presented and discussed.

1 Introduction

Over the past years, human centered technology and socio-technical projects have emerged that challenge existing evaluation methods. Project examples are wearables in health care, remote service systems for older adults, applications of cyber physical systems and others. A major part of those design projects is their evaluation. This part of the design process is especially crucial since it becomes more and more evident that it is not possible to plan all aspects of complex socio-technical systems (STS) in advance. Those systems rather require a mutual adaptation process between technology and the context they are used in [1–3] which requires suitable methods of evaluation.

Usability testing is a well-established procedure for evaluating interactive systems in this context and a variety of evaluation methods has been developed in the past. Within these methods, heuristics have become a recognized approach to identify usability problems. Heuristics can serve as a basis of cognitive walkthroughs where experts inspect the features of an interactive system step-by-step. Typical heuristics like the ones by Nielsen (c.f. Fig. 1) or by the International Standard Organization (c.f. ISO 9241-110, 2006) cover aspects such as the suitability of a system for a task, its controllability, individualization, self-descriptiveness, conformity with user expectations, error tolerance, and suitability for learning.

1. Visibility of system status
2. Match between System and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose and recover from errors
10. Help and documentation

Fig. 1. Usability Heuristics according to Nielsen [13]

In this contribution, we argue that it is useful to employ heuristics also in order to evaluate STS. This however requires existing usability heuristics to be revised or adjusted in order to cover the much broader context of STS. While usability issues are focusing mainly on human-computer-interaction (HCI) and individuals, STS are more complex systems in the sense that they involve HCI and team work which is mediated by technology. Consequently, our research questions are: To what extent and in which ways can existing heuristics be used for evaluating STS? Are there any aspects missing, and if yes, how should existing heuristics be revised towards 'STS heuristics'?

2 Contextualizing the evaluation of STS – From Usability to STS Heuristics?

Heuristic-based evaluation can be considered a formative evaluation method [4] that helps to identify which properties of a system are likely to hinder its success by meeting the interest of involved stakeholders. However, while it is almost always possible in the context of usability testing to test all possible dialogue sequences using a prototype (e.g., interfaces, displays), this is not possible in the case of STS since the variety of potential work processes (e.g., workflows, job activities) cannot be tested completely due to them being planned or conducted in the domain of organizational and technical change [5]. The complexity of STS and diversity of workflows indicate that existing usability heuristics might not be sufficient in order to evaluate STS. This 'heuristics gap' becomes obvious when considering well-known principles of socio-technical systems such as those discussed by Cherns [6], Clegg [7], Fox [8], Mumford [9] or Fischer & Herrmann [3]. These principles are primarily focused on the design phases of STS and consequently cover aspects of how an STS could be developed in order to meet the interests of current and future actors and stakeholders of that system. These empirically-based principles include requirements such as "the needs of the users have to be understood", "The core processes must be taken into account", "the interests and their interplay have to be analyzed", "allow for participation of the relevant stakeholders" and others. When comparing these STS principles and requirements to usability heuristics such as the ones illustrated in Fig. 1, we immediately see the difficulty of finding an appropriate level of description. This difficulty indicates that there is a need for different kinds of heuristics or for revised versions of existing heuristics.

Before we discuss the idea of how to study STS heuristics during the course of the next section, we first want to describe an STS design and development method in order to illustrate the complexity of STS design. Different approaches of user experience, human-centered and socio-technical methods exist in order to make sure that an STS contributes to the needs of social groups and end users. Since, in the usability context, heuristics are regularly used in the context of walkthroughs (c.f. cognitive walkthrough [10]), we focus on the method of the socio-technical walkthrough (STWT) which is characterized by Herrmann [11]. This method consists of a series of facilitated workshops where a group of selected stakeholders are supported by a facilitator to discuss features of socio-technical processes by inspecting diagrams which represent typical scenarios of a socio-technical process. These diagrams combine three phenomena in order to arrive at an integrated description of the current or future processes within a socio-technical system:

1. The communication and collaboration between people taking roles as they are taken and developed in organizational contexts.
2. Human interaction with computer based systems which are used for task handling and as a means of communication.
3. The technical infrastructure and the interplay between technical components.

