Spring 6-10-2017

A FRAMEWORK TO ADVANCE ELECTRONIC HEALTH RECORD SYSTEM USE IN ROUTINE PATIENT CARE

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Recommended Citation

Lienhard, Kenny; Job, Oliver; Bachmann, Lucas; Bodmer, Nicolas; and Legner, Christine, (2017). "A FRAMEWORK TO ADVANCE ELECTRONIC HEALTH RECORD SYSTEM USE IN ROUTINE PATIENT CARE". In Proceedings of the 25th European Conference on Information Systems (ECIS), Guimarães, Portugal, June 5-10, 2017 (pp. 1114-1128). ISBN 978-989-20-7655-3 Research Papers.
http://aisel.aisnet.org/ecis2017_rp/72

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Research paper

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Abstract

The digital transformation of routine patient care is much more than doing the same but with electronic instead of paper-based health records. The current literature provides strong evidence for the gap between the promises of electronic health record (EHR) systems and our knowledge on how to design systems that fit the requirements of daily clinical practice. Following the design science research paradigm, we develop a framework that allows one to empirically assess EHR system use in routine patient care. The suggested framework describes an objective assessment of physicians' way of executing routines to identify the user interface elements that afford and constrain physicians' executions of routines. We demonstrate our framework's use in a field study that reveals actionable insights into how to adapt physicians' ways to perform a routine and to identify potential misconceptions in EHR system design. This study contributes to and complements existing research on clinical routines and EHR systems, providing a framework to unpack the 'black box' of EHR systems and their use in daily clinical practice.

Keywords: Electronic Health Records, EHR, Organizational Routines, Affordances, Design Science.

1 Introduction

Information technology (IT) holds great promise for medicine. Health IT can improve the quality, safety, and efficiency of care, yielding cost savings, improving care coordination, and providing greater patient engagement in their own healthcare (Blumenthal, 2010). Electronic health record (EHR) systems are a common pathway of all these improvements, since they offer new ways to capture, retrieve, and analyze medical data in routine patient care. Following the International Organization for Standardization (ISO), we refer to an EHR as a repository of patient data in a digital form, securely stored and exchanged, and accessible by multiple authorized users (ISO/TR 20514, 2005).

Governments in various countries are encouraging the adoption of EHR systems by making incentive payments available to hospitals and health professionals. Starting in 2009, the U.S. government has spent more than U.S.$30 billion to computerize healthcare, with the goal to provide every American with a personal EHR. A recent study has shown the impacts of its efforts: 75% of U.S. hospitals have now implemented at least a basic EHR system – up from 59% in 2013 (Adler-Milstein et al., 2015).

However, despite EHR systems' growing adoption rates in hospitals, the implementation of IT in clinical practice has brought many new problems, most of which were not foreseen by IT vendors and became apparent only when physicians began to use IT in their daily routines. From a patient's perspective, a computer in an examination room risks dehumanizing patient-physician interactions (Shachak and Reis, 2009). Doctors are hidden behind a screen, typing at their keyboard while listening to the patient. From a physician's perspective, Kellermann and Jones (2013) have criticized the current state of health IT, stating that few health IT vendors make products that are easy to use. As a result, physicians are frustrated that technologies require time-consuming data entry and disturb rather than support their routines (Bhattacherjee and Hikmet, 2007; Wachter, 2015). A recent study in emergency medicine underlined these arguments: Hill et al. (2013) revealed that 44% of clinicians' time was spent on data entry, with only 28% of their time spent providing direct patient care. And a team at the Harvard School of Medicine recently investigated 1.04 million medication errors reported to a large database between 2003 and 2010. They found that 63,040 (or 6%) of all medication errors related to issues with computerized prescriptions (Schiff et al., 2015).

These studies underpin that the digital transformation of medicine involves much more than doing the same but with electronic instead of paper-based health records. Recent research (e.g. Hill et al., 2013; Schiff et al., 2015) provides strong evidence for the gap between the promises of EHR systems and our knowledge on how to design systems that fit the requirements of clinical practice. Kellermann and Jones, in their inspiring analysis, postulate the active engagement of clinicians in the development process and making usability a priority for EHR systems. Today, practices such as formal usability testing and the use of user-centered design processes are almost absent in engineering health IT systems (McDonnell et al., 2010). In line with these studies, we believe that the assessment of EHR system use in routine patient care can reveal important insights and recommendations on the design of current and future systems. This paper builds on this opportunity in research and seeks to answer the following research question: *How do we identify the affordances and constraints of an EHR system in routine patient care*?

Building on the design science research paradigm (Hevner et al., 2004), we develop and demonstrate a framework that allows one to assess EHR system use in routine patient care. The proposed framework is a novel approach to identify an EHR system's user interface (UI) elements that afford and constrain physicians when executing clinical routines. We demonstrate our framework's use with medical doctors in a Swiss hospital. Our demonstration illustrates how the suggested framework allows one to identify differences in physicians' EHR system use, and to relate these differences to specific UI elements that were not perceived as affordances. The framework provides empirical insights into the design of current and future EHR systems and identifies required changes in physicians' ways of performing routines to leverage the potential of EHR systems. This study contributes to and complements existing research on routines and EHR systems, providing a framework to unpack the 'black box' of EHR systems and their use in daily clinical practice.

