What Went Wrong? What can go Right? A Prospectus on Human Factors Practice

Article · December 2015

DOI: 10.1016/j.promfg.2015.07.592

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Procedia Manufacturing 3 (2015) 5222 – 5229

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

What went wrong? What can go right?A prospectus on human factors practice

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Abstract

Human Factors has informed both research and practice for over 100 years [1].In this time, many theories, methods, and design practices have been implemented.As a result, the way Human Factors as a discipline has been conceptualized and put into practice has undergone numerous changes. Human Factors, at its heart is the idea that technology influences humans, and that humans influence the performance efficiency and effectiveness of technology, and other humans.Recent approaches to Human Factors have created multiple baseline assumptions on understanding human system interaction. For example, McNeese et al. [2] identified four systems design paradigms wherein each produce a qualitatively different outcome: *Technology-Centered, User-Centered, Data-Centered, Group-Centered.*Although there is value and truth in each approach, individually each theme limits its scope by deemphasizing contributions from the others. Because isomorphic approaches abound in the field, this paper theorizes a more optimal approach to contemporary human factors - The Living Laboratory Framework – that posits a wholistic perspective addressing various underling parameters in complex problem solving and innovative design. In this contemporary approach, the *theory–problems–practice* becomes highly integrated, reflecting unique and dynamic methods to create human-system integration. Examples are provided in the domains of cyber operations and police cognition to demonstrate the value of this approach.

Peer-review under responsibility of AHFE Conference

*Keywords:*human factors practice, human-systems integration, problem solving, systems design

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doi:10.1016/j.promfg.2015.07.592

1. Introduction

Human Factors has existed and has played a major role in informing both research and practice for over 100 years [1]. While Human Factors as a discipline dates back over a century, the way it has been conceptualized and put into practice has undergone numerous changes. As Human Factors has changed and evolved, the challenges associated with the application of the research within systems development practices has continued to grow. Such difficulties include translating experimental research into specific design prototypes, discriminating where generic design guidelines fall short in specific applications, and accounting for the biases in the design methods that minimize the role of the user, to name a few.

At the heart of Human Factors is the idea that technology influences the human, and humans influence each other as well as technology, and technology and humans operate within a given context, which impacts performance efficiency and effectiveness.Various approaches to Human Factors have surfaced in recent years and create a number of baseline assumptions on how to understand human system interaction. McNeese et al. [2] identified four paradigms used to approach systems design, but in the process, produce qualitatively different outcomes:

1. *Technology-centered* - Implies a functional, engineering basis to design where technology is dominant.
2. *User-centered*- Where a traditional Human Factors design is grounded in principles, task analysis, standards, and guidelines wherein psychology is dominant,
3. *Data-centered* - Experimental results and/or use of a large data test set are utilized to evaluate variables or system design parameters**.**
4. *Group centered* – Considerations of teamwork and organizational factors are valuable in developing processes, decision aids, or interfaces.

There may be value and truth in each approach but any one of these themes is limited in scope by themselves. For example, in most cases these paradigms minimize the role of context, affect, and ecological system dynamics.If a broad, interdisciplinary framework is not active in consideration of mutual interdependencies then designers may have to explain ‘what went wrong’ as opposed to developing a system that produces success.This paper discusses just such a framework; The Living Laboratory [3] provides a sound, interdisciplinary foundation and the use of a multi-method approach for human-systems integration in complex environments.

2. Early Encounters

During the first author’s time with the USAF, the government used a traditional systems acquisition process wherein Human Factors was applied when apropos.During this time, the user-centered view was the prevalent perspective used for defining Human Factors programs with more or less emphasis depending on the program specifics and other socio-political factors.This overall process combined government supervision and monitoring with contractor performance in a typical kind of systems engineering orchestration.

The use of Mil-H-46855 and Mil-Std 1472D were the heart and soul of the process, as they leveraged what specific elements were necessary to complete a Human Factors program according to a set standard.

