UNDERSTANDING RESILIENCE AND EVOLUTION OF IOIS IN THE AUSTRALIAN PHARMACEUTICAL DISTRIBUTION INDUSTRY

Completed Research Paper

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Abstract

We analyse an empirical case study of an inter-organizational information system (IOIS) in the Australian pharmaceutical distribution industry, using a theoretical data coding approach, to provide a concise grounded account of changes in the material, normative and ideational structures within the participating practices over a 25 year period as the IOIS evolved from a proprietary closed system to a quasi-open shared ordering platform. We find evidence that the resilience of the IOIS over this long time period is explained by a layered accumulation of new structures at the level of individual practices, while the punctuated evolutionary change accompanied the appearance of a new practice, historically connected to the incumbent practices. These findings are in substantial agreement with systems evolution mechanisms proposed by Porra (1999). Understanding IOIS evolution will be important for the provision of key enabling information infrastructures envisioned in existing and planned ICT-mediated healthcare initiatives.

Keywords: Inter-organisational information systems, systems evolution, healthcare industry, distribution systems

Introduction

In the pharmaceutical distribution industry, as in many other sectors of healthcare, inter-organisational information systems (IOIS) that link diverse stake-holder organisations are widely regarded as key elements in the expected transformation of the industry to face changing demographics, increasing service expectations, increasing labour cost and the threat of fraud. These systems now have a five decade history and there exists a remarkable diversity in the forms these systems have taken in various countries (particularly in the extent of standardisation), and in the trajectories along which these systems have evolved over this period in response to local environmental changes. In the quest to make a reality of the e-health concept of widely used, open information infrastructures, it is important to understand the dynamics of this evolution so the appropriate policy settings might be devised.

However, at this time very little research attention has been paid to understanding evolution of IOIS over such long timescales. This is partly because the IOIS literature has inherited the traditional IS interest in adoption and implementation of systems at the timescale of particular projects (Robey et al., 2008). Evolution of IOIS on longer timescales presents two new phenomena that cannot be explained using traditional theories of adoption and implementation. Firstly, IOIS, once in existence, display a surprising degree of resilience. For example, computerized reservation systems in the airline industry in use today date back to the early 1960s (Copeland and McKenney, 1988; Farhoomand, 2000); efforts to replace long-established EDI-systems by newer -- and supposedly cheaper -- XML-based systems have proved surprisingly difficult (Wareham et al., 2005). Secondly, in seeming contradiction with this ability of IOIS to maintain their identity over long time periods, they also frequently display an ability to evolve. For instance the IOIS that we study in this paper evolved from a proprietary closed system to a quasi-open common ordering platform in roughly 25 years. As yet there is little empirically grounded theory to account for the simultaneous resilience of IOIS and their ability to evolve.

The research question addressed in this paper, therefore, is: How do IOIS evolve? More specifically, we ask:

- How do IOIS change while maintaining their identity?
- How is change coordinated across multiple organizations?

These sub-questions specify our research question by directing attention to two pertinent issues concerning evolving systems. First, system change might be accompanied by loss of identity in which case it would not be meaningful to speak of system evolution. Second, IOIS are distributed information systems in the sense of involving multiple organizations without a centralized governance structure. Thus, understanding IOIS change requires an understanding of how the several parts of the system residing in separate organizations maintain their alignment so as to continue functioning as a system.

Understanding IOIS evolution would not only satisfy academic curiosity but also be of practical relevance as, increasingly, efforts to develop and implement new IOIS take place in a context characterized by the existence of an "installed base" (Hanseth, 2000) of evolved IOIS that were initiated long ago. Thus, implementation of IOIS increasingly resembles adaptation of existing systems, that is, efforts to purposefully shape the evolution of IOIS. By understanding the processes by which existing IOIS reject certain external perturbations (including some deliberate change initiatives) and the condition under which they might also evolve in desired directions, we might eventually be able to make evidence-based recommendations for appropriate industry and government policy.

We draw on the results of an international comparative study to address our research question. Specifically, we present and analyse empirical data from the case of drug distribution in the Australian pharmaceutical industry. To perform this analysis we make use of our own model which views IOIS as a constellation of aligned practices each of which can be characterized by three dimensions of structural reproduction. This allows us to perform a theoretical coding of our interview data and describe the events and large-scale changes in the use of IOIS in the industry over a period from the early 1980s to the end of 2007, in terms of these structural dimensions in the participating communities of practice. Using the findings from this data analysis we can make empirical statements about the evolutionary trajectory of this IOIS, and in particular, test the plausibility of a mechanism of evolutionary change in information systems proposed by Porra (1999). Our conclusion from this analysis is that IOIS evolve as the totality of structure reproduced in connected practices changes and as new practices emerge; we also draw some tentative conclusions regarding the alignment mechanism required for IOIS to persist over time.

We set out by examining the small literature on IOIS evolution from which we will conclude that the evolutionary model presented by Porra (1999) provides an interesting candidate explanation for both the resilience of IOIS and their ability to evolve. Next we introduce a summary of our practice-based framework for describing IOIS, which we use to code our empirical data. The model has been presented in more detail elsewhere (Reimers and Johnston, 2008a; Reimers et al., 2010). Subsequently we present and justify our research design as well as our data analysis method. We also give a brief outline of the case for the reader to be better able to interpret and evaluate our findings which are presented in the subsequent section. In our discussion we use the findings from our theoretical coding of the data to evaluate the mechanisms for system identity maintenance and evolutionary change proposed by Porra (1999) which we thus relate to IOIS for the first time.

Literature: IOIS and Evolution

In a recent review of 51 systematically selected theory-based empirical studies of IOIS, Robey et al. (2008) classify the main themes of this research into adoption, governance and organisational consequences of IOIS. Adoption studies generally draw on theories of technology acceptance and adoption mostly at the organisational level of analysis with just a few treating the extra-organisational environment using the concepts of network externalities, trust or institutional conditions. Governance research on IOIS centres on the electronic markets hypothesis (Malone et al., 1987). Organisational consequences largely concern strategic, operational or relationship outcomes of IOIS adoption for organisations or networks of organisations. Thus, a large proportion of IOIS research uses short time frames, which are generally limited to episodes before, during or after the IOIS adoption project, and even within these timescales, change of the IOIS does not figure prominently in the topics studied.