We proceed as follows. In the next chapter, we review the theoretical foundations for our work. We then provide a background on the research method. Next, we describe the suggested framework on how to identify the perceived affordances and constraints of EHR system use in clinical routines. In Section 5, we demonstrate and evaluate our approach in a field study, which allows us to gather empirical insights into the UI elements that afford and constrain physicians in routine executions. In the conclusion, we discuss the theoretical and practical impacts of our findings, describe the study limitations, and propose directions for future research.

2 Background Literature

2.1 Prior Research on Electronic Health Record Systems

While EHR systems have always been perceived as a key driver to improve the quality of care and to lower costs in delivering healthcare services, there is a fundamental gap between these systems' promised benefits and what can be observed in clinical practice. A critical success factor for EHR system use in hospitals lies with the physicians (Sherer, 2010; Venkatesh et al., 2011), and failures of EHR system implementations are often linked to resistance from physicians (Archer and Cocosila, 2011; Bhattacherjee and Hikmet, 2007). In the literature, various factors explain this phenomenon, including poor system usability (Bowman, 2013; Kellermann and Jones, 2013), low end-user involvement in the implementation process (Rahimi et al., 2009), and power shifts between physicians and nurses (Bartos et al., 2008).

The value of health IT and its adoption within the healthcare sector have been the focus of the past information systems (IS) research on healthcare. Many studies rely on established IS theories such as the Technology Acceptance Model (TAM) and the IS Success Model (Abouzahra et al., 2015). Holden and Karsh (2010) note that the lack of context in technology acceptance theories prevents TAM from explaining all the factors that impact health IT's use. The impacts of contextual factors might even be higher in the healthcare sector owing to this domain's particularities. For instance, routines in patient care require very specific knowledge by health professionals, are time-sensitive, and are typically characterized by high uncertainty. Building on these arguments, Mettler (2013) suggested different clinical user profiles as a first step to more user-centered IS in healthcare as well as more precise usability and adoption studies.

On the other hand, research in the medical literature notes that, for physicians, the digital transformation of medicine remains more of a promise than a reality. Not only do physicians perceive current EHR systems as disturbing rather than supportive for clinical practice, these systems could even seriously harm patients. In their widely discussed paper, Han et al. (2005) observed an unexpected increase in patient mortality with EHR system implementation. The authors propose ongoing assessment of a system's human-machine interface in order to better understand EHR system use in routine patient care. Thus, it is surprising and worrying that formal usability testing is still not a priority in EHR system implementation (McDonnell et al., 2010). When analyzing a large database with medication errors reported between 2003 and 2010, Schiff et al. (2015) found that almost 80% of the erroneous orders could still be entered in today's EHR systems. More than one-quarter (28.0%) of these orders were entered without any warnings. The effective and efficient EHR system use would increase both physician productivity and hospital revenue. However, a recent study by Hill et al. (2013) has shown that physicians currently spent 30% to 40% of their workday on documentation, with electronic charting taking 30% longer than paper charts. In other words, a physician does 4,000 mouse-clicks during a busy 10-hour shift.

2.2 The Need to Study Electronic Health Record System Use

Studies in IS have focused on measuring the overall impacts (e.g. adoption and cost-reduction) of IT in healthcare. While these studies provided a foundation to quantify IT's value in healthcare from a more general perspective, there has been little research on the de facto EHR system use in daily clinical practice. Benbasat and Barki (2007) stated that "we reached a saturation point in TAM work after which few surprises were evident". In line with Benbasat and Barki, we argue that the knowledge that "usefulness is useful" has provided little actionable research and very few recommendations for designing EHR systems that fit the requirements of physicians' work practices in hospital contexts. To study EHR system use, we seek to objectively asses how a system is in fact used in routine patient care.

Work in healthcare is structured through the enactment of organizational routines. Thus, the systematic study of existing routines could be a useful starting point for the design of technologies such as EHR systems (Greenhalgh, 2008). Routines are a key characteristic of every human organization such as healthcare institutions, and is widely recognized as the way most organizational work is accomplished (Cyert and March, 1963; March and Simon, 1958; Nelson and Winter, 1982). Research refers to organizational routines as sequential patterns of social action that are carried out by multiple actors (Feldman and Pentland, 2003; Pentland and Rueter, 1994). In the hospital context, *clinical routines* refers to sequential activity patterns that caregivers (e.g. physicians) must engage in as they provide care to a patient (Wright et al., 1998). For instance, the referral to an emergency ward in hospitals is executed in a specific actions sequence by nursing staff and physicians. While both actors have a broad understanding what a clinical routine should do, a routine's ostensive qualities, the way a routine eventually occurs – its performative qualities – depends on an executant's specific actions taken in specific places at specific times (Pentland and Feldman, 2005).

To understand EHR system use in clinical routines, we turn to a theory of affordances. The concept on functional affordances allows us to describe the possibilities for goal-oriented actions afforded by technical objects (here: an EHR system) to the people (here: a physician) executing a routine (Markus and Silver, 2008). In his formulation of affordances, Gibson (1977) argues that people don't interact with a technology prior to or without perceiving what a technology is good for. Technologies such as EHR systems have material properties (e.g. the ability to store medical information) that are common to all people who encounter them. The affordances of a technology, however, can vary between people. To illustrate this point, consider the following example. When two physicians need to open a patient case in an EHR system, one might open the case by searching for the patient's family name and date of birth, while the other physician scans a patient's barcode printed on a paper document. Both physicians use the same material property of the EHR systems (i.e. the system's ability to retrieve information about a patient case). However, while physician 2 perceives the EHR system's barcode scanner as a functional affordance, physician 1 considers it as too complicated and prefers to use a manual text search. This simple example illustrates that two physicians can perceive an EHR system's materiality in different ways. Norman (1999) states that the system designer should create affordances strategically, so that users find them easy to perceive. People may perceive a technology as offering no affordances for goal-oriented actions. Instead of perceiving affordances, they perceive a technology's constraints when executing a routine. This research follows Norman's argument in that we believe affordances are *designed-in* properties of artifacts and that these affordances are always there, independent of context, waiting to be perceived by an individual.