Mil-H-46855 and Mil-Std 1472, which at this time were dated, did not integrate context, groupwork, or new information systems. Since their inception we have seen major changes in not only Technology, but also Information and People. A good example of this can be taken from traditional Human Computer Interaction (HCI) guidelines. HCI guidelines are predicated on research prior to readily available web-based, mobile, and distributed systems, which make them archaic in terms of keeping up with contemporary developments.Many of the assumptions that were true for design years ago are no longer relevant and applicable to a world that is exceedingly global, mobile, and socially distributed with open source information freely available. Use of technologies such as crowdsourcing, cloud computing, social media, and wearable computers have completely changed how people interact with, store, access, understand, and expect access to information, all upon which human performance and decision making is based.If the assumptions are no longer relevant then the application of these guidelines, principles, and standards may have also lost relevance.If Human Factors, as a field, wishes to continue to move forward, then it needs to continuously evolve. In his work on *Human Actors,* Liam Bannon [4] suggests that as researchers we need to take a metaphorical approach to living systems, wherein feedback, adaptation, resilience, and dynamic action facilitates ecological mutuality between a user and his/her environment. If Human Factors continues course with current tendencies and procedures, it will be doomed to repeat its failures and problems of the past.

The Living Laboratory framework is presented as an example of the vision Bannon put forth 25 years ago.To demonstrate how it has been used two particular applications are highlighted to articulate human-system integration within complex environments: a) *police cognition* and (2) *cyber-security awareness*.Before discussing the particulars of the framework and examples of use, it is worth considering what success could mean if it was done correctly given the many levels of socially distributed cognition that underline design in a contemporary society.

3. Success – What could go right rather than wrong?

Imagine a perfect world where Human Factors is thoroughly planned and thought out, theoretically sound and practically significant, and integral with all parties concerned. A world where design teams are made up of interdisciplinary members (designers, scientists, users, and business specialists) who are on the same page and seamlessly collaborate to produce the best product or system possible. Where the use of design is resilient, and specifically tailored yet adaptive within the context of use.In this hypothetical world, the *theory–problems–practice* would be highly integrated and reflect unique and dynamic methods to address boundary constraints and change of use. System development processes involving Human Factors would exemplify the following tenets:

- *Theory* would influence the design of experiments for the purpose of understanding and improving practice, accomplish the mission at hand and to make life better.
- *Data* generated from experiments used to directly inform generation of designs and establish trusted baselines such as Human Factors standards and guidelines.
- *Users* within a *field of practice* could discuss and agree upon what*problems/issues* are salient, explore together the appropriate means to solve problems, and act collectively with one mindset.
- *Methods* for implementing Human Factors system designs would clearly establish how data and *users* influence requirements and how requirements utilize Human Factors standards / guidelines, as applicable across the design and evaluation system life cycle.
- *Approaches* to design alternatives would be balanced and include related system design areas but primarily focus on humans as actors within a dynamically changing and interdisciplinary macrocontext that includes information, technology, and people.

When we consider how to appoint a broad approach to human factors, the field of practice is a beginning point for understanding how the mission, user experience, and contextual variation dynamically influence each other.This perspective emphasizes that the polis of information and ideas are directly picked up through the context of a field of practice.Practice may yield what is right (best practices) or what is wrong (errors, misunderstandings, failure) as human actions are specified by affordances they encounter. Therein, problems and issues are identified directly by observation and become messengers for defining what to address and why it is important for Human Factors consideration.Practice yields feedback and feed forward loops that express whether a design team has been successful or not in implementing a Human Factors approach to a problem.The framework presented in this paper actively fuses theory with problems and practice, hence interconnecting top-down and bottom-up approaches in a meaningful fashion.

4. Introduction to Living Lab Framework

The Living Lab is a holistic approach to design that integrates technology, context and humans into a cyclical development process. Numerous researchers and system developers, to better aid in design and incorporate multiple research approaches and perspectives on cognition, work and technology have adopted this approach. Living labs were first discussed in the context of information communication technology by Lasher [5]as a methodology for promoting partnerships with the firms they were working with.