There is a small number of papers that do address evolution of IS or IOIS over large timescales. Kanellis and Paul (1997) address the question of adaptability of IOIS over the period of their existence. They argue that IOIS, in order to persist, must have the capability to develop their own identity, which should not be determined in advance by the system's designers. This is only possible if an IOIS contains elements that are willing and able to set their own goals. An example given to illustrate their concept suggests that this element consists of human beings. In short, these authors propose a conceptualization of IOIS as systems inhabiting a "time continuum" that contain technical and human elements. Together, these form an identity that is the basis for the property of adaptability and thus a precondition for the system's persistence.

Fedorowicz et al. (2004) argue for an 'information ecology lens' to study IOIS and, in doing so, address the issue of IOIS evolution. Specifically, they propose that (1) users of IOIS make adaptations in inter-organizational processes and structures; (2) users and system co-evolve; (3) flexible process and design features enable successful response to rapid environmental change; and (4) adaptation and co-evolution lead to change in IOIS forms and relationships. While these authors thus suggest that actions of participants are a major source of change, they also seem to imply that technical means must provide the flexibility required for adaptation to rapid environmental change.

Ciborra and Hanseth (Ciborra and Hanseth, 2000; Hanseth, 2000) adopt an implicitly evolutionary approach when they discuss the dynamics of corporate infrastructure. They reject the managerialist notion that IT should be seen as an instrument of corporate strategy, which can and should be streamlined and aligned to strategic goals, for a view of infrastructure having its own dynamic and even agency. Drawing on Star and Ruhleder (1996), they argue that infrastructures are never made from scratch but are ecologies of parts which evolve by sedimentation of layers upon successive installed-bases. They have deep ecological penetration which means that their uses are difficult to control and predict. They are socio-technical and contain technical elements that are shared by multiple communities. However, Ciborra and Hanseth see the main dynamic of information infrastructures as dialectic between management control and infrastructure evolution, an idea that does not easily translate to the IOIS we study, where centralized management is often absent.

However, the most developed and penetrating analysis of the nature of evolution of information systems is given by Porra (1999), although not in the context of IOIS. Porra argues that previous accounts of change in systems theory have drawn either on mechanistic or organic metaphors which provide an explanation only for incremental feedback-driven change (homeostasis). Porra proposes to address this inadequacy by drawing on biological evolution theory. Using Eldredge and Gould's (1972) theory of punctuated equilibrium, Porra argues that in evolution theory two mechanisms for change are recognised, which operate on different timescales and different units of analysis. One is continual variation and selection at the genetic level which accounts for variation among individuals of a species, and the other is the less frequent but more dramatic creation of new species of organisms. In

order to bring to systems theory this second mechanism of change, which she argues is essential for understanding evolution of information systems on long timescales, Porra introduces a new unit of analysis to systems theory which she calls a "colony". Colonies are voluntary collections of individuals that share a common history, common methods for realizing both stability and radical change, and a common local context (Porra, 1999, p. 39). Porra proposes that the homeostatic mechanisms of traditional systems theory explain stability and gradual change within colonies, while shared history and context explains identity maintenance. However, it is the creation of new colonies from old (the equivalent of speciation) that explains instances of radical change on system evolution timescales. Creation of new colonies occurs by a mechanism called "punctuated prototyping". Colonies experiment with new forms of organisation and technology that have not previously existed in the colony. One or more of these prototypes may prove crucial for survival in a new environmental reality. In this case one or more new colonies may form around these prototypes and continue as new colonies inheriting the colony's history to that point, but developing their own history and context (identity) from there-on.

Of these conceptual contributions to the IS and IOIS literature we find Porra's contribution the most useful to our project. Porra's framework appears to provide an explanation for both the resilience of IOIS, which allows their identity to be maintained in the face of environmental change, and also the ability of IOIS to transform in radical ways, such as the transformation from closed system to quasi-open infrastructure observed in our case study. Furthermore, Porra's definition of a colony is very similar to Lave and Wenger's notion of a community of practice (Lave and Wenger, 1991; Wenger, 2002) which we have used in our own practice-based framework for describing IOIS.

IOIS as Aligned Constellations of Practices

We now present our own practice based framework which aims to describe inter-organizational information systems and how they change over time and which we use as a basis for coding our empirical data. In broad outline, the framework draws on practice theory (Wenger, 2002) to describe IOIS as a constellation of aligned practices connected by a specific type of boundary structures. We have argued elsewhere that such a practice view of IOIS is appropriate for describing IOIS at evolutionary timescales and as socio-technical, rather than merely technological, systems (Reimers et al., 2008).

The key concepts we use to describe a practice are *structures* which have extended existence over time, and *patterns* which are the ephemeral traces of practitioner's *actions*. Based on Wenger (2002), we assume that structures are reproduced in communities of practice (CoP); new members to a CoP become attuned to these structures through apprenticeship, i.e. by observing the behaviour of experienced members and their responses to own engagement in action. New members try to identify patterns of action, attempt to make sense of these observed patterns, i.e. sense possible structures which could have enabled/constrained the actions resulting in the observed patterns and then tentatively engage in their own actions, continuously adapting and updating their sense-making regarding rules and affordances. As such behaviour is repeated, parts of it become routine and automatic, i.e. some parts of behaviour are relegated to "body memory" which makes use of the affordances of the physical environment, including technology. Actors also develop a "moral sense" which helps them to distinguish right from wrong actions. Finally, actors learn how to rationalize their actions in view of ideas that are reproduced in that CoP through repeated discourses.

The three dimensions which emerge through these distinctions (material, normative, ideational structures) have a counterpart in corresponding patterns, namely patterns of flows of material things (including movements of the human body), sanctioning patterns and discursive patterns. Actors may accidentally, consciously or strategically change these patterns which may affect the reproduction of structures; in addition, actors may change their perceptions of patterns which could also affect the reproduction of structures (Giddens, 1984). Thus, the process of structural reproduction allows for changes while structures cannot be changed arbitrarily. In the spirit of Giddens' work (ibid.) our division of structure into separate dimensions is largely analytical and differs from his division. These three categories may not exhaust the possible dimensions of structures and patterns, but have proved particularly relevant for describing IOIS. They form the basis of our data coding method.

Several CoPs can be connected through brokers and boundary structures (Wenger, 2002; Star and Griesemer, 1989). Both brokers and boundary structures do this through multi-membership in the several communities. Brokers can also affect the reproduction processes in these several communities and thus align practices if that should become necessary, for example in view of imminent failure of transactions between communities.

