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KEEP UP WITH CARE: RESEARCHING SYSTEM ADAPTABILITY IN CHRONIC CARE MANAGEMENT OF ELDERLY PATIENTS

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Research in Progress

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Abstract

The demographic change in Europe is leading to an increasingly aging population, increasing also the number of aged patients in health care. Subsequently, treatment of chronic diseases as well as integrated care approaches become progressively more important. We report preliminary evidence from four case studies on implementation and deployment of adaptive case management (ACM) systems for integrated care in context of chronic care related services and management. Our analysis focuses on what causes adaptations to the system's initial model, and how the changes evolve over time. We identify several aspects of qualitative adaptations induced by clinical practice, including process parallelism, decision iteration, content fault tolerance, information presentation and combinative task variability. We also carry out a quantitative analysis of system changes. These changes comprise adaptations of different scope, which we categorize as in-structure, in-object and in-content changes. Our preliminary evidence and analysis indicate that ACM health information systems design must be able to accommodate particular types of changes triggered by the clinical context.

Keywords: Adaptive case management, implementation of health information systems, integrated care, information systems adaptation.

1 Introduction

Integrated care is a topic of great current interest to health IS researchers as well as practitioners, particularly regarding service provision to elderly patients with chronical diseases (Bui et al., 2018; Nielsen et al., 2014; Zonneveld et al., 2018). Previous research has focused on topics such as integration of service providers (Ahgren et al., 2009), continuity in assistance (Anderson and Robey, 2017), or patient-centric information management (Pinsonneault et al., 2017) and has emphasized the importance of an included and empowered patient (Romanow et al., 2011; 2012). Despite the insights gained about the procedural aspects of doctors' and therapists' interactions with the patient, health information systems (HIS) that allow to effectively individualize patient care remain a challenge.

Among the reasons for this state of play are "technical… and organizational impediments that need to be overcome" when HIS and services require to become integrated and interoperable (Lucas et al., 2013). Particularly, the handling of "complexity in redesign, as well as ongoing learning requirements" (Aanestad and Jensen, 2016) during the design and deployment phases proves difficult.

Adaptive case management (ACM) systems provide an approach to overcome these challenges as they allow adapting processes at run-time (White, 2009). While in recent years ACM systems have found their way into health care practice, we lack knowledge and experience about their deployment and related adaptations in-use (Vargiu et al., 2017; Michel and Matthes, 2018; Michel et al., 2018).

In our research, we address this gap by studying "design, implementation and meaningful use" (Agarwal et al., 2010) of an ACM HIS prototype in context of treatment of chronic diseases with elderly patients. We follow an action design research approach for generating prescriptive design knowledge while implementing and evaluating the prototype (Sein et al., 2011). Four case studies of hospitals that have been testing the system provide insights on the system adaptation process. We study what type of adaptations occur during implementation and what causes them. In addition, we investigate the scope and progress of adaptations until a reasonable service level is achieved.

This report provides early evidence on the adaptation process and draws preliminary conclusions for system design. Our evidence indicates that ACM HIS design must be able to *accommodate particular types of changes triggered by the clinical context*. We see this as a first step towards generating broader insights, to inform the design and implementation success of ACM HIS, to allow projecting the implementation efforts required in clinical settings, and to enlighten and strengthen the potential benefits of integrated care management.

In the following, we introduce the context of HIS for chronic care management and the adaptive case management approach (section 2), outline our research method and case studies (section 3) and provide details on our analysis (section 4). After some remarks on limitations and future work, we end with a short conclusion (section 5).

2 Related Literature

2.1 Health information systems for chronic care management

The demographic change in Europe is leading to an increasingly aging population, increasing also the number of aged patients in health care. Subsequently, treatment of chronic diseases as well as integrated care approaches become progressively more important (WHO, 2015). Hence, health information systems (HIS) for chronic care management become a substantial necessity in contemporary care (Van der Klauw et al., 2014). Integrated care focuses on the organizational and information system arrangements towards better coordinated and integrated forms of care provision (Zonneveld et al., 2018).