For the purposes of our own research and this paper, we subscribe to the Living Lab as proposed by McNeese [3].This approach integrates theory and practice to enable tool and technology development through a continual process. The Living Lab Framework is made up of four main components, ethnographic studies, knowledge elicitation, scaled worlds, and reconfigurable prototypes (Figure 1).

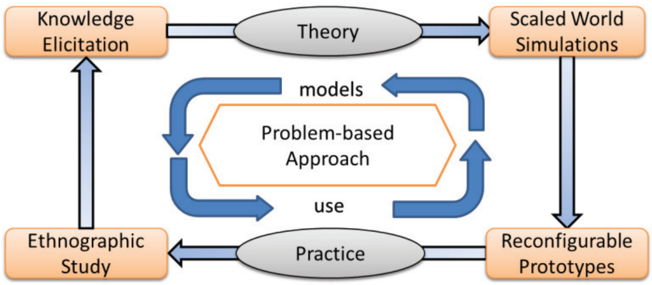

Fig.1: Living Lab Framework as Proposed by McNeese ([3], adapted)

More specifically, the Living Lab Framework utilizes observations of humans within their work domain alongside a deeper understanding of their knowledge to aid in the design and implementation of realistic simulations to be used to test theory and technology in a controlled setting. Results from laboratory studies can then be taken back out into the field and implemented into the actual environment. During this process, researchers can use their findings to help further theory, model and tool development. While presented visually and described as a cyclical process, the Living Lab Framework is flexible enough that one can move between the components forwards, backwards, crosswise, or even perform them in conjunction with each other.

5. The Living Laboratory Experience

Through the work of many projects, requirements, simulations, and designs we have noticed a wide variety of situations that create differences in how the Living Lab Framework approach is put into practice. As is the case in many practices there are biases and beliefs that make things “the way they are” and lay the foundation for inertia or change. Clearly this has been the case as we have used the Living Lab Framework for projects that have specific purposes and in turn generate constraints on the overall framework.Therein, adaptivity is one principle inherent in application of the Living Lab that has been reinforced over time.It is obvious to many that the impact of time-cost-schedule do present visible constraining conditions that a design team will have to be conscious of and take into consider when engaging the four elements of the Living Lab Framework. There are also other cognitive, social, and political biases that ensue when trying to apply methodologies to implement Human Factors requirements into design.

This is especially true if teams are involved in these types of decisions, as decision makers tend to uphold the old principle of social psychology wherein liking and similarity produce increasing linear relationships.If you are the only member of a design team that represents the human and many of the other members are technology-centric then it could produce an uphill battle to implement Human Factors.This battle has unfortunately been experienced and well-documented by not only the first author but also many other scientists and practitioners who have tried to get approval of Human Factors into the design, despite the argument of standards, protocol, and guidelines necessitating this.

In turn, one really critical element of the Living Lab approach – the central node of identifying and defining overall problems (and their sub problems) in terms of system-to-human and human-to-human effects, is a very strategic element in establishing the overall truth of the approach.Taking time to explore problems given the nature of the human and the changing contextual surroundings acts to ground each of the four elements on the pinnacle of the *problem space*.As information is sought and found using the elements of the Living Lab Framework it should increase more comprehension of the problem and therein lead to solutions that work the best.Success equates to having the four elements be the means to the end wherein the end is holistic understanding from multiple perspectives.

Finally, utilizing a flexible infrastructure and software language to help facilitate rapid prototype design and easy simulation start-up's is a key to seeing multiple options and how they impact performance.As we examine the reasons for choosing it – we keep coming back to looking at it as:

a) A *lens* to understand and define problem states in ways that are flexible not rigid.
b) A *bridge* to integrate various models and representation of humans in a system or system of systems where context is really important to decipher
c) An *engagement* of the mutuality of the four elements to improve practice which is where differences are made and evaluations undertaken to determine whether the problem (if correctly defined) can be effectively solved within the constraints specified
d) A *means* to enable a living systems feel to underline the importance of adaptive change in response to needs that evolve over time via multiple sources.