We can now use this framework to define an inter-organizational information system as a set of CoPs located in separate organizations which are connected through specific material IOIS boundary structures. IOIS boundary structures can be either a shared definition of data to be exchanged between data processing applications or a shared data processing application, including a shared database. Such boundary structures are "brittle", i.e. they are not interpretatively flexible, and thus need to be frequently aligned which can be done through brokers or so-called "encounters", that is, meetings between delegates of the involved practices (Wenger, 2002). In this way our framework conceives of the alignment of practices through IOIS as an on-going practical socio-technical achievement, rather than a passive property of a set of extended information technologies. Figure 1 illustrates our concepts of practice and IOIS.

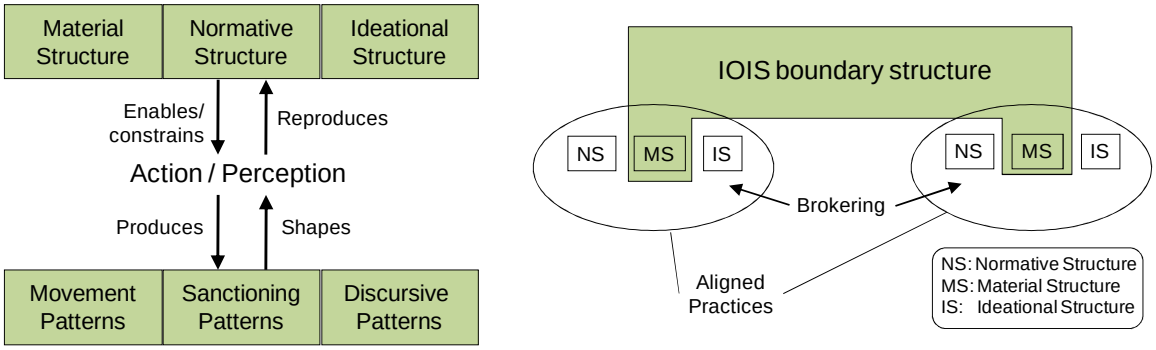

Figure 1. Our model of practice (left) and our practice-based concept of IOIS (right)

Method and Research Design

Research Choices

IOIS as a phenomenon are very difficult to bound (Reimers et al., 2004, Fedorowicz et al., 2004). This is true when looking at IOIS at a given point in time but the problem is exacerbated when studying IOIS evolution. IOIS lack the "natural" boundary available, for example, for defining company-wide information systems as study objects where the company as a legally defined organizational unit serves as the boundary criterion. IOIS resemble network phenomena in this regard that require a definition of who or what is considered to be part of that network. If IOIS evolution is considered, the additional difficulty consists of accounting for the possible influence of potential network members; for example, standardization efforts which are often crucial for IOIS development usually take the needs or possible responses of firms into account which are part of the industry but do not directly participate in the standards related negotiations. Thus, IOIS are, almost by definition, a phenomenon that is difficult to separate from its environment, an empirical situation for which case study research is recommended as an appropriate methodology (Yin, 2009). Moreover, we ask a how-question which is effectively addressed by case research methodology (ibid.).

In terms of data collection method, we decided to use open, semi-structured interviews. According to our theoretical model, we needed to collect data on material, normative, and ideational structures reproduced in several practices that, together, form an IOIS (see Section 'IOIS as Aligned Constellations of Practices'). The ideal data collection method would consist of actually participating in each practice for some time, given the routinized character of a practice which one would expect to be largely tacit and unspoken. However, for two reasons this was infeasible. First, we wanted to uncover structures whose origins lie in the past, necessitating a retrospective reconstruction of these structures. Second, even if we were only interested in uncovering most recently established structures, our limited resources made participant data collection infeasible in view of the exploratory nature of our research and its broad scope, involving several practices to be included as our research subject comprises constellations of practices. We submit that, due to the possibility of reflexive monitoring of action, traces of material, normative, and ideational

structures can be found in interview data to an extent that allows for their reconstruction through our theoretical coding.

Regarding the domain to be studied, we chose the pharmaceutical distribution industry. While medicine manufacturing is a global industry, distribution of medicine is still a highly domestic business. This is related to the usually extensive regulation of drug distribution which, in turn, is justified by the high proportion of cost of medication in overall healthcare costs and by the safety risks related to drug consumption (Geiger and Goldschmidt, 2009). This property of the industry makes it a suitable setting within which to study evolution of IOIS since global influences can be discounted while national influences are highlighted. The absence of global influences simplifies the problem to be addressed and also allows for an international comparative approach. The emphasis of domestic influences was important to us as we were specifically interested in the influence of national characteristics on IOIS evolution. We therefore selected drug distribution as the empirical setting within which to study IOIS evolution.

We have studied IOIS in this industry across several countries, including Ireland, Germany, China and Australia. However, in this paper, we only present and analyze data from the Australian case study. This case is especially relevant and pertinent for the research question addressed in this paper as IOIS in the Australian pharmaceutical distribution industry have evolved from proprietary, closed systems to quasi-open systems. The opening of the systems was not imposed on the participants but emerged in a bottom-up, evolutionary process. Thus, on the one hand the system characteristics changed significantly; on the other hand, this change was the result of an evolutionary process. While we acknowledge that similar cases characterized by evolution from a proprietary to an open system are familiar from the literature, this case is unique in that this evolutionary process was entirely emergent without intervention of a central actor which allowed us to focus on uncovering emergent evolutionary processes and therefore submit that a single case design can be justified in view of this unique development pattern. Before describing our data collection and analysis methods we give a brief overview of the case in order to motivate our data analysis and collection procedures.

Case Overview

The around 5000 pharmacies in Australia are mostly supplied by three national wholesalers, the so-called full-line wholesalers. The full-line wholesalers supply prescription drugs -- about 4000 -- and other non-prescription healthcare products, so-called over-the-counter (OTC) products. About 10% of supplies are provided by regional wholesalers who focus on a specific segment of the total product range, the so-called short-liners. Beginning in the 1990s, manufacturers of generic medicines -- that is prescription drugs whose patent protection has expired -- also ship directly to pharmacies.