Integrated care proves to be particularly important in service provision to elderly patients with chronical diseases. This patient group has special needs with regard to continuous health monitoring, managing co-morbidities, scheduling regular control examinations and check-ups, receiving service support remotely (at home), and other processes. Apart from the patient, this context involves large health care providers such as hospitals, medical service providers as e.g., in home care, health professionals such as clinicians, nurses, medical doctors as well as other service providers (Payton and Brennan, 1999; Ragbupathi and Tan, 2002; Ahgren et al., 2009). These need to coordinate and communicate across sites and activities in order to achieve continuity in care (Anderson and Robey, 2017). *Continuity* is essential to assure consistent and coherent information about the patient and his or her medical history, therapeutic progress, medication monitoring or biotelemetry, i.e., when continuously monitoring vital parameters. This involves sharing, or shared access to, electronic health records (EHR) as well as patient generated health data (PGHD) and eventually communication capabilities adjusted to the care context, e.g. for telemetry data collection or virtual consultations. HIS in this respect need to offer *data integration as well as workflow coordination capabilities*, e.g., for managing clinical and therapeutic paths. Regarding health care outcomes, continuity is vital for ensuring a trusting relationship between patient, attending doctors and therapists and service provision professionals (Kelley et al., 2014).

Earlier studies have asserted a slow pace of progression and the limited impact medical informatics and health information technology (HIT) have had in general on *day-to-day patient care* (Cantrill, 2010). In fact, HIT adoption has at times met with substantial resistance by doctors and patients (Lapointe and Rivard, 2005; Bhattacherjee and Hikmet, 2007; Davidson et al., 2018). Studies that have looked at improved interpersonal care, customer satisfaction, customer loyalty, patient mortality and reduced emergency room (ER) waiting times have not found conclusive evidence for a relationship between HIT adoption and use, and critical (patient) health outcomes (Bui et al., 2018). Hence, collective approaches were claimed for that bring together care stakeholders in order to provide an *integrated personal health information management* (Pratt et al., 2006; Nielsen et al., 2014; Bui et al., 2018). Suggestions for viable mechanisms to improve successful deployment of HIS include using standards, encouraging learning and adaptation mechanisms in care practices, becoming patient-centric, and improving value-oriented measurement of HITs clinical impacts (Thompson and Dean, 2009; Romanow et al., 2012; Bui et al., 2018). Extant research has also shown the core role that medical doctors play in adopting and leveraging HIS across involved user groups (Venkatesh et al., 2011).

Research on HIS has emphasized the positive effect of integrated HIS for patient-centric information management, e.g., by providing more complete information to health providers, allowing them to *better manage patients' cases and raise the quality of care* (Lucas et al., 2013; Pinsonneault et al., 2017; Davidson et al., 2018). Decisions about clinical paths can benefit from error reduction when automating care delivery processes (Aron et al., 2011). Also *patients themselves are empowered* when provided with information appropriately to their individual clinical context, for instance for becoming better aware about their condition or for adopting self-care practices, which can lead to improved therapeutic success (Hamburg and Collins, 2010; Kelley et al., 2011). Integrated systems are a basis for *clinical decision-making*, e.g., to facilitate preventive and personalized care with data analytics (Lin et al., 2017) or "to predict the propensity, frequency and timing of readmissions of patients" (Bardhan et al., 2014; quoted from Davidson et al., 2018).

2.2 Adaptive case management and clinical practice

Software engineering and business process management literature discuss process adaptations under the term *case management*, defining two categories of workflow management application systems (Van der Aalst et al., 2005; Reichert and Reijers, 2016). Production case management (PCM) refers to processes that are defined by software engineers at design-time and principally remain stable while serving for a particular domain or problem (Swenson, 2012). Adaptive case management (ACM) on the contrary refers to situations "where the path of execution cannot be predetermined in advance of execution; where human judgment is required to determine how the end goal can be achieved; and where the state of a case can be altered by external out-of-band events" (White, 2009).