The cycle requires evolution to mature solutions to the point of being *resilient and effective* in the face of change.

6. Application of the Living Laboratory

In this retrospection, it is important to pause and reflect on the growth and pervasive application of Living Labs to inform innovation and design.For example, Følstad [6] reports that Living Labs are a relatively new innovation and development environment to evaluate users, and data on users' responses, for new information and communication technology (ICT) solutions.He supports this claim with evidence that Living Labs could meet innovation challenges among ICT providers [7], and growing Living Lab interest among other ICT areas, including:

- Mobile ICT [8-9]
- Ubiquitous computing [10-11]
- Collaborative work [12]
- Cognitive systems engineering [3,13]

In addition, the Living Lab Framework has been used as the basis of numerous research projects across multiple military and educational institutions. One notable example of the utilization of the Living Lab Framework was within the study of Emergency Management officials. Within this implementation of the living lab, an ethnographic study of emergency management center's was conducted [2] as well as knowledge elicitation of intelligence and image analysts. This knowledge was used in the development of several NeoCITIES scaled worlds [14], which served as the bases for tool development [15-16] to support collaborative group work, and continued development of theories such as team mental models and team situation awareness.

6.1 Domain of Application I:Cyber Operations and Security

Over the last decade, Cyber Operations and Security continues to grow as a critical thread in Human-Centered research. Due to the complex interactions between humans, technology and organizational constraints, the cyber domain fits perfectly within the framework of the Living Laboratory as discussed in this paper. Building our own experience from studying emergency response teams for the purpose of developing synthetic task environments, collaborative tools, and theories such as team mental models and team situation awareness [14-16], we extended our contextual focus to that of cyber security operations.

To develop a holistic understanding of the domain, we leveraged extant literature, and conducted one of the earliest ethnographic methods (e.g. interviews, observations, and knowledge elicitations) analyses of cyber security analysts [17]. While this research led to numerous findings, one particular finding of interest was the organizational boundaries that were implicitly created due to the variety of specializations within the operations center. During our interviews, we found evidence of a particular workflow for filing incident reports that was quite troubling, from a practical and theoretical standpoint. Whenever an operator would file an incident report, they would document their findings and pass it off to another operator with a different specialization to continue to fill out the report. We would anecdotally refer to this action as throwing the report over the "metaphorical wall," as the operators, for all intents and purposes, did not know where the report landed (who would continue it), or what would happen to the report once it was on the other side. This was not an act of malice, or a specific operating policy, but rather a lack of organizational knowledge of the varying specializations that resided within their operating center. This caused a multitude of problems: (1) the operator who was responsible for the report would lose track of it, (2) since they didn't understand the person picking up the report they did not know their informational requirements, and (3) it created a disconnect and an incomplete boundary object that hurt, rather than helped, the collaboration.

This finding resonated with a seminal organizational research theory known as transactive memory systems [18]. Put simply, transactive memory is the knowledge of who knows what within a team or organization. Previous research has shown that strong transactive memory systems (i.e. a complete knowledge of the specializations and knowledge within the team) lead to better team cohesion and inter-group processes, which ultimately improve team performance [19-20].

Continuing within the Living Laboratory framework, we viewed our findings from our knowledge elicitation and ethnographic study through the theoretical lens of transactive memory in development of the scaled world simulation TeamNETS[21]. Within the simulation, participants were able to share reports across their team in order to complete them using various cyber specializations (i.e. Malicious Software versus Intrusion Detection). To study the knowledge of the team, we manipulated how the teams were trained, with either specific specialties (like real cyber teams), or with a broader, but less deep, understanding of multiple specialties [22]. Our findings showed that when teams were trained in specific specializations, they behaved very similar to the cyber operators we observed in practice, participating in minimal collaborative processing and recreating the "metaphorical wall" of report sharing. However, when teams were trained with less specializations, with a broader set of knowledge, we observed a more cohesive collaborative team, sharing more information, and working together to file reports. While our findings showed no performance differences, teams with less specialization reported higher levels of team cohesion, and showed signs of a stronger transactive memory system, leading us to believe that over a longitudinal period of time that they would surpass the teams with more specializations. This finding shows that more effective cross training initiatives may facilitate better collaborative processes, and the development of effective transactive memory systems to improve cyber team performance.