3 Research Method

Our research follows the design science research paradigm, which emphasizes a construction-oriented view of IS and is centered around designing and building an innovative IT artifact to solve an identified business need (Hevner et al., 2004). Our research process follows the design science research methodology (DSRM) proposed by Peffers et al. (2007). The research was conducted in an engaged collaboration between a team of researchers (two IS and two medical researchers) and a senior physician at the Eye Clinic at the Cantonal Hospital Lucerne, Switzerland's largest public eye clinic. The Eye Clinic recently implemented a new EHR system called Eye Clinic Manager (ECM), which is offered by a private IT company. ECM was developed in a close collaboration with the Eye Clinic and is now available as a commercial off-the-shelf product. The overall project duration for developing ECM was more than 42 months.

The DSRM is triggered by the *(I) problem formulation,* which we addressed by reviewing the literature and by analyzing practitioners' perceptions and problems with EHR systems. Current studies have provided little actionable research, and there have been very few recommendations for designing EHR systems that fit the requirements of the physicians' work practices in the hospital context. From a practical perspective, recent studies have reported serious issues with EHR system use in routine patient care (e.g. Hill et al., 2013; Schiff et al., 2015). From the problem definition, we inferred the following *(II) objectives of a solution*: Since many hospitals recently adopted an EHR system, it seems unrealistic that they would start designing new EHR systems from scratch. Hospitals would rather try to refine existing EHR systems instead of replacing the systems that are now deeply embedded in clinical practice. Thus, we sought to design and develop an artifact (i.e. a framework) that could cope with these circumstances and that supports the improvement of existing EHR systems. Specifically, the framework's objectives are 1) to identify affordances and constraints of EHR system use in routine patient care and 2) to provide actionable insights into how to improve EHR system use in a hospital.

In the *(III) design and development* activity, the core of the design science research, we started by determining the artifact's desired functionalities and then creating the actual artifact (i.e. the framework presented in Section 4). In an engaged academic-practitioner relationship, we built the framework in an iterative approach. The research team regularly met to evaluate and refine prototype versions of the framework. Thereby, we considered both extant literature on EHR system use and clinical routines as well as inputs from senior physicians working on our research project. The systematic analysis of the literature ensured that our framework builds on a robust knowledge base. We subsequently (IV) *demonstrated* and *(V) evaluated* the framework's use at the Eye Clinic at the Cantonal Hospital Lucerne. This demonstration allowed us to illustrate how the framework solves a specific instance of the problem, i.e. the empirical assessment of the use of a specific EHR system in the patient case presentation routine. We used the demonstration at the hospital to observe and measure how well our suggested framework supports a solution to the problems formulated in the first activity of the DSRM. The evaluation activity mainly involved the comparison between the defined objectives of activity II and the empirical outcomes from the artifact's use in the demonstration. Thus, the demonstration should allow us to identify the affordances and constraints of the EHR system under study. Further, the outcome should provide actionable insights into how to improve EHR system use at the Cantonal Hospital Lucerne's eye clinic. If these two criteria are met, we would consider our demonstration successful. The final phase of the DSRM process is the *(VI) communication* of the identified problems, the artifact, and its effectiveness (Peffers et al., 2007). This paper is our first report on ongoing research activities on this topic.

4 A Framework to Identify Affordances and Constraints of Electronic Health Record System Use in Routine Patient Care

We propose a framework to empirically assess EHR system use in routine patient care. The suggested framework seeks to optimize EHR system design and alignment with physicians' ways of working. It allows to identify affordances and constraints, insights that can then be used to improve EHR system use with systematic interventions. To evaluate the interactions between an EHR system and the clinical routine, we rely on the following understanding: Standard operating procedures (here represented as medical guidelines) describe the routine's ostensive qualities, i.e. the activity pattern that reflects the way the routine is understood. The way a physician performs a specific routine at a specific time is constrained and enabled through the routine's ostensive qualities (i.e. the medical guidelines). In care delivery, medical guidelines ensure best practices in clinical routines. They are fairly stable and usually change in the context of new scientific medical knowledge. It is the system designer's responsibility to design affordances into an EHR system, representing these medical guidelines. The affordances are then accessible via an EHR system's UI elements and should guide physicians in executing clinical routines. A physician, however, might not perceive the affordances designed by a system designer. We would then say that the corresponding UI elements are perceived as constraints rather than as an affordance. This is what our framework allows one to identify. We will now describe our framework's stages, each anchored in its concrete tasks and outcomes (for a summary, see Table 1).