ACM includes knowledge workers into system adaptations at run-time (Hauder et al., 2014). This system capability to adapt processes at run-time enables a quicker response to organizational or routine changes, to master unpredictable situations in processes, facilitating continuous service provision as well as learning effects (Swenson, 2010; Marin et al., 2016). However, this requires systems to provide appropriate execution environments that enable knowledge workers without programming and modelling expertise to modify processes on their own during run-time (Marin et al., 2016). Consequently, respective design requirements for execution environments have been defined along classifications such as data integration, knowledge worker empowerment, authorization and role management, knowledge storage and extraction, and more formal definitions of adaptability, routines and further factors (Hauder et al., 2014).

Research on HIT adoption has emphasized that "organizational differences… may be particularly salient in the healthcare setting" (Avgar et al., 2018) while the need for integrating process stakeholders and variations in work practices seem to be "especially pronounced" (Avgar et al., 2018; Hitt and Tambe, 2016). With regard to clinical practice, particularly in context of care for chronic diseases, ACM thus becomes increasingly relevant to configure care processes' fit to the individual patient (Agarwal et al., 2010; Fichman et al., 2011; Lin et al., 2017). This comprises tasks such as "prevention and detection of acute events through continuous monitoring and assessment; patient… behaviour modification…; specialized treatment plans coordinated by disease experts; and preserved continuity of care across diverse patient care settings" (Ouwens et al., 2005; Ferguson and Weinberger, 1998).

Previous research in integrated care contexts has identified *limitations of current ACM HIS* capabilities such as "…lack of contextualization and poor dynamic adaptation to changes" and request "(ad-hoc) modifications to (process models) implemented in the process of (HIS) development" (Cano et al., 2015). Current recommendations for ACM implementation focused on chronic care management suggest *treatment templates* that include steps such as case identification; case evaluation/patient characterization; personalized work plan definition/execution/follow-up; event handling; and discharge (Cano et al., 2017; Swenson, 2010). Extant design-oriented research on ACM HIS has provided insights about *system architectures* to support clinical case integration across the diversity met between hospital settings; communication and data synchronization issues across systems; and stakeholder coordination (Michel et al., 2018; Michel and Matthes, 2018). However, we still lack evidence on ACM HIS adoption and use in practice that informs research on how to design ACM HIS *to be extendable* in terms of functionality or app integration, and *to what extent* such systems must be extendable to allow serving the majority of use cases.

3 Research Method

Our research intends to provide insights into the implementation and deployment process of ACM HIS in integrated care for informing both research and practice (Avison et al., 1999; Hevner et al., 2004; Sein et al., 2011). We are particularly interested in *what type of adaptations* occur during implementation and *what causes them*. In addition, we investigate the *scope and progress of adaptations* until a reasonable service level is achieved. We target a better understanding of the adaptation process in order to inform design research on ACM HIS, and to contribute arguments for improving ACM HIS implementation processes in practice (Sherer, 2014).

This is why we position our work as *action design research (ADR),* which allows generating prescriptive design knowledge while implementing and evaluating our ACM HIS prototype in distinct organizational settings (Sein et al., 2011). In particular, this report focuses on the 'Building, Intervention and Evaluation' (BIE) stage of ADR in its organization-dominant form, as we have been developing, testing and re-configuring the system's core element, the conceptual case model (see section 4), in direct interaction with the end-users in case studies. Hence, regarding the ADR research cycle our case studies can be positioned in a 'beta' cycle of the BIE stage that includes operational system use. However, in this research-in-progress report we do not address the theoretic, reflection and formalization aspects of the ADR research cycle.