Figure 2. A typical banner-group pharmacy's dispensing area

Over the last three decades, the three full-line wholesalers have maintained roughly equal market shares. They used to have a regional focus but, mostly during the 1990s, expanded through acquisitions of local competitors to become national players. During the same period, pharmacies have increasingly expanded the OTC segment so that the area in which they sell prescription drugs -- the dispensing area -- has shrunk relative to the total shop space. While wholesalers are legally forbidden from owning pharmacies, recently all three wholesalers have formed own marketing groups, known as banner groups, with between 1500 and 2000 pharmacies associated with a banner group. Banner groups offer catalogues, signage and uniforms to pharmacies, among other services. Pharmacies thus convey the impression of belonging to a retail chain while they are legally independent units. Figure 2 gives an

impression of a typical pharmacy's dispensing area, also showing how the 'look-and-feel' of a pharmacy may be determined by the signage from a banner group (in this case 'Terry White').

In the early 1980s, the full-line wholesalers had started to offer electronic ordering facilities to pharmacies. These involved mobile devices which could be used to scan a barcode printed on shelf labels. These barcodes represented proprietary product codes of wholesalers. The mobile devices -- called PDE devices -- could (and still can) be used for ordering drugs. Pharmacy personnel would scan items to be replenished and manually enter the number of products to be ordered. If placed in a dedicated cradle, an electronic data connection with the wholesaler who has provided the devices would be automatically established and order data transmitted. These were (and still are) automatically processed into the wholesaler's system and electronic invoices returned which also notified the pharmacy about out-of stock items. Pharmacies could then order such items from a secondary wholesaler by telephone. In the 1990s, pharmacies began to use computerized inventory management and sales systems, so-called Point-of-Sales (POS) systems. These systems also supported electronic ordering. Although the influential standard for retail product numbers, the European Article Number (EAN), was increasingly used on retail packs also in the pharmaceutical industry, replenishment ordering was still based on the proprietary product codes of wholesalers. This required that the POS vendors maintained cross-reference files that mapped the several proprietary product codes of the three wholesalers onto one another. As a result, pharmacies could now order electronically from all three wholesalers. In the 2000s, several initiatives to extend electronic ordering systems occurred. First, driven mostly by government, an Internet platform was established with the express purpose to link all three distribution stages, manufacturers, wholesalers, and pharmacies (the so-called PeCC system). However, this system was ultimately only used to support order flow between wholesalers and manufacturers. Second, some new entrants attempted to establish an electronic ordering platform that would automatically route orders to the lowest cost supplier. However, this initiative failed. Finally, the POS vendors set up an Internet-based platform through which electronic orders would be routed from pharmacies to wholesalers. While this system -- called PharmX -- was operational since the end of 2008, it was in the planning stages while data collection for this case study took place.

Data Collection and Analysis

The main means of data collection consisted of interviews, supplemented by published material and information taken from websites, mostly those of the full-line wholesalers. Between March 2006 and September 2007 nine interviews were conducted involving wholesalers, POS vendors and pharmacies. All interviewees had many years of industry exposure which, in most cases, covered the whole period of this case study (from the early 1980s to 2007). Interviews lasted between half an hour and two hours with an average duration of 63 minutes. All interviews were tape recorded and transcribed, yielding about 200 pages of transcriptions which constitute our main data set. Table 1 gives details on these interviews. Information was taken from websites concerning the history of wholesalers regarding mergers and acquisitions as well as creation of banner groups and was used for dating structures as described below. The authors acted as independent researchers and were in no way enrolled in industry practices nor acting as consultants.

Table 1. Summary of interviews

Type of firm	Job title of interviewee	Date of interview	Mode of interview	Duration (min.)
POS vendor A	Owner, CEO	March 12 2006	In person	120
POS vendor B	General Manager of Technology, Health	April 29 2006	Telephone	60
Wholesaler A	Technical manager customer support	April 28 2006	Telephone	70
Wholesaler B	Supply chain manager	March 12 2006	In person	70
Wholesaler B	IT manager	March 14 2006	Telephone	35
Wholesaler C	Head of IT for pharmaceutical distribution	April 19 2006	Telephone	48
Wholesaler C	IT manager	April 19 2006	In person	70
Pharmacy A	Proprietor	Sept. 13 2007	In person	66
Pharmacy A	Stock manager	Sept. 13 2007	In person	30

Data analysis proceeded in four steps. First, the scope of the IOIS was defined as consisting of three sets of connected practices: (1) the wholesalers' practices of taking and processing orders from pharmacies including operating and maintaining their order taking and processing systems; (2) the POS vendor practices concerned with development and maintenance of pharmacy POS systems (which consisted, among other things, of updating product codes and communication protocols according to wholesalers' requirements); (3) the pharmacies' replenishment practices involving the placement of electronic orders but also including stock taking and other means of replenishment (such as telephone orders).

Next, all interview data were coded according to our theoretical model. First the transcripts were read looking for references in the text to structures which constrained or enabled action of participants of the practices. A description of the reference closely based on the text passage was recorded in a spreadsheet database as instance of a structure. References to essentially the same idea or condition in other interviews were counted as triangulations of the structural instance and were recorded as a measure of the reliability of the identification. 85 instances of structures were identified and their identification was verified by two researchers. These instances were then coded according to their structural type, relevant practice and historical era. Coding rules were developed and iteratively refined in order to apply similar principles across the whole data set and thus ensure construct validity (Reimers and Johnston, 2008b). Assignment of codes was independently checked by two researchers involved in this project.

The most important of these rules concerns the way structure instances were classified into the three dimensions of structure. Material structures constrain and enable bodily movements or are experienced bodily; technical artefacts are usually easily identified as material structures; however, we also included all structures that involve external incentives under this category as these incentives are also usually considered to be material; normative structures refer to moral rules and are indicated by formulations such as 'should' or 'ought'. Normative structures are usually not considered in IS studies. Ideational structures refer to shared beliefs about cause-effect relationships and are indicated when informants offer a rationale or explanation for a behaviour or a phenomenon.

Instances were associated with one of the three practices that constitute the IOIS of interest based on the criterion that this instance is actually reproduced in that practice. This usually implied that we had a reference to that structure from a representative of the practice with which that practice was to be associated. However, exceptions occurred. For example, it might be the case that an informant speaks about a norm but explicitly refers to another practice for which it is relevant. In this case, we would associate this norm with that other practice to which the informant referred. In contrast, an informant may appropriate that norm and also defend it as justified in the interview in which case we would conclude that this norm is reproduced in the practice that he or she represents. The same procedure was applied to material and ideational structures. Based on these associations we could identify structures that were shared across practices and which we call boundary structures. Boundary structures can be material, normative, and ideational (see Section 'IOIS as Aligned Constellations of Practices').