Stage	Tasks	Outcomes
Stage 1: Select a representative clinical routine	- Select a routine, based on three criteria: 1) physicians have a shared understanding about the routine's ostensive qualities, 2) the routine is executed often and directly impacts the medical outcome, and 3) routine execution heavily relies on EHR system use	- Definition of a clinical routine
Stage 2: Define an activity pattern and its representation in the EHR system	- Define the activity pattern for the selected routine, informed by medical guidelines - Describe the activity pattern's representation in the EHR system: properties designed into the system and ready to be perceived	- Activity pattern for the selected clinical routine - Representation of the activity pattern via the EHR system's UI elements
Stage 3: Prepare to collect data on routine execution	- Identify candidate physicians who will perform the selected routine: they must be familiar with the routine and EHR system use - Selection of patient case(s): 1) a patient's EHR should contain a significant number of medical records, and 2) the physicians performing the routine should not be familiar with the patient case	- List of physician candidates - Patient case(s)
Stage 4: Track the routine execution in a naturalistic setting	- Track actions taken by a physician executing the selected routine (e.g. mouse-clicks, system logs, and eye-tracking)	- Empirical data on the routine's performative qualities
Stage 5: Identify affordances and constraints	- Define the outcome measurement - Assess empirical data on routine execution, comparison to defined outcome: identification of affordances and constraints	- Definition of the outcome measurement - UI elements that afford and constrain routine execution

Table 1. Five stages to identify affordances and constraints of electronic health record system use in routine patient care.

Stage 1: Select a representative clinical routine. To select a representative clinical routine, we suggest the three following criteria. 1) The clinical routine should be familiar to the hospital's physicians: i.e. physicians should have a common understanding and should agree on what the routine should do (i.e. the routine's ostensive qualities) and a common name to refer to the routine. 2) The routine is often executed to deliver care to patients and should directly impact the medical outcome's efficiency and quality. 3) The routine should strongly rely on EHR system usage (i.e. it involves a significant number of UI elements implemented in the EHR system).

Stage 2: Define an activity pattern and its representation in the EHR system. The first task in stage 2 is the definition of the activity pattern (Feldman and Pentland, 2003; Pentland and Rueter, 1994) that the physicians execute when performing the clinical routine selected in the previous stage. The activity pattern should reflect the routine the way it is understood (i.e. the routine's ostensive qualities) by the physicians. In medicine, activity patterns are often informed by national or international medical guidelines. While a routine's execution depends on its specific context (e.g. the physician's experience, her working style, and the patient case), medical guidelines ensure best practices in delivering care. Several research streams provide formal ways to describe or model an activity pattern (e.g. flow charts, task modelling, and the business process model and notation), which can be used for this task. The second task in this stage is a description of the EHR system's representation of the activity pattern. When building an EHR system, the system designer has an understanding (if she is good at her job) of how an activity should be represented and strategically designs affordances into the EHR systems. The system makes these affordances available via its UI, so that these affordances are waiting to be perceived. For instance, if a physician must look up a patient's allergies, a system designer may decide to provide an icon on the system's top navigation bar to make the patient's allergies available via a single click. By linking each activity (e.g. looking up a patient's allergies) to its representation in the EHR system (e.g. top navigation bar), the system designer describes the affordances, or signifiers (Norman, 2008), designed into the EHR system and ready to be perceived by a physician executing a clinical routine.

Stage 3: Prepare to collect data on routine execution. The first task in this stage is to identify the physicians who will perform the routine and from whose performance the hospital can learn how to improve the interaction between the selected clinical routine and the EHR system. The physicians should 1) execute the selected routine in their daily clinical practice and 2) the EHR system should be a key tool in their work. The second task in this stage is to select appropriate patient case(s) to perform the routine. A patient case should have a significant number of medical records, so that it is not straightforward for the physicians to overview the entire case. Further, participating physicians should not be familiar with the selected patient case. This ensures that none of the physicians has advanced knowledge about the selected case, which might bias the outcome.

Stage 4: Track the routine execution in a naturalistic setting. Stage 4 seeks to collect data about the physicians' ways to execute the selected routine. Data should be captured on the physicians' system behaviors. For instance, which UI elements they are using, where they enter erroneous data, or where they have difficulties to find the correct UI element to perform a specific activity. This could be done by collecting system logs, by tracking mouse activities, or by using an eye-tracker to know where the physician is looking on the screen. Research on human-computer interaction offers several usability techniques (e.g. task analysis and thinking aloud) to track a user's system behavior (Abras et al., 2004). Using the thinking aloud technique (Boren and Ramey, 2000), physicians could be asked to explain what they are looking at on the EHR system and what they think, do, and feel while executing the predefined activities. However, we suggest using a usability technique that allows one to track participants' behaviors by retaining a naturalistic setting (e.g. an eye-tracker mounted unobtrusively beneath a physician's monitor). This has two main advantages: 1) The physicians perform the routine without needing to execute additional tasks and 2) the presence of a researcher in the examination room is not required, since this may hinder the natural interaction among physicians or between the patient and the physician. The collected data should reflect the actions taken by a specific physician while executing a specific instantiation of the clinical routine (i.e. it should describe the routine's performative qualities).

Stage 5: Identify affordances and constraints. This stage seeks to identify the UI elements (i.e. materiality) that afford and constrain distinct physicians in performing goal-oriented actions. The first task in this stage is to define and operationalize an outcome to evaluate a physician's routine execution (i.e. the routine's performative qualities). The second task in this stage is the assessment of physicians' de facto executions of the selected routine. This is done by analyzing the data collected in stage 4 and by quantifying the deviation of the routine execution to the outcome defined in the previous task. The objective assessment of routine performances allows one to understand the physicians' ability to interpret and perceive affordances designed into the EHR system.