We have carried out four case studies with three hospitals in different European countries, located in The Netherlands, Israel, and Spain. For their integrated care management in context of treatment of chronic diseases with elderly patients (older than 65 years), each of the hospitals had distinct boundary requirements in terms of offered services, third parties to be involved to therapeutic processes, boundary conditions for documentation and process flow, and further factors. Nevertheless, major building blocks of the services were identical due to the principally comparable medical treatments and procedures. Thus, this setting provided us with a set of similar, typical cases while allowing for observing and comparing case-specific adaptations (Schacht et al., 2015).

Each hospital was provided with access to our ACM HIS prototype that allows to connect stakeholders, coordinate and adapt clinical paths and to integrate health data. The prototype offers two key system modules; the Smart Adaptive Case Management (SACM) used by clinical professionals to enter patient data; and the Self-Management System (SMS) used by the patient to accomplish the prescriptions of the professionals. SACM rests on an ACM engine that orchestrates SMS services and that follows the reference architecture for model-based collaborative information systems (Hernandez-Mendez et al., 2018), aligning also with the ACM principles as illustrated by Swenson (2011).

Implementation of the ACM HIS prototype started in 2015 and will be concluded end of 2019. The system has been used in operative processes and facilitated adaptive case management, i.e. the capability to adapt procedures at (model) run-time according to the individual patient's needs. As each hospital has individual requirements, each tenant needed to be modelled according to the needs of the local clinical partners in a continuously ongoing modelling process. Five persons have been involved into these modelling processes as expert modellers, or facilitators. They interact with clinical staff in their practice settings for diagnosing, action planning and taking, evaluating and re-specifying the case models, iteratively leading to improved, i.e., better aligned, process support. They also support medical doctors in understanding the system, identifying lacking functionality or process inflexibilities and further factors. While primarily, the medical doctors are initiating system adaptation, the facilitator role permits to minimize the time medical personnel has to spend on system adaptation activities.

The implementation process in all cases started with an initial conceptual case model of major process fragments. During the deployment of the system, adaptations to this initial model needed to be accomplished, leading to varied resulting models in each case. As the research team followed the projects, they looked at what causes adaptations and how the changes evolve over time. To this end, they collected evidence on the qualitative changes that occurred over a three years period, in form of notes from interviews, project reports and software documentations.

During a ten-month period, we also collected and aggregated quantitative log data about system model elements, system use and configurations that help interpreting the scope of changes and comparing the different resulting system configurations at the end of the data collection period. Model adaptations are modelled through analysis of the XML schemas that define case models. Such schemas are imported into the SACM to be executable. The history (versions) of XML schemas are managed in a repository that allows tracking changes including meta-data such as modification date and editor. To enable model changes at system run-time, the modeller performs modification on the XML file according to the clinician's requests, and after a testing cycle including automated tests and user feedback in a test environment, *commits*, i.e., imports the new file to the SACM's productive environment.

4 Analysis and Findings of the Research-in-Progress

In this section we provide evidence from qualitative and quantitative case study data. Upfront to ACM system implementation, the research team carried out an initial business process analysis to specify requirements for the integrated care services and processes to be covered, which led to definition of one basic initial conceptual model shared by all three hospitals. This model contained (a) stages, i.e., major process fragments as "building blocks" of the treatment process (case identification, case evaluation, workplan, and discharge), (b) tasks to be accomplished within these stages, and (c) sentries, i.e., defined prerequisites as conditions to progress between tasks and stages. Figure 1 provides a sample model from one of the case studies in CMMN notation (OMG, 2016; Marin et al., 2016).

In the first stage, *case identification*, patient criteria are collected and reviewed such as, the patient (a) is older than 65 years, (b) can use a smartphone, (c) is scheduled for a high-risk surgery defined as interactive surgery lasting more than 180 minutes, and (d) signed a written informed consent according to local regulations. The second stage, *case evaluation*, contains several tests and questionnaires that provide the compulsory summary of the patient’s health status. Depending on the case evaluation outcomes, the responsible clinician creates an individual patient-centred *workplan* (third stage). The patient performs the therapeutic or medication tasks as described by the customized work plan, and documents them through a mobile application via smartphone. Workplan tasks comprise, e.g., answering patient questionnaires, physical activities such as walking a minimum of 10,000 steps a day, or monitoring prescriptions such as measuring blood pressure every morning and evening. In the fourth and final stage, the patient is *discharged*.