Finally, we 'dated' each instance by associating each instance with one of four development periods (early 1980s: proprietary closed systems (PDEs); late 1980s: influence of EAN, pharmacist as retailer; 1990s: spread of POS systems as semi-open gateways; 2000s: new, open systems initiatives (PeCC, PharmX etc.)). There were three possibilities for dating. First, interviewees may explicitly mention a time when a certain instance first appeared. This usually was the case for material structures that came to existence at a defined point in time (PDE devices were first offered to pharmacies in the early 1980s etc.). Second, outside information might be available for dating. For example, it is usually possible to establish when a certain law came into existence. Finally, if the first two options were not available we attempted to establish when a certain instance could logically have appeared for the first time. For example, a norm referring to POS vendors could only have developed in the 1990s since POS vendors came into existence in the 1990s.

Assumptions, Validity and Reliability

Our analysis contains two assumptions. First, we assumed that the three practices considered in this study are sufficiently similar across firms to justify creation of generalized descriptions of them. Specifically, we assumed that norms, rationales, and material structures are sufficiently similar across pharmacies, POS vendors and wholesalers respectively. For most instances we have two independent sources of evidence supporting these assumptions. Specifically, we have interviewed all three wholesalers but only two of the 20 POS vendors and only two people in a single pharmacy.

Second, the methods for dating instances of material, normative and ideational structure are approximate. Specifically, it is possible and very likely that structures have changed over time and that interviewees presented them differently at the time of our interviews from how they would have presented them in earlier periods. To gauge the extent of such deviation over time it would be necessary to consult archival material and match this with our dating efforts. While we recognize these weaknesses, we submit that our familiarity with the industry that has grown over the past four years of research offers a measure of safety against gross mistakes in our analysis. Also, the relatively large number of instances should make any possible mistake in the coding, indexing (association of an instance with a practice) and dating process relatively small in view of the total amount of data. However, we still urge the reader to keep these assumptions in mind when we present our findings and interpretations in the following two sections.

Findings

The findings are presented in two formats. Tables 2 through 4 list the instances that were extracted from the interview data according to the procedures described above for each practice by dimension -- material, normative, ideational -- and era. Figure 3 visualizes the boundary structures that are shared across two or all three practices, again differentiating between type of structure and era. When reading Tables 2 - 4 the reader should refer to the precise definitions of the three types of structure and the coding principles used, as described earlier, since the usage of these terms differs in the literature and in general use.

The lists of structural instances displayed in Tables 2 through 4 reveal the change that occurred in the IOIS over a period of almost three decades as a layering of newer instances on top of older ones. The textual descriptions characterizing each instance are short-form versions of longer descriptions created in the coding process. They were created to increase readability of the tables without sacrificing accuracy. Reading through these tables conveys a sense of how the systems have changed in terms of new ideas, norms and material structures that became associated with the IOIS. Comparing instances of earlier periods with those of later periods enables the reader to gauge the extent of the change that took place. We have tried to capture this change by characterizing each new era based on the essence of instances that appeared during that era. Figure 3 abstracts from the contents or substance of the change that took place and focuses on the relations between the practices as defined by shared structures, i.e. boundary structures.

The results of our theoretical coding as displayed in these tables and the figure can be synthesized by five findings. First, it is noteworthy that we were actually able to find structural instances for all three dimensions of our theoretical model. While there is a risk of circular reasoning (we coded our data according to pre-defined categories and take the result of this coding as evidence for the truth of these theoretical categories), we submit that there are two reasons to support our claim that these theoretical categories correspond to empirical realities. First, it was possible to define a small number of simple coding rules according to which instances could be unequivocally categorized, and obtain considerable agreement between researchers in their application. Second, there are relatively few normative instances as compared to ideational and material ones. This is probably a result of interviewer bias as the interviews were conducted before our theoretical model was fully formulated. Thus, rooted in the tradition of IS research, interviewers focused on material structures (mostly technologies) and rationales that interviewees were challenged to offer for the development of systems they were describing. Questions addressing the moral dimension of systems were not asked. However, as we used an open format for the interviews allowing for a free flow of topics to be addressed, interviewees would occasionally mention normative structures on their own accord. While this would account for the relatively smaller number of normative structures identified, it is also suggestive of the real existence of normative structures in the sense that such norms are reproduced in the practices studied. Both these reasons indicate that classification of structures into three categories is not an artefact of our theoretical model.

Secondly, we note that IOIS structure -- as defined by the sum of all 85 instances that were extracted from our interviews -- evolved in all three dimensions, i.e. new instances become associated with the IOIS in each dimension as the system progressed from one era to the next, a change that becomes especially obvious after a new practice has emerged that intermediated the pre-existing two practices. Some generalizations regarding the way that structures have changed in the three dimensions over the roughly 25 years are possible. Material conditions changed from supporting closed proprietary systems to quasi-open systems enabled by third party cross-referencing of entrenched proprietary standards. Norms changed from focussing on the legitimacy of the pharmacy - wholesaler relationship to focussing on the obligations of and to intermediaries in the relationship (POS vendors and banner groups). Rationales moved from aspects of close pharmacy - wholesaler relationships, to rationales concerning cautious

intermediation of that relationship. In addition, we note that there is some discernable consistency in the way structures in the three dimensions have changed. Specifically, change in all three dimensions contains the topic of third-party intermediation. Because of this consistency of change across the three dimensions we were able to refer each era by a phrase that captures the common themes in all three dimensions.