5 Demonstration: The Patient Case Presentation Routine

To demonstrate the use of the developed artifact, we implemented our framework in a field study at the Eye Clinic at the Cantonal Hospital Lucerne, Switzerland. Our objective was to assess the Eye Clinic Manager (ECM), an EHR system that supports all relevant clinical routines in ophthalmology, exchanges data with medical devices and other hospital systems, and is fully integrated into the Eye Clinic's daily clinical practices. All health records at the Eye Clinic are digitized and stored in ECM's centralized database. ECM offers a standardized way to efficiently execute routines. However, ECM also offers some flexibility, because the physicians can use different UI elements to perform the same task. For instance, the history of a patient's medical consultations is accessible via a visual timeline and via a simple document list with a search function.

Stage 1: Select a representative clinical routine. In the selected clinical routine, physicians must present a patient case to a senior physician, who will take a management decision on the case. The patient case presentation is a very common clinical routine and was familiar to all the Eye Clinic's physicians. The routine was purposefully selected, because it strongly relies on ECM's system functions. Physicians must use a significant number of different UI elements, since they must look up various medical information in a patient's health records (e.g. patient information and medical consultations) to present the case.

Stage 2: Define an activity pattern and its representation in the EHR system. A senior physician working at the Eye Clinic defined the sequence of activities for the presentation of the patient cases that reflects the typical way of working. We used a simple flowchart to represent the activity pattern. For each activity, the senior physician, who was actively involved in ECM's design defined the UI elements that represent the activity (see Figure 1). Thus, he described the ideal form to execute the routine. Table 2 lists all the involved UI elements and provides a general description of each element. Figure 2 provides a screenshot of ECM's main screen. The codes in Figure 2 refer to the UI elements listed in Table 2.

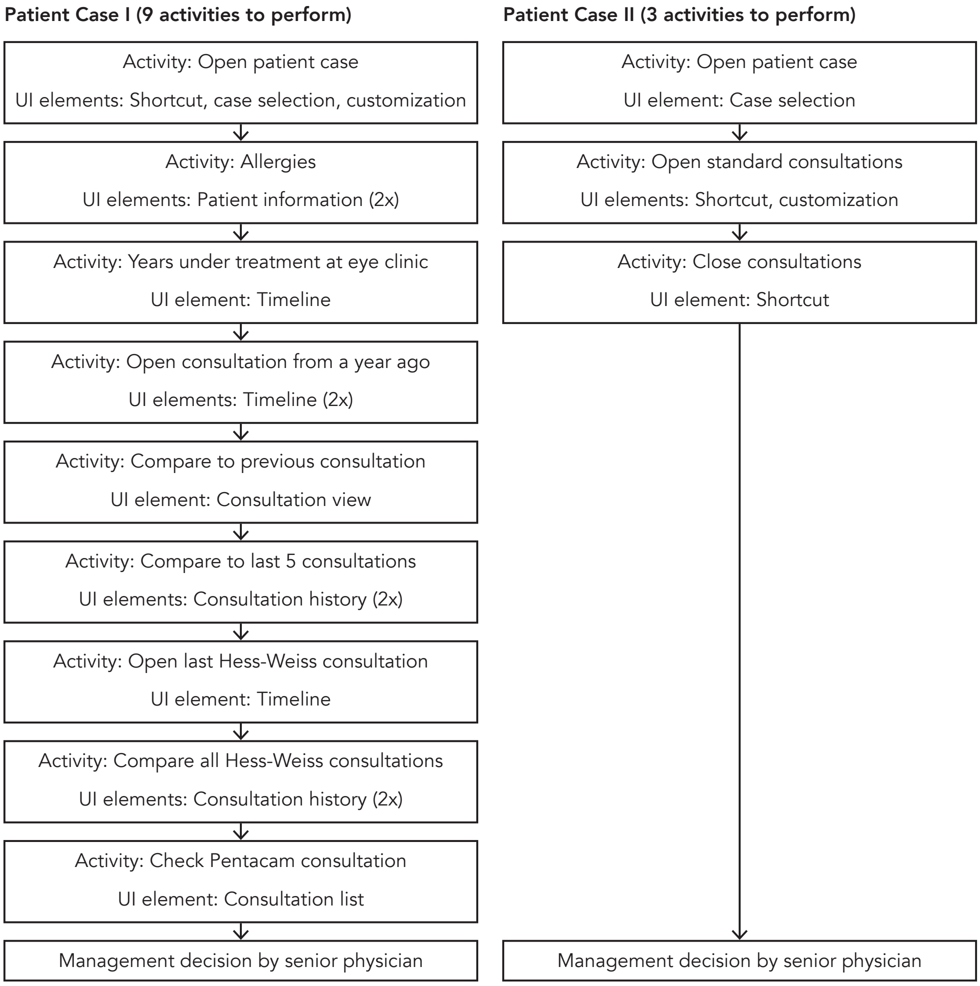

Figure 1. Sequence of activities and their representation in ECM

Stage 3: Prepare to collect data on routine execution. Our field study involved 10 physicians. To ensure independent and reliable results, no incentives were offered for participation. Each physician provided written informed consent about study participation. Participants were between 26 and 32 years old, and had maximum four years' experience in ophthalmology. Some participants were very recent users (i.e. less than three months) of ECM. All participants use the ECM in daily clinical practice, and the presentation of patient cases was a very common routine to all the participating physicians. We selected junior physicians for our field study, because they represent the largest population of physicians at the Eye Clinic and they are the ones working with ECM the most (e.g. to document and present patient cases). Each of the 10 participant physicians had to present two real-world patient cases to a senior physician. We ensured that none of the participating physicians was familiar with the cases, so that no physician had advanced knowledge.