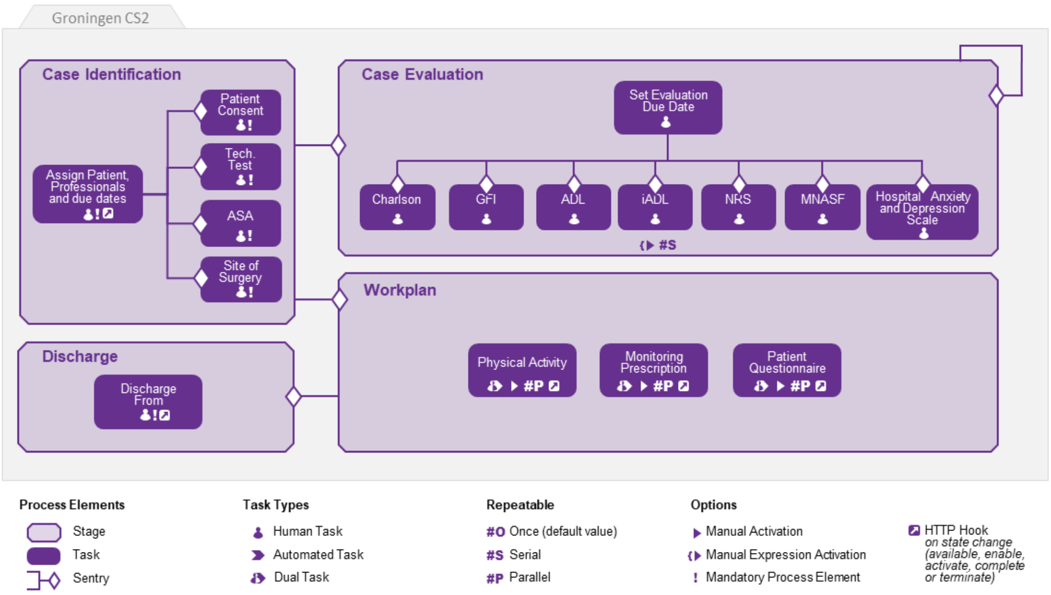

Figure 1: Conceptual case model (sample from case study “Groningen”)

During the system implementation and deployment phase, various adaptations of the system took place. Across all four cases we could identify several key factors as triggers of changes, which each provided for particular reasons for change, and varied scope of changes: (1) *Usage-induced adaptations* involve iterative improvements such as adding detail descriptions for task parameters; (2) *Practice-induced adaptations* stem from clinical practice (including those at other case study hospitals) and might consist in removing a sentry definition to enable simultaneous work on two stages or changing default values etc., and (3) *Feature-induced adaptations* are triggered by availability of new system features or apps, such as adaptive visualization features to improve user interface usability.

With regard to *practice-induced adaptations*, as we have experienced throughout the case studies, the execution of chronic care management as a knowledge-intensive process heavily depends on the assessments and decisions of doctors, on continuity of the doctor-patient relationship, and on the adequate inclusion of patient’s performance data. These aspects led to several qualitative changes to the initial model; these comprise process parallelism, decision iteration, content fault tolerance, information presentation and combinative task variability.

Process parallelism. During conversations with clinical staff, we noticed that repeatedly, users could not proceed in the process due to uncompleted tasks. The stage/task conceptual model implied a certain process logic in the sense that tasks have to be “completed” before the process continues, i.e., content is completed and a decision is taken, to proceed in the overall process. In clinical reality, this is often not possible, or not considered a prerequisite. On the contrary, doctors may decide to continue with technically incomplete information and decisions, leaving tasks unattended—until later action—while the process continues. This opens space for complexity in actual process sequences, which compromises common workflow coordination rules and notations.

