Visualizing Purpose and Functionality Overlaps of Health IT Systems using an Abstraction Hierarchy

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The development of health IT fuels a digitalization process that affects the work of hospital staff negatively in the case of poor integration of IT systems. A challenge lies in keeping track of the existing IT systems and possible overlapping functions. The Abstraction Hierarchy model from the Cognitive Work Analysis framework describes how parts of a complex system relate to the over-arching goals of the system, which could work as an overview of the IT systems. In this study, we explore how an Abstraction Hierarchy can be used to visualize how IT systems’ functions overlap, interfere with, or depend on each other. The Abstraction Hierarchy was developed based on documentation, interviews, and a study visit at a hospital ward. The overlaps in functionality visualized in the Abstraction Hierarchy could serve as indicators for the need for further investigation of effects on the hospital staff’s work.

INTRODUCTION

The digitalization of healthcare, with computer systems replacing paper-based documentation and manual registration of data being increasingly automated, continue to affect the work environment of healthcare staff. In the case of documentation, and including the manual registry of data from medical devices, the work of nurses is often primarily affected. Improvements granted by digitalization compared to using pen and paper are for example the enabling of multiple staff members to access information simultaneously, that the information is easier to search through, and the avoiding of the same information having to be recorded multiple times in different places.

However, to reach these positive effects, it is not enough that IT systems are well designed from a single-system perspective, the combination of IT systems that are necessary for a task also need to constitute a well-designed whole to support the staff in their work. At a hospital where the process of digitalization has been ongoing for decades, with a plethora of IT systems of different size, age, and complexity, where there are partial overlaps in functionality and where the hospital units have had the autonomy to create their processes of work, creating this well-defined whole is no modest endeavor. One significant challenge lies in merely understanding and keeping track of how the different IT systems are used today, and where multiple systems are involved in performing the same task, and in what way. Ideally, a nurse only needs to interact with multiple systems if they all contribute to performing the task in a meaningful way, and not, for example, to enter the same information into several systems because of a lack of integration between them.

Using an Abstraction Hierarchy (AH) could be one way to visualize how different IT systems are involved in performing tasks and can be used to highlight the need for system integrations.

The AH is used to model a work domain during the first phase of the Cognitive Work Analysis (CWA) framework (Rasmussen, Pejtersen, & Goodstein, 1994; Vicente 1999). The AH contains a mapping of a work system’s physical (or digital) components and its functions to more abstract purposes, and in the end to the overall values and purpose of the work system (Vicente, 1999). Group managers and engineers at a vehicle manufacturer reported that an AH of its drivers’ work domain could be used for visualizing connections between different subsystems in the vehicle, each developed by a different team in the organization (Bodin & Krupenia, 2015). The AH was by the managers seen as a way to get an overview of how the subsystems relate to each other, and it was realized that it would be possible to map the branches of the AH to the different development teams in their organization.

The CWA framework has been applied within healthcare and many other domains, often to support interface design (Read, Salmon, & Lenné, 2012). An example from the healthcare domain is an application of CWA focused on managers within healthcare to identify environmental constraints to support the development of a decision support tool (Effken et al., 2011). Other examples are a work domain analysis including organizational factors in a pediatric intensive care unit, which was used for prototyping a mobile patient monitoring application (Gorges et al., 2013), and a work domain analysis of the work conducted by intensive care nurses bed-side the patient (Bodin, Fröjd & Jansson, 2015).

The study presented aims to investigate if and in what way the AH could be applied to highlight and document functionality overlaps between IT systems used within the same organization. The focus is on the work by the organization, rather than the work domain of one particular hospital ward or work role within the organization, as in the studies focused on the work domain of intensive care nursing by Bodin et al. (2015).

In the current document we describe the method for the study, including the organization where the study took place, a brief description of the CWA framework’s first phase, as well as the data collection and analysis. We present the AH
The Case

The study presented here was carried out at a large Swedish university hospital, which we saw as a compelling case because of the numerous IT-systems in use as well as an ongoing digitalization process. The work carried out within the hospital organization is diverse because the hospital provides a full range of secondary as well as tertiary care with an uptake area covering approximately two million inhabitants in the surrounding regions and with the most specialized units being one of a kind in the country as part of the national healthcare infrastructure for tertiary care. The organizational structure is complex as well, where the IT systems used in the hospital wards belong to either the ward itself, the hospital, or to the IT unit at the County Council’s Health Information Technology unit. The difficulties associated with IT development in this context inspired this study, and also made for a fitting case to try it out.