Stage 4: Track the routine execution in a naturalistic setting. To understand the physicians' ways of performing the selected routine, we collected data while the physicians presented two patient cases to the senior physician. The senior physician would interrupt by asking clearly defined questions about the case, thus provoking actions on the system. For instance, he would ask a physician about a patient's allergies, and the physician would look them up. While the physicians executed the routines, we recorded the screen and all the mouse activities via Morae Recorder, Version 3.3.4 (TechSmith Corporation, US). Further, we used the myGaze eye-tracker (Visual Interaction, Germany) to record where a participant is looking on the screen. The eye-tracker was mounted unobtrusively beneath the monitor of the physician's desktop computer. To ensure accuracy in eye-tracking data collection, the physicians' eyes were calibrated prior to the execution of the routines. Once this was set up, the patient case presentations could take place in a natural environment. After completing the two case presentations, every participant replied to a structured questionnaire that asked about possible external factors influencing the performance on the EHR system. Specifically, the questionnaire inquired physicians' experience (2 question items), working style (3 items), interest in IT (2 items), and ECM usability rating (2 items). Each question item had response options on a four-point Likert scale (from 1 = strongly disagree to 4 = strongly agree).

Stage 5: Identify affordances and constraints. To empirically assess the actions taken by the 10 physicians during routine execution, we analyzed the activities performed in the patient case presentation routine. Each physician performed 12 activities over the two routines (see Figure 1). Overall, we assessed 120 activities. Given that an UI element was represented at least in one activity and that 10 physicians participated in our field study, each UI element was involved at least 10 times in routine execution (see possible score in Table 3). We compared each participant's actions taken on the EHR system, i.e. the UI elements used, to the ideal routine execution as defined by the senior physician (see Figure 1). We assessed the physicians' performances as follows: A point of 1 was attributed to the UI element in each activity, if the physician executed the routine as suggested by the senior physician (0 otherwise), i.e. the participant used the UI element that the system designer wanted them to use to perform the activity (see score in Table 3). This score represents the conformance with the ideal routine execution. We also noted whether a physician relied on an alternative UI element to perform the routine and attributed a point of 1 to this alternative UI element if the medical outcome was correct (see alternative elements in Table 3). To analyze the screen recordings and the eye-tracker data, we manually coded the screen recordings using Morae Manager, Version 3.3.4 (TechSmith Corporation, U.S.).

UI element	Code	Description
Shortcut	UI-A	Provides an accelerated way of doing or achieving something. Shortcuts are typically accessible via function keys (e.g. F2) or via icons on the top navigation bar.
Case selection	UI-B	Possibility to access a patient case via search fields (e.g. patient ID, family name, and date of birth), which are available in a structured form. There is also a list of the recently accessed patient cases. In ECM, there is an additional possibility to open a patient case by activating the patient ID input field (e.g. via mouse-click) and using a barcode scanner connected to the system.
Patient information	UI-C	Provides structured information about a patient case, including personal data (e.g. address and insurance number) and basic medical information (e.g. allergies).
Timeline	UI-D	Provides a graphical history of a patient's health records (e.g. referral letters from their general practitioner and medical consultations), ordered by date. The granularity of a timeline might differ, and health records can be grouped by year or month.
Consultation view	UI-E	Provides basic functions related to a single document describing the outcomes of a medical consultation. The consultation view offers the possibility to navigate to related documents, to print a document, and to close the current document. These functions are typically accessible via icons combined with text explanations.
Consultation history	UI-F	Visualizes the entire history of consultations related to a specific medical examination and shows how the patient's results have evolved over time. Depending on the medical examination, the history is represented with numbers, written text, and/or graphical illustrations.
Customize system	UI-G	Offers the physicians the possibility to create their custom view. For instance, the Eye Clinic has several subspecialties (e.g. retina and glaucoma), each with their custom view on a patient's clinical data. The physicians would use such a predefined custom view when working in a specific subspecialty.
Consultation list	UI-H	Provides a list of all patient-related documents (e.g. referral letters from their general practitioner and medical consultations) that can be filtered via a search field.