Decision iteration. We noticed regular re-evaluations iterating between stages that involved sets of tasks with a dynamic interrelation. Case evaluations principally serve as one-time input to defining the treatment approach; however they can be recurrently carried out (creating multiple evaluation instances) as afforded by therapeutic progress and changing patient conditions so that the treatment plan in the workplan stage can be dynamically adapted. This introduces cyclic decision sequences into the case model that acknowledge the cases' knowledge-intensive characteristics and give way for case progression on basis of doctors' decisions; this required redefinition of sentries in the model.

Content fault tolerance. On several occasions, wrongly answered tasks required correction even after task or process completion. This formed a generic phenomenon in that certain enveloping degrees of freedom are assumed around the information presented at hand, which might require change later on.

Information presentation. Clinicians are often under enormous time pressure. Therefore it is important to screen the critical parameters of a patient quickly. This requirement led to a new modelling element that allows for automatically creating structured summary pages based on the data of accomplished tasks. The summary page shows individual scores as well as a body representation visual. Further changes involved introducing adaptive colouring of numeric values according to certain thresholds for user interfaces that required clarity to improve clinicians' recognition of critical values. Thus, time criticality triggered a revision of information representation on several occasions.

Combinative task variability. The model notation originally comprised two types of tasks, manual tasks to be accomplished by a human user, and automated tasks that call existing functions. To simplify modelling of tasks including data from the patient's smartphone app, a new task model element was introduced, which allowed the clinician to specify parameters for the automated task following manual inputs. Within such 'dual tasks,' the clinician can define several parameters, e.g., questions for the patient questionnaire, start/end dates, time of day for questionnaire completion and further parameters.

These qualitative, practice-induced adaptations allow absorbing process uncertainties or deficiencies and improve continuous service provision. Regarding the scope of change across the three types of adaptions, while practice and feature-induced adaptations primarily involve alterations to the *model structure*, usage-induced adaptions primarily consist in *modifications of model elements*.

For post-deployment quantitative analysis of model adaptations we collected all versions of XML files containing model definition schemas (see section 3). Those files allow to calculate changes produced through commits with help of indicators; the research team defined 181 such indicators and three categories to analyse the commits. In addition, related meta-data such as commit message, date and author were analysed. From 612 commits across the four case studies, 538 could be parsed and used for further analysis. The classification categories refer to the *scope of changes*, defining changes (a) *in-structure*, e.g., adding or removing workflow elements, (b) *in-object*, e.g., changing task parameters, and (c) *in-content*, e.g., changing object labels. Every commit was labelled with exactly one classification category; if it matches criteria (a) the label is assigned, if not, the next criteria is checked and so on. As the commits contain various code changes that do not *naturally* belong to any of the above categories, we use a perspective following fuzzy set theory (Zadeh, 1965, Halpern, 2003) to interpret our data: Practice-induced adaptations chiefly correspond to changes in-structure but to some extend also in-object; new features might trigger changes across all three categories; usage-induced changes chiefly refer to in-content changes but in rare cases can extent to in-object and in-structure sections.

Figure 2 illustrates the evolution of commits in each case study, displaying data from only one of several clinical case trials; the vertical, dotted grey lines indicate model deployment into the productive environment, i.e. for clinical use ("release"). The analysis of curve progressions allows some conclusions about how adaptations evolve. The number of commits with practice-induced changes remained relatively low, and the majority of these adaptions could be accomplished during the implementation phase before deployment. This implies that facilitators grouped sets of structural changes before deployment (in graph (2), the facilitator deviates from that). Usage-induced changes were the largest group of changes; these generally took place *after* structural changes had been carried out. This seems plausible because new process "settings," i.e., flows or rules, need to be appropriated in-use and lead to further adaptation requirements. In-content changes progressed continuously, but reappeared also during deployment phases, indicating that user adoption regularly led to "smaller" revision requests.