The STWT has been mainly applied to support the design and development of socio-technical solutions. Therefore, each walkthrough is guided by questions such as “which information is needed here”, “which activity must or can follow here”, “which roles should be involved” etc. We propose to use heuristics as a method for evaluating STS. These methods can be based on revised versions of existing usability heuristics.

3 How to develop appropriate heuristics?

In principal there are two ways to revise existing heuristics and develop new ones:

1. A survey with experts can be conducted by asking them about the most crucial problems occurring in the context of STS to their knowledge. These problems can then be used as a basis for statistical analysis in order to derive a comprehensive set of heuristics.
2. We can build upon existing heuristics, guidelines or principles and refer at least to certain aspects of socio-technical systems. These can then be transformed into intuitively understandable criteria which can be applied to STS.

We argue for starting with the second approach, since

1. It is not possible to identify a suitable amount of experts that focus on STS as a coherent whole since they are mainly focused on selected aspects such as job design, usability, coordinative issues etc.
2. There are already a lot of existing heuristics which can be used as a basis.
3. Extensive studies to collect data and heuristics on a statistically secured basis is not possible when one copes with new technologies such as big data, cyber physical systems, crossactionspaces, mixed reality etc.

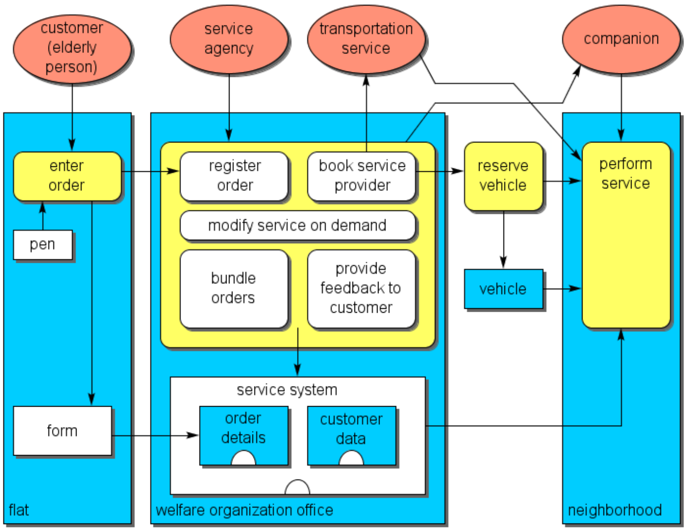

Fig. 2. Roles, activities, components of a combined service for transportation and shopping support (“Shopping companion”) modelled using SeeMe [12]).

We propose to take heuristics into account which can be derived from various areas and disciplines. It seems particularly promising to select established principles that cover relevant aspects of STS. They possibly have to be transformed or reformulated to serve this purpose. We strive towards heuristics that may be phrased in a way either to be applied to

1. real life phenomena (e.g., Ebay, LinkedIn, …),
2. to representations of potential processes which correspond to STS (c.f. Fig. 2),
3. to a combination of both.

For applying heuristics in a walkthrough we can use representations such as the one shown in Fig. 2 which depicts an overview of a process where elderly people can order a service which supports them during their weekly shopping. The original diagram showing the details to be taken into account is much more detailed and contains about 123 activities (c.f. [2] for more details on about the case to which the diagram is to).

4 Identifying areas from which to draw STS heuristics

We propose following areas as relevant:

1. **Socio-technical design principles:** This kind of principles are widely discussed by Cherns [6], Clegg [7], Eason [13], Fox [8], and Mumford [9]. Cherns' principles, which are grounded in the work of the Tavistock Institute, play a leading role in this discussion. A typical example of the principles discussed is: "minimal critical specification of rules". Principles like these have to be made concrete in the form of heuristics such as "Are strict sequences of activities only prescribed if necessary or logically indispensable?" or "Can the actors freely decide between a set of possible tools which one they will use for carrying out a task?". In the diagram depicted in Fig. 2 sequences are sometimes explicitly left vague. Activities are instead embedded into higher level activities which shows that they are part of these activities while leaving their sequence open (such as "modify service on demand" or "bundle orders"). On the other hand, a principle such as "core processes should be integrated" [7] can hardly be transformed into heuristics since its application would require more extensive knowledge about the context of an organizations´ processes. This knowledge is hard to include into an artefact or into prototypical situations to which the heuristics should be applied.
2. **Principles of Job Design:** In the context of socio-technical design, Mumford [9] emphasizes the need for principles of job-design, such as knowledge fit, psychological fit, efficiency fit, task structure fit or ethical fit. There are also other sources for job design criteria such as the ones proposed by Hackman and Oldham [14]. They consider the following criteria as influential: Skill variety, task identity, task significance, autonomy and feedback. Once again the question arises whether heuristics can be derived from these criteria which can be applied to a phenomenon being the object of an STWT. Mumford's "Knowledge Fit" and Hackman's & Oldham's "Skill Variety" require that necessary skills and knowledge are somehow perceptible during the STWT. Consequently, it is necessary to provide representa-

tions of the competences being required by the activities of a socio-technical process. If they are displayed in diagrams such as shown in Fig. 2, a heuristic could be phrased such as: “Does the set of task which are assigned to a certain role require a variety of skills?” Other principles, such as Mumford’s “ethical fit” are hard to take into consideration during an ex-post evaluation but have to be met during the development and evolution of STS.

3. **Usability heuristics:** The most prominent usability heuristics have been proposed by Nielsen [15] although Tognazzini [16] provides a more detailed list which includes aspects such as offering appropriate colors or using feasible metaphors in dialogues. Obviously, the more abstract heuristics are, the better candidates they are to be transformed for the purpose of STS-evaluation. “Visibility” for example requires that a user of a system can generally understand what is going on. This can be easily transferred from the realm of human-computer interaction to a workers socio-technical environment. Visibility in a socio-technical environment does not only require feedback such as “Can the actors realize how their contributions effect their environment”, but also includes information about the options for activities which are available at a certain moment. Also “documentation and help” is an interesting candidate since it is relevant on the level of organizational procedures and not only for human-computer interaction – and can be closely connected to learnability (see ISO 9241-110 or Tognazzini [16]). For STS evaluation, it becomes obvious that taking the area of usability into account adds new aspects which are on a more concrete level than those in the context of socio-technical design principles as discussed before.
4. **Principles for the design of computer supported cooperative work (CSCW):** Applying the usability perspective limits STS evaluation since this perspective is mainly related to individuals interacting with a computer. By contrast, the discussion of socio-technical principles focuses on team/group work and the related social aspects. Therefore, it is reasonable to refer to approaches which extend usability aspects to the level of CSCW. Herrmann et al. [17] provide a set of heuristics which are transformed to the group level. For instance, “visibility” is also extended to a requirement which takes the awareness for the activities of others into account. The aspect of “controllability” is phrased in a way that takes into account that the autonomy of one actor might restrict the autonomy of another actor. Consequently, on the level of an STS-heuristic, the new heuristics would scrutinize, whether the system provides communication channels and routines with which the autonomy of various actors can be balanced, e.g. by means of negotiation. Another approach by Baker et al. [18] focuses on mechanics of collaboration and mainly requires suitable communication support such as “Provide means for intentional and appropriate gestural communication”. Another one of their guidelines, “Provide protection”, aims at avoiding to lose a user’s work results. This is more appropriate on the socio-technical level e.g. by asking: “Are there routines ensuring that work results cannot be overwritten, neglected or destroyed?” Additionally, it can be helpful to consider coordinative issues [19] and requirements which have been elaborated in the context of designing workflow-management systems.

5 Next steps and Further challenges

It seems to be achievable to compile a promising set of heuristics which can be applied in walkthroughs to evaluate representations of socio-technical systems. However, it is still an open question, how this list can be made consistent and how a short list of the most prominent candidates can be extracted. Nielsen's [20] approach to arrive at suitable usability heuristics was to prioritize them so that with a small set of 10 items a large percentage of the most urgent problems can be identified. To pursue the same goal with a set of socio-technical heuristics it would be necessary to evaluate them in a number of projects, in order

- to see whether they help to identify problems which are considered as crucial by experts,
- and to check whether it is possible to prioritize them in a way which can lead to general validity.