The Analysis and Modeling Framework

The modeling tool used in the study presented in the current manuscript is the AH from the CWA framework (Vicente, 1999). The AH belongs to the first out of five phases of the CWA framework, the Work Domain Analysis (WDA), where the focus is on understanding the ecology of the work, and the constraints that form the work, rather than how the tasks are carried out (Vicente, 1999). In the AH the structure of the work system is modeled in five abstraction levels, which illustrates how the physical (or in this case digital) components of the work system contribute to its higher level purpose. The five levels of the AH includes nodes representing the work systems objects, functions, and purposes and the connection between the nodes represent why (when reading from down and up) and how (when reading from up and down).

Data Collection and Participants

We developed the AH model in iterations based on information from documents describing the IT systems from the suppliers, documents describing the hospital’s high-level goals, eight interviews with managers at different levels of the hospital and County Council organization, three interviews with system experts working with implementation and management of the IT systems, as well as a brief (3 hour) visit to one of the hospital wards where the systems had been implemented.

The interviews with managers from the hospital and County Council were semi-structured and focused on the work with implementing IT at the hospital. The interviewees’ roles in the organizations ranged from responsibility for digitalization on a strategic level to specialists assigned to a particular IT system. The AH was updated in-between the interviews, and shown to the interviewee towards the end of five of the interviews (the exceptions being the two first interviews and one focused on procurement). For this part of the interviews we asked questions from Naikar, Hopcroft, and Moylan (2006) related to the different levels of the AH, and the focus was either on a higher level abstraction, such as the overall goals of the hospital, or one of the IT systems, depending on the interviewee’s role in the organization.

The interviews with system experts were used to evaluate that the AH portrayed the IT systems accurately, to exclude functions mentioned in the documentation from the suppliers but not implemented in the particular hospital, and to add functions they found missing. During the visit to the hospital ward, we had the chance to see how the nurses use the IT systems represented in the AH, to get a better understanding of the IT systems’ functions.

RESULTS

The Scope of the Abstraction Hierarchy

During our meetings and interviews with people from the university hospital and the County Council’s Health Information Technology unit, we learned about two systems with different purposes implemented almost at the same time, but where the two systems had overlaps in functionality both between each other and with the existing general electronic health record system. One of the new systems, the clinical information system, is a decision support tool for intensive care. The other system is a surgery planning tool used for surgery scheduling and planning activities related to surgical practice. At first glance, the systems seem very different and separated from each other. However, for several activities they are both used in the same time and place, such as during surgery where infiltration is added to the surgery planning tool, and the clinical information system is used for a patient under anesthesia, they do make up a compelling case, which we modeled in the AH (figure 1).

The IT Systems and their Functions

The AH includes the three considered IT systems at the Physical Object level, and the second lowest level in the AH, the Object-Related Processes level, includes the IT systems functions. The color of the nodes for the IT systems functions, correspond to the color of the node of the connected IT system, or the combination of their colors in the case of multiple connections.

Ten of the functions on the Object-Related Processes level that are all related to patient data are grouped, in the group called patient data. General information such as the patient’s contact information, that the patient has arrived at the hospital, and to provide an overview of the whole care process are examples of functions of the General electronic health record system (green color in figure 1). The functions of the Clinical information system (blue) is instead, for example, an overview of patient data and current medical parameters, and
also some overlap with the General electronic health record system, as care documentation and test results (turquoise). The Surgery planning tool (red) does also have the function of storing the patients contact information, which the General electronic health record system also does, and all three systems have the function of documenting when a treatment is completed, in the case that the treatment is a surgery (see care documentation; completed treatment [gray]).

The Overview local & bed occupancy that also are on Object-Related Processes level in the AH has a system decomposition to show that the function of the three IT systems do not overlap entirely in this case, but rather complement each other with the function of overview local and bed occupancy for different wards.

The Purposes, Values and Purpose-Related Functions

The highest level of the AH includes the hospitals’ Functional Purpose, which is to provide health care to residents, today but also in the future, and this purpose is what the IT systems, in the end, should support. This aim is realized through long term goals the university hospital has set up, which are adapted and presented as the Values and Priority Measures in the model. Those include patient involvement, medical quality, and improvement work, an effective organization, research and innovation, and the work culture.

The Purpose-Related Function level in the AH includes general functions in the organizations and their connections to both the values and priority measures, and also to the IT systems functions. On these levels the functions are expressed in a more general way than the lower level functions on the Object-Related Processes level of the AH. They are more closely connected to higher level values and priorities and the purpose of the organization, compared to the lower level functions, which are closely connected to the IT systems. An example of a Purpose-Related Function is planning and coordination of the work and organization, which is connected to many lower level functions: the three Value and Priority Measures about medical quality, an effective organization, and work culture.

Most of the nodes on the Purpose-Related Function level in the AH have connections to all three of the IT systems (the ones in gray), but for example the Purpose-Related Function Continuity in care, coordination between healthcare providers is only supported by the General electronic health record system. Some nodes are grouped into either Patient focus or Care implementation to make the functions easier to overview.