Apart from such general patterns, the curves also reveal a correspondence between the case context and model adaptations. The initial model in case (2) for instance had to be particularly scrutinized and adapted to case boundary conditions (in contrast to the other cases), so that in-structure changes step up during an intensive project phase (February 2018). Across all cases, step-wise groups of commits are executed periodically, in between reaching plateaus of enactment before further adaptations.

Limitations and Outlook. Our case study approach limits the representativeness of our preliminary insights particularly to the applied system architecture and clinical setting. Reasoning about adaptation dynamics of ACM HIS implementation/deployment in integrated care contexts needs to acknowledge the high number of deployed changes as exemplified by >500 commits involving thousands of model changes in our four case studies only. Our current analysis and suggested categorization thus represent only a first step towards dealing with uncertainties in analysing adaptations. Principally, ACM HIS adaptation comprises changes in two dimensions. *System* changes can occur during *system* design-time, run-time, or feature processing. Model changes occur during system run-time, including *model* design-time or run-time changes. Our current analysis focused *model design-time changes and their reasons*. These can inform other researchers when analysing larger data sets about *run-time changes*, particularly with respect to individual, patient-centred treatment plans. In addition, acknowledging the role of external services such as communication and notification features might influence run-time adaptations beyond our analytic scope reported here.

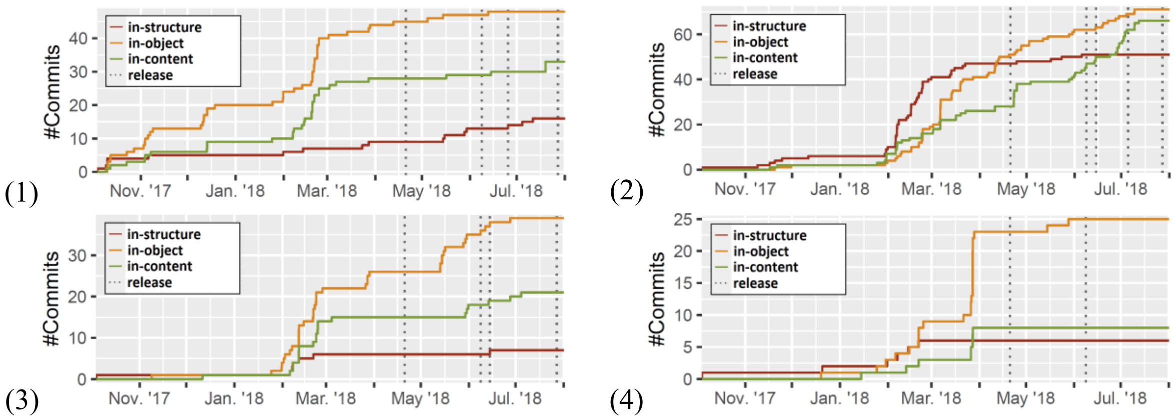

Figure 2: Analysis of commits across four case studies (1-4)

5 Conclusion

We report preliminary evidence from an action design research project involving four case studies of hospitals that implemented and deployed an ACM HIS for integrated care in context of chronic care services and management. Our analysis focuses on what causes adaptations to the system's initial model, and how adaptations to the model evolve over time. We identify several qualitative adaptations induced by clinical practice, including process parallelism, decision iteration, content fault tolerance, information presentation and combinative task variability. We also carry out a quantitative analysis of model changes that mirror immanent requirements emerging from clinical practice. To our interpretation, this indicates that ACM HIS design must be able to accommodate particular types of changes triggered by the clinical context; and we consequently suggest a categorization of changes as in-structure, in-object and in-content changes. Further research is required towards projecting implementation efforts required in clinical settings in relation to ACM HIS functionality and design.

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