Table 2. Overview of the user interface elements involved in the field study

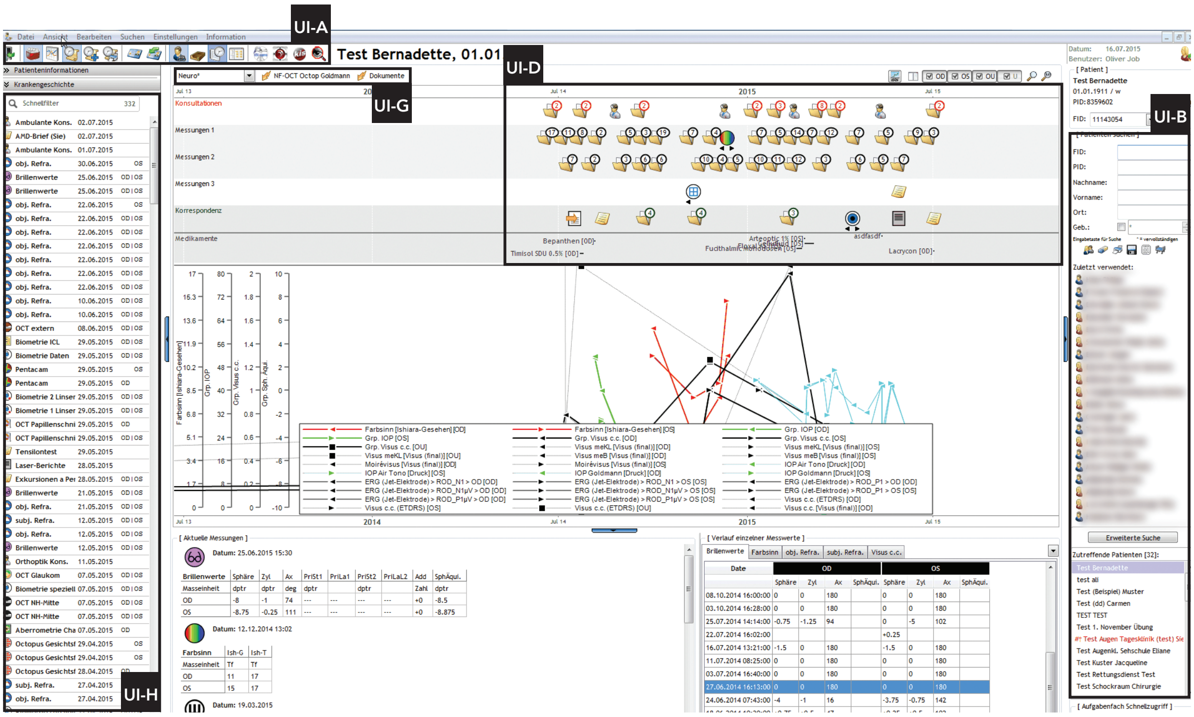

Figure 2. Main screen of ECM

Interestingly, the maximum score a physician reached was only 60% of the possible total score, and the physicians' average score was less than 40%, pointing at a relatively low conformance of actual routine execution to the 'ideal routine'. Physicians with a better score, i.e. physicians using more often the UI elements intended by the system designer, required less time to execute an activity. This is a strong indication that the way the system designer wanted a physician to execute the routine is the most efficient way. Compared to physicians with higher scores (≥ 40% correct), average performers (20% to 40% correct) had the higher number of clicks (1.23 additional mouse-clicks, 95% CI: 0.07 to 2.39, p = 0.040) to perform the activities. The number of clicks in the lowest performance group (< 20% correct) did not differ from those of the highest performance group (0.33 additional mouse-clicks, 95% CI: -0.93 to 1.60, p = 0.553). This can be explained because low performers were not aware how to execute certain activities in the EHR system and were hesitating to decide how to perform them. They would have relied on the senior physician's help to perform these activities. None of the factors gathered via the questionnaire (experience, working style, interest in IT, and usability rating) significant impacted on the physicians' performances.

Element code	UI-A	UI-B	UI-C	UI-D	UI-E	UI-F	UI-G	UI-H
Rank order	1	8	5	4	7	2	3	6
Possible score	30	20	20	40	10	40	20	10
Score (%)	1 (3%)	18 (90%)	14 (70%)	13 (33%)	8 (80%)	8 (20%)	4 (20%)	8 (80%)
Alternative elements (%)	UI-B: 9 (30%) UI-E: 8 (27%)	–	–	UI-H: 26 (65%)	UI-H: 1 (10%)	UI-H: 4 (10%) UI-E: 10 (25%)	UI-H: 8 (40%)	–
Score + alternative (%)	18 (60%)	18 (90%)	14 (70%)	39 (98%)	9 (90%)	22 (55%)	12 (60%)	8 (80%)
Error rate	40%	10%	30%	2%	10%	45%	40%	20%
Perceived as	C	A	A	C	A	C	C	A

Table 3. Results of the user interface elements: score, alternative element used, and classification as affordance (A) or constraint (C). For the element code, see Table 2

To understand the constraints, we wanted to identify the UI elements with a low score. These are the UI elements physicians did not perceive as an affordance when executing the routine. Participants used either an alternative UI element or would have required support from the senior physician to continue the routine execution. We ranked the UI elements involved in our field study based on the score (in %, how often physicians used the UI element as intended by the system designer divided by highest possible score); if the score for distinct UI elements was equal, we compared the score for alternative UI elements (see Table 3). The UI element with the lowest score was ranked first (i.e. the most constraining UI element) and the UI element with the highest score was ranked last (i.e. the UI element most often perceived as an affordance). We identified four UI elements with a score of less than 50% of the possible score: *shortcut (UI-A), consultation history (UI-F), customize system (UI-G)*, and *timeline (UI-D)* (see Table 3). We classified these UI elements as constraining. The participants often decided to use other UI elements than the one designed by the system designer to perform a given activity, even though our experiment illustrated that the alternative UI elements required more time and more clicks to perform the activity. For the UI element *timeline (UI-D)*, interestingly, in 65% of the cases, the physicians switched to the alternative UI element *consultation list (UI-H).* Even though the *timeline* takes a large portion of the main screen (see Figure 2), physicians rarely (33%) perceived the affordance this UI element would offer in performing an activity. The error rate in Table 3 represents two different situations. First, if a physician could not execute an activity, because she did not know how to use the EHR system, the senior physician provided support. In such a situation, we also did not count the number of mouse-clicks. Second, and very rarely, physicians used inappropriate UI elements, which led to wrong information in their case presentation.

Although a senior physician was actively involved in ECM's design, the physicians in our study did not perceive all the affordances designed into the EHR system. The fact that distinct physicians perceive different affordances when using the EHR system explains the variety in EHR system use we could observe in our study. Our framework allowed us to identify four constraining UI elements, which are now candidates for an intervention. We propose two intervention types: an educational intervention about EHR system use or a redesign of the constraining UI elements based on the learnings from this field study.