DISCUSSION

Abstraction Hierarchy of Health IT Systems

The purpose of the work domain analysis is to gain an understanding of the ecology of work through modeling the work domain in an AH. Work domain analysis has been carried out many times within health care (Jiancaro, Jamieson, & Mihailidis, 2014), but even when studying similar work domains, what the analysis focuses on makes for a difference in what is expressed in the AH model. In the study by Miller (2004) about intensive care, it is the intensive care patient that is modeled in the AH. A rationale for this perspective is that in intensive care the constraints that the work has to respect, comes from the constraints of the patient’s body, and therefore a model of the patient is useful when designing a system for intensive care. Similarly, Rezai and Burns (2014) present an abstraction decomposition hierarchy of blood pressure management where the patient is seen as the whole system. In a study by Ashoori (2014) team CWA is used to reveal healthcare team interactions. In their study both the patients (mother and baby), and the medical equipment and tools are included in the AH. Bodin et al. (2015) used a similar approach where the bedside patient work was the focus of the domain analysis. The higher levels correspond to the constraints imposed from the patient’s needs, such as support of the patient’s basic and vital functions, the circulation and respiration, and to prevent secondary complications such as lung damage. The lower levels of the AH include the medical devices and technology, and their functionality. The idea is to understand the work for the development of a holistic information environment, including all existing medical devices currently in the intensive care unit.

The lowest level of the AH presented in this manuscript does only include IT systems, which is unlike the usual case of including all kinds of physical objects (Vicente, 1999). The purpose of this was to provide an overview of the IT systems to identify how they are related, and hopefully be able to support the development of a more coherent IT environment, rather than to understand the work domain of the hospital staff. Only including IT systems mean that the AH is missing other paper-based systems that potentially have overlapping functions with the IT systems modeled in the AH. The idea is to have the work that is to be carried out in focus during development of the (multiple) IT systems at the hospital, and that the domain analysis therefore would be useful.

Another characteristic of the AH presented in this study is the organizational perspective. The top level of the AH, that includes the overall purpose of the work domain, is in the current study describing the whole organization’s (the university hospitals) overall purpose. The second highest level includes the Values and Priorities, adapted from the hospitals longer term high-level goals, and visualize important values within the whole organization. The purpose and values differ from the nodes on the top levels of the AH for intensive care nursing by Bodin et al. (2015) because of the different scopes.

Practical Implication

A practical implication of our work is that the AH itself could be used by managers in the organization when making strategic decisions about the requirements on future systems, including both the continued development of existing IT systems as well as the procurement and implementation of new ones. In particular, the AH contributes by highlighting where multiple systems are involved in a task either for legitimate reasons (they all contribute to the task), because of functionality overlap (either system could technically be used), or because of a lack of integrations between systems.
That multiple IT systems are connected to a function can mean different things, and the goal should therefore not be to minimize the connections. Instead, the overlaps should indicate a need for further investigation of what the overlapping functionality means, and how it affects the workplace. Is it the same functionality needed by all systems? One example of this is the Login function & access management (black) in the AH in figure 1. Does the visible overlap indicate that different systems fulfill the same or a similar function and are used by different work roles, for different patient groups, or in different wards? In figure 1 we see this type of overlap for the group of functions called Overview local & bed occupancy. The overlaps could also identify a healthy redundancy that ensures higher safety, for example, the function of alerting hospital staff of a patient’s allergy or contagious disease (see Warn of infection, allergy, etc. in patient [gray] in figure 1).

That multiple IT systems connect to the same node in the AH can also mean that they have overlapping functionality, which in the worst case could force the hospital staff to perform the same task several times using multiple systems. One example of this in the AH in figure 1 is the function of documenting that a surgery is completed (see care documentation; completed treatment [gray]) which requires nurses to document the completed surgery three times. Cases of double, or as in this case triple, documentation that nurses need to deal with could be identified and visualized using the AH.

Future work

This manuscript has the purpose of describing the development of the AH visualizing purpose and functionality overlaps of IT systems using an AH. We have yet to investigate how the information could be used in the organization and what value it has for different stakeholders. To learn more about how the AH could be used in gaining an overview of a work system to be used in the development of, and by a complex organization the next step will be to investigate how well the information provided within the AH maps to the information need of different stakeholders, and if the AH is a step towards handling the difficulties of IT development in complex organizations.

Conclusion

We modeled the purposes and functionality of three Health IT systems in an AH to visualize how they relate to each other and how parts of their functionality overlap. The AH could serve as an indication of a need for further investigation of how each identified overlap affects the hospital staffs’ work, which should preferably be investigated before the IT systems are implemented.

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REFERENCES


Figure 1. The Abstraction Hierarchy that describes how three Health IT systems functions correlate and contribute to the Functional Purpose of a hospital.