An Investigation into the Disparities in Hospital Database System Designs: Issues of Usability and Interoperability

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Since the early 20th century, advancements in technology have proven to be a major catalyst in the improvement of healthcare across the world. Nonetheless, the number of issues that exist within it continues to grow. While many of these recent advancements in technology, policy, and medicine have sought to deal with the multitude of issues relevant in healthcare, many issues still remain, including novel issues that have recently come into focus. Many of these issues stem from unforeseen challenges and weak points within the solutions that were originally introduced to address prior issues, which were already pre-existing in the framework of healthcare and medicine. An emerging problem that has been taking over the past one or two decades has to deal with the digitization of medical records, which require the involvement of healthcare database systems to organize and store these records.

Different hospitals and hospital systems utilize different database designs, which as a result has led to many issues regarding interoperability, or the ease/ability at which data can be shared and accessed from one database system to the next. Interoperability, which is the focus of technical portion of this thesis, is merely but a subset of many issues at play when it comes to the usage of health information systems. I argue that these issues, including issues surrounding interoperability, stem from the lack of a more user-centered approach in developing a system that is more conducive to data sharing. Hence, despite astounding strides made in both fields of healthcare and data sharing/analytics, the current state of interoperability remains an issue amongst disparate hospital systems that utilize different database systems, among other issues. Explorations into the design factors of these hospital system database designs can provide insight on how to best move forward with improving them for the sake of more efficient hospital care. I

will be utilizing the science, technology, and society (STS) concepts of User Configuration to analyze the inter-relationships between different hospital systems and their associated users when it comes to the issues involved, particularly the sharing of hospital data.

Background on Healthcare Databases

With the advent of interconnected electronic systems in the 1990s, there have been countless innovations in the ways we process and handle massive amounts of data and information. Consequently, there has been an explosion in the amount of data that is now available in the world. These rapid developments in information technology have made its way to the healthcare industry, which is one of the biggest epicenters in terms of the amount of data and information that is at the industry's disposal. To properly store and manage all this information, healthcare institutions have slowly switched from shelves upon shelves of paper records to electronic records, coining the term electronic medical records (EMRs). Consequently, this digitization of health records has led to the rise of electronic healthcare databases and database systems.

In other words, an electronic healthcare database is any structured collection of health-related data (i.e. patient data, hospital employee info, billing, immunizations, etc.) organized for storage, accessibility, and retrieval that is stored digitally in some fashion, like on a central server (Institute of Medicine (US) Committee on Regional Health Data Networks, 1994). Such database types include -- but not limited to -- electronic medical records (EMRs) and electronic health records (EHRs). One of the immediate benefits of this digitization of healthcare information is the speed and efficiency with which data can be created, updated, and retrieved, without having to spend time sifting through piles and piles of paper. This is due to the fact that

these healthcare databases promote a standardized methodology for record keeping, including but not limited to notes from doctors and nurses, patient assessment results, and so forth, which allows doctors and hospital staff to quickly search through vast amounts of data and information to find relevant ones within a matter of seconds.

Through digitized means of uploading data, there is also a vast reduction of errors relating to data precision and accuracy, which could potentially result from misinterpretation of staff handwriting or mistakes made in hand-written notes. Many of these databases have a lot of built-in compliance within their structures and designs, which is very useful for efficiently minimizing the risk that hospital systems unintentionally break complicated state and federal healthcare regulations, especially violations against the Health Insurance Portability and Accountability Act (HIPAA). Hence, with the usage of healthcare databases, patients can enjoy improved privacy and security when it comes to their sensitive, confidential data and information. Additionally, these databases general a lot of data that medical professionals can use to their own advantage for bettering care and treatment for patients. In 2014, the National Institutes of Health authorized $32 million in grants so that researchers can make these vast biomedical datasets available for hospitals to utilize (NetSpective Media, 2020). Such datasets can be analyzed by researchers and hospital staff to help them more accurately assess and determine the best diagnosis and treatments to use for patients who display, say, a particular set of symptoms. Clearly, there have been significant strides in the automation and standardization of many clinical and business-related logic and processes associated with healthcare systems.

Usability of Healthcare Databases

Despite all its benefits, this technological innovation concerning the digitization of medical records has shed light on a host of other issues, both technical and ethical. While many in the healthcare industry appreciate the benefits that have come from the massive amounts of data that are generated from these databases, others have shed light on some valid concerns. Issues regarding privacy of data, regulations at state and federal levels, and the challenges of standardizing and collecting data have been brought up as having significant ramifications on the efficiency of healthcare. Maintaining and managing such complex databases have also increased the overall workload of every hospital organization, which are coupled with increased frustrations from medical staff as well (NetSpective Media, 2020). Oftentimes, the systems can crash or slow, which can have detrimental effects for patients. As a result, medical professionals can become forced to focus on system-related tasks, which can detract from attention and care given towards their patients

According to Dr. Hardeep Singh, who is the chief of Health Policy, Quality and Informatics Program at the Center for Innovations in Quality, Effectiveness and Safety at the Michael E. DeBakey Veterans Affairs Medical Center in Houston, Texas, "[We] received survey responses from 50 institutions. Nearly all (96%) institutions reported at least one unplanned downtime (of any length) in the last 3 years [before 2014] and 70% had at least one unplanned downtime greater than 8 hours in the last 3 years" (Collier, 2014). Singh's statement indicates how widespread and normalized system crashes are in the technological systems hospitals use, especially for their databases. In fact, they're not only widespread, they are practically inevitable (Collier, 2014). During such a downtime, hospitals can become backed up, as they are unable to register new patients or discharge any of the current ones, which directly limits care.