Furthermore, it is necessary to clarify how people that will use those heuristics have to be prepared. This would require an understanding of who will be the potential users and addressees of the heuristics. Potential users can be project managers or change mangers, software-engineers, quality assurance people, researchers, but also the workers or customers who are active within a socio-technical process. They have to be trained to understand the heuristics and how they have to be applied during an evaluation, since it is not just about giving a rating whether certain criteria are fulfilled or not but to note potential problems so that they can be verified and potentially solved.

A crucial challenge is that a socio-technical evaluation requires much more contextual knowledge than it might be the case with pure usability testing. Thus the question is how far it is necessary to somehow make the relevant context available or whether it is possible to judge a socio-technical solution from an outside perspective. Probably it is necessary to include several evaluators of whom some are coming from the context of the system that is to be evaluated and others provide a less biased perspective from the outside. Finally, since it is likely that multiple evaluations will take place during the course of an STS project, heuristics have to be easily applicable still yielding sufficient information to inform the STS project.

6 Literature

1. Orlikowski, W.J., Scott, S.V.: 10 Sociomateriality: Challenging the Separation of Technology, Work and Organization. The academy of management annals. 2, 433–474 (2008).
2. Herrmann, T., Prilla, M., Nolte, A.: Socio-technical Process Design – the case of coordinated service delivery for elderly people. In: Blurring the Boundaries Through Digital Innovation. Springer (2016).
3. Fischer, G., Herrmann, T.: Socio-Technical Systems: A Meta-Design Perspective. International Journal for Sociotechnology and Knowledge Development. 3, 1–33 (2011).

4. Theofanos, M., Quesenbery, W.: Towards the design of effective formative test reports. Journal of usability studies. 1, 27–45 (2005).
5. Baxter, G., Sommerville, I.: Socio-technical systems: From design methods to systems engineering. Interacting with Computers. 23, 4–17 (2011).
6. Cherns, A.: Principles of Sociotechnical Design Revisted. Human Relations. 40, 153–162 (1987).
7. Clegg, C.W.: Sociotechnical principles for system design. Applied ergonomics. 31, 463–477 (2000).
8. Fox, W.M.: Sociotechnical system principles and guidelines: past and present. The Journal of Applied Behavioral Science. 31, 91–105 (1995).
9. Mumford, E.: Effective systems design and requirements analysis: the ETHICS approach. Macmillan (1995).
10. Polson, P.G., Lewis, C., Rieman, J., Wharton, C.: Cognitive walkthroughs: a method for theory-based evaluation of user interfaces. International Journal of Man-Machine Studies. 36, 741–773 (1992).
11. Herrmann, T.: Systems Design with the Socio-Technical Walkthrough. In: Whitworth, B. and de Moore, A. (eds.) Handbook of Research on Socio-Technical Design and Social Networking Systems. pp. 336–351. Hershey: Idea Group Publishing (2009).
12. Herrmann, T.: SeeMe in a nutshell - the semi-structured, socio-technical modeling method. (2006).
13. Eason, K.: Information Technology and Organisational Change. Taylor and Francis, London (1988).
14. Hackman, J.R., Oldham, G.R.: Development of the job diagnostic survey. Journal of Applied psychology. 60, 159 (1975).
15. Nielsen, J.: Enhancing the explanatory power of usability heuristics. In: CHI ’94: Proceedings of the SIGCHI conference on Human factors in computing systems. pp. 152–158. ACM (1994).
16. Tognazzini, B.: First principles of interaction design. Interaction design solutions for the real world, AskTog. (2003).
17. Herrmann, T., Wulf, V., Hartmann, A.: Requirements for the human centred design of groupware. Human Factors in Information Technology. 12, 77–100 (1996).
18. Baker, K., Greenberg, S., Gutwin, C.: Heuristic evaluation of groupware based on the mechanics of collaboration. In: Engineering for human-computer interaction. pp. 123–139. Springer (2001).
19. Crowston, K., Osborn, C.S.: A coordination theory approach to process description and redesign. (1998).
20. Nielsen, J.: Heuristic Evaluation. In: Nielsen, J. and Mack, R.. L. (eds.) Usability inspection methods. pp. 25–62. Wiley (1994).