6.2 Domain of Application II: Police Cognition

The Living Lab Framework in action was also used to investigate challenges in the cognitive activities of municipal policing. These activities focused on decision making, judgment and problem solving as officers face real world constraints in the performance of their duties.This is particularly interesting as municipal police officers perform independently within a large, socially distributed problem space that occasionally involves situations with potential high risks [23].

Ethnographic methods such as observations and interviews permitted the researcher to develop an understanding of the interplay between cognition, work and technology within the police domain, while simultaneously identifying those activities that constrain the cognitive abilities of officers.It became apparent that municipal policing offers several such opportunities for human factors investigation, ranging from geospatial mapping and dispatchers through to devices permitting officers to swipe card data from drivers' licenses.Perhaps most exigent, however, are situations where officers are confronted by an armed gunman [23].

The researcher continued the Living Lab Framework process to elicit knowledge by combining the Critical Decision Method (CDM) [24], with concept mapping. Guided by probing questions based on the Recognition-Primed Decision (RPD) model [25], officers were able to retrospectively evaluate cues and information used during armed confrontations. This naturalistic decision-making theory elicits worker judgments and decisions in high stake environments that consist of time pressure, multiple players, and ill-defined goals. The model suggests that absent time to deliberate, domain experts will use knowledge, training, and experience to quickly recognize and develop a course of action.Officers were asked to recall and map a previously encountered armed confrontation, along with the actions, thoughts, and observations during the incident [23]. Of particular interest for tool development were situations that evolved into barricaded gunman cases that require a lengthy duration to resolve, and as such, support from officers arriving from other jurisdictions.Incident commanders struggle to quickly and accurately brief and position these supporting officers as needed, as well as for the support officers to appropriately observe and report back to the command [23].

A scaled model was created and provided to officers to enable tool development.Officers played the roles of incident commanders and briefing support officers.This scaled model consisted of a readily available aerial view (e.g., Google Earth) projected onto a magnetic white board, along with dry-erase markers, and a variety of magnetic shaped and colored pieces, similar to common operational pictures [26] used in military domains.The officers used these tools to develop symbols to locate the gunman's location on the map, the locations where deploying officers would be assigned, timing information to know when to replace an officer, as well as other critical information (e.g., road blocks).In this case, the scaled model has been implemented in a mobile command post available to the research jurisdictions [25].

Combining methodologies of the successive layers of the Living Lab Framework enabled the researcher to identify an exigent problem, and the participatory design by end-users to develop a tool capable of reconfiguration and implementation by officers.

7. Conclusions

Making the Living Lab a foundation for how we do research and design enables an outcome that can be questioned and challenged to get it right, to work out biases or individual differences in training or specialties among roles, and to add new knowledge from users, experts, and designers that foments user science, technology innovation, and collaborative work to support Human Factors design.The crux of interdisciplinary design work requires this kind of collaboration to be transformative enough to really make a difference in success. Though not a new thing, in this paper we have presented the Living Lab Framework as a dynamic and flexible methodology for Human Factors design and research. The reader has been provided with two distinct examples of its application to real world problem domains to demonstrate what a wholistic approach to Human Factors means.Through our experience in both Human Factors and numerous Living Lab research programs, it is a step in the right direction to help insure that design can go right and support important components of human-system integration.

Acknowledgments

Work on this paper was partially supported by U.S. Army Research Office (ARO) MURI Grant "Computer Aided Human Centric Cyber Situation Awareness" W911-NF-09-1-0525. The Opinions expressed in this paper are those of the authors only and do not necessary represent the official position of the Army Research Office, the US Army, the Department of Defense or the Pennsylvania State University.

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