Table 2. Instances of structure for the wholesalers' practice, by structural dimension and historical era. Acronyms used in the description are defined in Table 5

Material Structures	Normative Structures	Ideational Structures
2000s: Open systems initiatives (PeCC, PharmX etc.)		
19. Wholesalers create common order platform (PeCC) with manufacturers *20. PeCC does not support orders from pharmacies to wholesalers* *21. Broadband Internet access is available nationally* *22. Wholesaler-owned banner groups provide marketing services and incentives*	*29. POS vendors should not unilaterally force terms* *30. POS systems should not direct traffic by price comparisons*	*44. If 2 wholesalers join common platform then all 3 will have to* *45. Solidarity against common platforms is a collective good* *46. Adoption of PeCC exposes wholesalers to threat of disintermediation* *47. As intermediaries, wholesalers reduce costs by creating a hub* *48. Common platform may cause customer defection because lock-in reduced* *49. POS vendors too fragmented to provide common platform* *50. Pharmacists are adoption laggards because they do not like change* *51. Advantage of PharmX is replacement of point-to-point with Internet hub* *52. Pharmacy guild support would facilitate common platform adoption* *53. Pharmacy guild conflict of interest might hinder common platform adoption* *54. Wholesalers cannot cooperate through their trade association for legal reasons* *55. Lower profit necessitates wholesaler market consolidation* *56. Creating banner groups reduces competitive pressure for wholesalers*
1990s: Spread of POS systems as semi-open gateways		
10. POS systems generally support all wholesalers' proprietary product nos. *11. POS systems can connect to wholesaler's proprietary input systems* *12. By law, POS systems must not tie orders to wholesalers* *13. Five large and 20 smaller POS software vendors* *14. Installed POS systems are from 20 system vendors* *15. About 2/3 of pharmacies have POS installed* *16. Wholesalers have ERP systems receiving electronic orders* *17. One of the 5 large POS system vendor is half owned by pharmacy guild* *18. Wholesalers encourage electronic ordering with rebate*	*25. Pharmacies should check that POS software supports all wholesalers* *26. Pharmacies should not bypass electronic ordering process when using POS* *27. POS vendors should maintain product x-ref files* *28. POS vendors should be professional in software development and standards*	*37. Easy switching between wholesalers necessary for competitive expansion* *38. Having good x-ref files is competitive advantage for POS vendors* *39. Legacy use in POS of proprietary numbers justifies non-adoption of EAN* *40. High profit margins worked against wholesaler cooperation on standards* *41. Fragmented POS market complicates electronic ordering* *42. Introduction of VAT tax helped uptake of POS systems* *43. Unlike wholesalers, bargaining power of pharmacies not legally restricted*
Late 1980s: Influence of EAN, pharmacist as retailer		
9. 90% of pharmaceuticals have an EAN number		*35. Pharmacies cannot demand EAN therefore proprietary codes necessary* *36. Pharmacists need professional support because they are not businessmen*
Early 1980s: Proprietary closed systems (PDEs)		
1. Retailers use PDEs supplied by (typically only one) wholesaler *2. PDEs use wholesaler's proprietary product and communications standards* *3. 10-15% pharmacies have PDEs* *4. Modem-based communication widely available* *5. Government incentive for wholesalers to operate full-line* *6. Government controls wholesaler's maximum margin* *7. Government forbids wholesalers owning pharmacies* *8. Three wholesalers control 80-90% of supply to pharmacies*	*23. Pharmacies should be loyal to wholesalers* *24. Wholesalers should not cream-off the market*	*31. Proprietary PDE systems can create competitive advantage* *32. Binding pharmacies contractually violates their pecuniary interests* *33. Full-line wholesaling is a necessary community service* *34. Twice daily deliveries help pharmacies reduce inventory*

Thirdly, the majority of material structural instances (16 of 28) are shared across two or all three practices. This is unsurprising as we looked at these three practices from the perspective of IOIS research, i.e. we specifically selected these practices and studied them in order to understand how IOIS evolved. As emphasized by Wenger (2002), any joint analysis of several practices always emphasizes a certain theoretical issue of special interest to the analyst. This circumstance is aptly captured by the term "constellation of practices" coined by Wenger as any constellation (group of stars) can only be defined from a certain point of view (in the literal sense).

Table 3. Instances of structure for the POS vendors' practice, by structural dimension and historical era. Acronyms used in the description are defined in Table 5

Material Structures	Normative Structures	Ideational Structures
2000s: Open systems initiatives (PeCC, PharmX etc.)		
21. Broadband Internet access is available nationally *60. Four POS vendors have joint venture to create PharmX common platform*	*29. POS vendors should not unilaterally force terms* *30. POS systems should not direct traffic by price comparisons* *61. Wholesalers should carry the cost of POS software updates they cause*	*66. Distributing software updates best using hub configuration* *67 Using POS systems complicates troubleshooting electronic orders* *68. POS vendors only are positioned to implement common platform* *69. Internet aids standardisation by providing dedicated connection hardware* *70. POS vendor possessiveness of features prevent creation of common platform* *49. POS vendors too fragmented to provide common platform* *71. Wholesalers cannot create common platform due to competitive conflict* *51. Advantage of PharmX is replacement of point-to-point with Internet hub* *52. Pharmacy guild support would facilitate common platform adoption* *53. Pharmacy guild conflict of interest might hinder common platform adoption* *72. The spread of DSL makes it difficult to maintain modem-based connections* *73. Incumbent system vendors charge less because of intangible benefits* *74. Because trust takes time incumbent system vendors are advantaged* *75. PharmX initiators wary of government funding due to historical failures*
1990s: Spread of POS systems as semi-open gateways		
10. POS systems generally support all wholesalers' proprietary product nos. *11. POS systems can connect to wholesaler's proprietary input systems* *12. By law, POS systems must not tie orders to wholesalers* *13. Five large and 20 smaller POS software vendors* *14. Installed POS systems are from 20 system vendors* *15. About 2/3 of pharmacies have POS installed* *57. POS systems use their own proprietary numbers on patient record files* *17. One of the 5 large POS system vendor is half owned by pharmacy guild* *58. Market for POS software is nationally isolated* *59. Modem-based communication is available nationally*		*62. EAN is not suitable to use for pharmaceuticals because it is unreliable* *63. Lack of standards means only large wholesalers supported by POS x-ref* *64. Electronic reimbursement by government stimulated pharmacy POS uptake* *65. Monopoly concerns among wholesalers hamper cooperation among POS vendors*

Fourth and in contrast to the previous point, normative and ideational structures are generally not shared across the three practices (except for the most recent era discussed below). This may seem surprising as it might be expected that norms and rationales that refer to shared material structures are similar across the three practices. While rationales and norms do not always refer to IOIS material boundary structures, they mostly do. For example, five of seven ideational structures of the wholesalers' practice in the POS era refer to POS systems, three of four for POS vendors and three of three for pharmacies. Thus, ideational and normative structures tend to be local and specific to a practice with respect to older structures even when referencing the same material boundary structure.