6 Discussion and Conclusion

While different studies in the medical literature (e.g. Hill et al., 2013; Schiff et al., 2015) have reported on serious shortcomings of EHR system use in routine patient care, research in IS continues to use traditional methods (e.g. the TAM and the IS Success Model) to quantify health IT's impacts (Abouzahra et al., 2015). However, this research has provided little in terms of actionable knowledge on how the address the identified problems in EHR system use. Our framework provides a new lens to empirically assess EHR system use through the concept of clinical routines, which represent the way work in hospital organizations is enacted. In his seminal paper on flexible routines and flexible technology, Leonardi (2011) argues that, with today's technologies, we have the choice to adapt the technology with which we work or to adapt our routine. While the perception of constraints leads people to change the technology, the perception of affordances leads them to change their routines. Our framework builds on this phenomenon and suggests a way to objectively assess EHR system use in clinical routines and to identify affordances and constraints. We demonstrated our framework's use in a field study and illustrated how it allowed us to identify the UI elements perceived as affordances and constraints by the physicians at the hospital. The actionable insights we gained by applying our approach in a real-world setting now provides a basis for recommendations for improving EHR system use in the Eye Clinic.

Depending on EHR system design, we see two extreme cases to increase performance (i.e. effectiveness and efficiency) in EHR system use: 1) In case of a rigid EHR system, the focus will be on assessing the extent to which a physician follows the implemented medical guidelines and to identify UI elements that constrain routine execution. If a specific UI element is designed into the EHR system to execute a specific activity at a specific time, we expect the physician to use this element to perform the activity. The physician, however, might not perceive the related affordance. If available, she would eventually use an alternative UI element (i.e. a workaround) to perform an activity. In the absence of alternatives, she would be blocked in executing the clinical routine. In a very standardized and rigid EHR system, such a physician might require formal training to adapt her routine to the inflexible technology. If repeated training does not lead to an improved perception of the affordances designed into an EHR system, the system designer would have done a bad job, given that it was her task to strategically design in affordances, so that they are ready to be perceived. Our framework allows one to identify these constraints, providing a list of specific UI elements that lack sound design. 2) In case the EHR system design is flexible (i.e. it supports a broad variety of ways of executing a routine and thus allows for adaptations to a physician's individual way of working), we propose a slightly different approach. From routine execution, we can now learn the extent to which a specific way of performing a routine is associated with full adherence to medical guidelines. If such medical guideline adherence is not fully reached, either the physician's way of performing the routine must be changed (e.g. through formal training) or the system designer must redesign the UI elements responsible for non-adherence. Alternatively, assuming that all physicians perfectly adhere to the medical guidelines, the most efficient ways to execute a routine can be studied. These insights may allow one to refine the operationalization of the medical guidelines in a hospital organization (i.e. a routine's ostensive qualities) or to train physicians how to perform better.

Recent studies (e.g. Kellermann and Jones, 2013; McDonnell et al., 2010) promote the active engagement of physicians during the development of an EHR system in order to ensure that the system meets the requirements of clinical practice. Our research has shown, however, that the involvement of physicians in the design process of an EHR system does not necessarily mean that other physicians will later perceive the affordances designed into the EHR system. The objective assessment of physicians' ways of executing routines are a necessity to understand which UI elements and system functions physicians perceive as affordances and which they perceive as constraints. Our empirical approach presented here supports this endeavor and helps practitioners to leverage EHR systems' true potential to assist the physicians' work. Our framework can be used when designing new systems and when assessing existing EHR system use in routine patient care. Multiple intervention and evaluation cycles might be required to achieve a satisficing interaction between a clinical routine and a technology.

As a follow-up study, we would like to investigate whether physicians start to perceive constraining UI elements as affordances after they received a formal training about EHR system use. After such a training session, we will repeat the field study by using our framework to verify whether physicians start using these UI elements. If physicians continue to ignore the constraining UI elements and no effect of training can be measured, it would be a strong indication of shortcomings in EHR system design. These insights would then call for a design science research approach (Hevner et al., 2004), in which researchers redesign the identified UI elements and evaluate the improved system design in an empirical study (i.e. learning through building). A design science research approach could then also lead to the formalization of design principles or a design theory of UI elements for satisficing EHR systems. From a conceptual perspective, we plan to develop our framework further to shift from (EHR system) use to *effective use*. The latter is a concept introduced by Burton-Jones and Grange (2012) and is described as using a system in a way that increases the achievement of the goals for using the system. The framework presented here can then be used as an objective assessment for the effective use of EHR systems in clinical routines.

Our study comes with limitations. Although, in our view, the framework presented in this paper is sufficiently generalizable, readers are cautioned to remember that we applied it only to one clinical routine using one EHR system. The assessment of another routine and other EHR systems might reveal further insights that would allow us to refine our framework. The routine in our field study required physicians to retrieve various information in a patient's health record. Alternatively, one could select a routine in which physicians must enter a variety of clinical data while examining a patient. We are also aware that EHR systems follow different design paradigms, which may impact affordances as well as constraints. We investigated a fairly rigid system that allowed only for some flexibility in routine execution. For instance, it did not learn from a physician's way of executing routines to adapt to her individual way of working. Further, our study participants were junior physicians. They include digital natives, who are not used to executing routines with the support of paper-based artifacts. However, we are confident that this study is an important step in improving EHR system use in hospitals, and that it provides a better understanding of the interactions between a technology and the physicians using it to provide patient care.

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