Fifth, as indicated above, the majority of shared structures in the most recent era (open systems initiatives) are normative and ideational structures. While the relatively low number of material boundary structures is unsurprising given the fact the these initiatives had not materialized by the time the interviews were conducted, the significant number of shared normative and ideational structures (six) is noteworthy given the otherwise near absence of such occurrences (only one (no. 23) in all previous eras). All shared normative and ideational structures in that era refer to new systems initiatives.

Table 4. Instances of structure for the pharmacies' practice, by structural dimension and historical era. Acronyms used in the description are defined in Table 5

Material Structures	Normative Structures	Ideational Structures
2000s: Open systems initiatives (PeCC, PharmX etc.)		
78. Generics manufactures establish loyalty schemes with pharmacies directly *21. Broadband Internet access is available nationally* *22. Wholesaler-owned banner groups provide marketing services and incentives*		
1990s: Spread of POS systems as semi-open gateways		
76. Pharmacies employ on average one person on order data entry *10. POS systems generally support all wholesalers' proprietary product nos.* *11. POS systems can connect to wholesaler's proprietary input systems* *13. Five large and 20 smaller POS software vendors* *18. Wholesalers encourage electronic ordering with rebate* *77. Dispensing and POS compatible if supplied by same software vendor*	*80. Pharmacies should order from banner group wholesaler* *81. Pharmacies should use POS systems marketed by banner group* *82. Pharmacists should be more organized in their order process*	*84. Using banner group POS systems assists managing product range* *85. Price comparison even using POS difficult due to time required* *86. Setup effort discourages using POS for automatic replenishment*
Late 1980s: Influence of EAN, pharmacist as retailer		
9. 90% of pharmaceuticals have an EAN number	*79. Pharmacies should not neglect dispensing for retailing*	
Early 1980s: Proprietary closed systems (PDEs)		
1. Retailers use PDEs supplied by (typically only one) wholesaler *2. PDEs use wholesaler's proprietary product and communications standards* *4. Modem-based communication widely available* *7. Government forbids wholesalers owning pharmacies* *8. Three wholesalers control 80-90% of supply to pharmacies*	*23. Pharmacies should be loyal to wholesalers*	*83. Importance of service to pharmacists shown by competitor help on stock-outs*

Table 5. Acronyms used in Tables 2 to 4

PeCC	Project electronic Commerce and Communication for Healthcare
OS	Point of Sale (system)
PharmX	An initiative by POS vendors to create a joint Internet-based hub
ERP	Enterprise Resource Planning (system)
EAN	European Article Number
PDE	Portable devices used in pharmacies to scan barcodes and send electronic orders

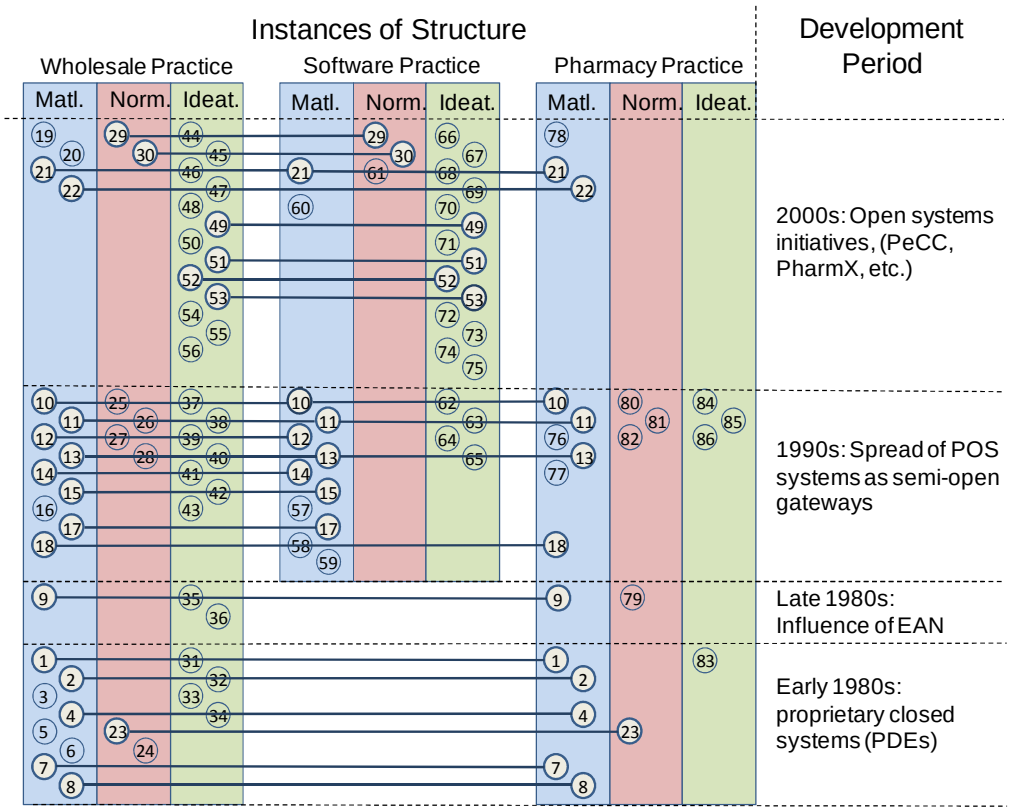

Figure 3. Boundary structures between the three practices. Structural instances joined by lines are reproduced in two or more practices. Numbers refer to instance descriptions given in Tables 2 to 4

Discussion

Our findings support the foundational position of our practice view of IOIS that IOIS are not adequately analysed by reference to material information technologies alone. Evolution of IOIS manifests itself as change in the totality of structure (material, normative and ideational) reproduced in communities of practice connected by IOIS boundary structures rather than as change in just the particular material structural elements of a practice associated with technology. A narrow focus on only the material structural elements of the IOIS studied here would present a picture of relative stasis or reproduction with only slight adaptations (for example, PDE devices have been updated and re-designed to reflect changes in their technological environment). Only when changes in the multiple structural instances within a practice are observed does the change from closed, proprietary systems to quasi-open systems become visible and understandable. The totality of structure seems to be layered as a result of historical evolution processes such that the current condition of a practice reflects its total history (Porra, 1999), although admittedly we have captured only a small part of this history due to the limitations of our data collection procedure. Hanseth (2000) uses the term “installed base” to refer to a similar notion of layering in the growth of an information infrastructure.

Moreover, our findings support Porra’s argument that the source of major changes in the course of system evolution is not gradual adaptation but punctuating events involving the formation of new practices (colonies for Porra). Specifically, significant change occurred in our case after the new POS software practice had emerged. This change was not just limited to the appearance of this new practice but also resulted in changes in the interacting practices that were thereafter intermediated by that new practice. New norms and ideas reproduced in the wholesaler and the pharmacy practices reflected the arrival of the new intermediating POS practice while largely referencing the new material boundary structures that facilitated electronic exchange of data between wholesalers and pharmacies. Many

of these new boundary structures were now shared by all three practices. Eventually this punctuating event led to the radical change from proprietary systems to quasi-open systems in the industry.

The new practice of the POS vendors was founded mostly by former members of the existing practices, i.e. they were either pharmacists or employees of wholesalers. Material, normative and ideational structures unique to this practice were then reproduced (see Table 3). Parallel to this, we observe that structure of the former two practices changed significantly as a result of the arrival of the new practice (see Tables 2 and 4). At the same time, they maintained their unique identity by reproducing different structural incidences, which is a prerequisite for their persistence. These observations are consistent with Porra's theory of punctuated prototyping which would suggest that the new practice emerged as their actors became sufficiently isolated from their previous practices and began to reproduce practice-specific structures.

However, the work of Porra considers only the evolution of unconnected practices, whereas the evolution and continued persistence of IOIS necessitates that the multiple communities of practice linked by the IOIS must evolve to some degree on a coordinated trajectory. Practices in an IOIS need to share certain material structures in order to facilitate exchange and automatic processing of electronic data; at the same time, they need to maintain their own identity necessitating the reproduction of unique structures. We have presented evidence for both the existence of boundary structures as well as of unique structures particular to each practice. This gives rise to the question of how the multiple involved practices maintain their alignment over time required for the IOIS to persist.

Venturing a new proposition, we suggest that the very mix of shared and practice-specific structures accounts for continuing alignment of practices such that an IOIS can persist. Rationales specific to a practice supply the reasons why members of that practice take appropriate steps when reproduction of material boundary structures appears precarious, for example when electronic orders do not go through as expected or electronic invoices do not arrive when expected. Norms specific to a practice additionally motivate and legitimize such efforts. Failure to take action in these situations could lead to the use of non-sanctioned manual methods of ordering (such as phone calls) and threaten the on-going use of the IOIS as a boundary structure for electronic exchange of data. The circumstance that such norms and rationales are specific to the several practices joined together through shared material boundary structures allows for maintenance of unique identities that may even include negative stances towards members of adjacent practices (such as that pharmacists are not business people and therefore need professional help, see instance 36, Table 2). In short, we submit that the problem of alignment is solved as the sum of myriad efforts by members across adjacent practices to take appropriate steps whenever alignment is threatened. This requires that norms and rationales are separately reproduced in the several practices that suggest reason and morale that make such efforts worthwhile and desirable to the members of the several practices from their separate perspectives (as indicated in Tables 2 - 4).

That leaves open the question of how the introduction of new material boundary structures is coordinated, for example the installation of POS systems in pharmacies that occurred in the early 1990s. Coordination requirements in such cases go beyond the efforts required for continuous maintenance of alignment of existing equipment. A possible mechanism is suggested by a tentative finding reported above, namely that a significant number of shared normative and ideational structures are reproduced ahead of the introduction of new material boundary structures. This would create the semblance of a joint practice for a transitory period during which the members of the several practices work together as if they were part of a single practice (cf. Levina and Vaast, 2005). Once the new boundary structure is in place, reproduction of ideational and normative structures drifts apart as the several practices re-establish their unique identity. Ongoing alignment from now on is assured by the mix of shared and individual structures as described above.

While the short descriptions of our data point to a considerable degree of consistency across the three dimensions within a given practice, a circumstance that allowed us to identify and name eras of system evolution and to speculate about stabilizing mechanisms, how this consistency comes about and is maintained is as yet an unsolved theoretical problem. Given the constraining and enabling relation of structure to actions, this question becomes how is it that the separate processes of reproduction of material, normative and ideational structures result in structures that by and large provide consistent support for actions? In our explanation and interpretations of the findings, this consistency takes a prominent role; however, in order to further support these interpretations we would have to understand the mechanism that accounts for this observed consistency. We leave this question for future research.

Conclusions

The research provides evidence for the following answers to our research questions. Changes take place in all three dimensions of the practices studied. These changes are characteristic of each practice and display a degree of thematic consistency within a given practice. This change appears to occur through a layering process of adding new structures to a historical installed-base (shedding of structure might also occur but could not be observed by our method). It appears that persistence of IOIS over long timescales may be accomplished through this mechanism. However, the major evolutionary change (from closed to quasi-open system) occurred through the appearance of a new practice, with historical routes in the incumbent practices, and the subsequent accommodation of these to it. This is consistent with Porra's proposed mechanism of punctuated prototyping. Thus, the research provides support for the proposition that major punctuated evolutionary change in IOIS occur at the level of the composition of the constellation of connected practices, the conditions for which are provided by changes at the individual practice level. This provides a satisfying explanation of how coordinated large-scale change can take place in IOIS by evolution without centralised top-down control, which however requires confirmation by application to further cases.

The paper makes several contributions to theory. Firstly, the detailed application of our practice-based IOIS framework to a specific case of IOIS evolution gives support to our position that these systems can only be understood as technology mediated practices operating on a number of dimensions. Secondly, the paper applies elements of Porra's colonial systems theory to IOIS for the first time, yielding new insights into the mechanisms of their evolution. Finally, the paper uncovers an important issue in systems evolution which has not been considered by Porra, namely, the successful evolution of constellations of practices whose operations are intimately linked by IT, and makes a proposal about how this is achieved for future work.

IOIS are increasingly seen as important elements in the reform of the healthcare sector. If the required infrastructures are never created from scratch (Hanseth 2000) but evolve over historical embedded layers by the kind of punctuated evolutionary processes we have uncovered here, then the issue for policy makers who seek widely accessible and open enabling infrastructures is to come up with policy settings that might steer the evolutionary process in desired directions. Our case indicates how challenging this will be. Sound evidence-based advice to practice must await further empirical research and theory development to which this paper makes a humble initial contribution.

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