Interdepartmental communication becomes increasingly challenging, as does ordering medication and receiving/processing tests results back from the lab. Billing for all the provided services becomes an even greater pain to manage and carry out. Simply put, patients need to have their information accessed and/or uploaded by medical staff as soon as possible to ensure best possible treatment. Hence, to maintain efficiency and reliability of these complex database systems, hospital systems are forced to invest millions of dollars, which is not cheap at all.

System crashes form just one aspect of issues surrounding healthcare information systems. In general, there is much uncertainty and lack of knowledge rampant among medical professionals when it comes to these systems. Most of the time, many inexperienced medical professionals, particularly nurses, have reported that either they (a) have never interacted with such complicated technical systems before or (b) have been forced to use these systems by their umbrella organizations without any kind of experience or substantial training given to them (Ahmadian et al., 2017). A lot of the time, the latter case is true, which is particularly problematic as users often find themselves being unable to use and/or navigate these systems to complete necessary tasks easily, which just embeds further frustration and ambivalence towards using such systems that were supposedly designed to make their lives and work easier.

In 2015, Ahmadian et. al conducted a cross-sectional study across different hospital systems located in Kerman, Iran in order to gauge the challenges that medical professionals face while working with information systems in hospitals. In their statistical study, they asked nurses to complete a questionnaire consisting of two sections. The first section asked for general demographic questions such as age, gender, educational degree, job title, work experience in the healthcare environment, as well as overall experience with using health information systems. The second section included a list of questions relating to the challenges of using information systems

from the dimensions of system characteristics, human environment, organizational environment, human factors, and hardware factors, which were answered on a 5-point Likert scale.

Among the statistical findings of this study, the researchers found that there was a significant relationship between overall experience with using hospital information systems and the mean score assigned to human challenges. This indicates that participants who had greater experience working with these information systems were more likely to feel less frustrated and more enthusiastic about using these systems, as opposed to a participant who had little to no training or experience. In a separate study, Ahmadian et al. found that medical professionals directly involved with the information technology departments of the hospitals ranked higher than hardware/software challenges in the system as being the most significant barrier to full satisfaction with using these systems. Interestingly, nurses ranked higher on the statement that "negative attitudes of society towards information systems" as being a great barrier.

Ahmadian et al. attributes this discrepancy to the fact that both users of the system are involved in different domains, which explains why each one cares more about one issue over another. This seems to allude to the fact that the information systems used by all did not properly tackle/address concerns and needs unique to each user. In alignment with these findings, there was a general consensus among nurses in Kerman that there really was "no incentive to use [these] system[s]". Ahmadian et al. attributes this particular finding to many issues that were associated with the earliest models of these systems that were introduced to hospitals in Kerman, particularly lowered speeds and overall anxiety and unawareness surrounding the systems' safety and legal issues. This seems to stem from a lack of input of user needs and concerns into the process of implementing these systems in hospitals, and the unpredictable tendencies of these systems to crash or slow down – which can be detrimental to overall patient care. Motivation for

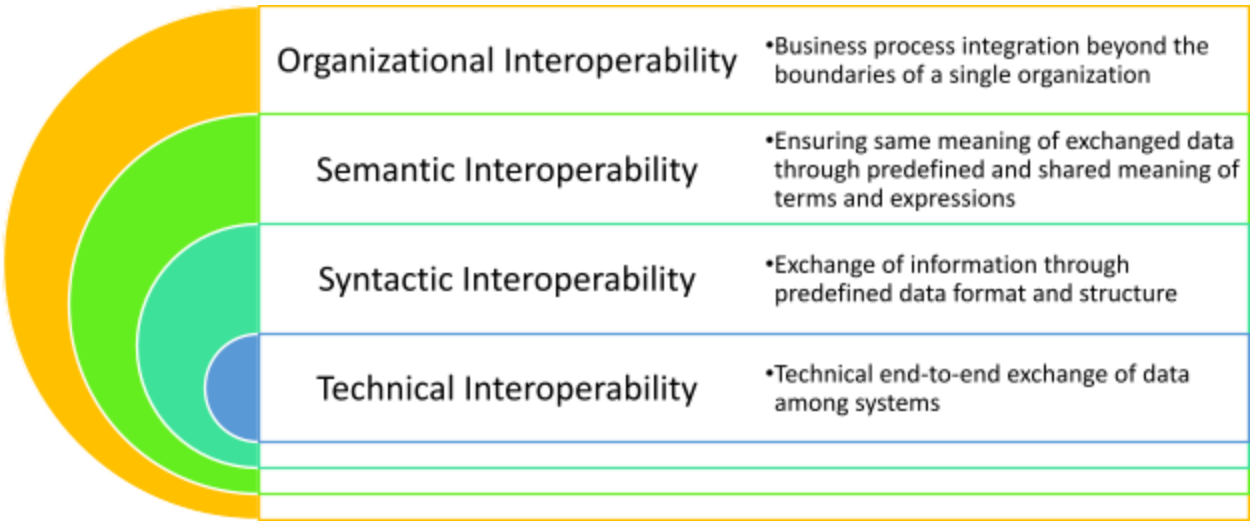
medical professionals to use these systems would increase across the board if such issues are addressed.

Interoperability of databases

Medical professionals routinely face usability challenges with using and interacting with electronic healthcare databases. On a more macroscopic level, unrelated hospital systems that rely on different database schemas face challenges in transferring data and information from one to the next. Hence, hospitals here in the US and across the globe face issues of interoperability amongst their differential databases. Interoperability refers to the ease/ability at which two or more disparate components, applications, or systems can exchange and use each other's information (Bhartiya et al., 2016). The better the interoperability of two or more disparate systems, the more easily information can be accessed and transmitted amongst them, which is why discussions of interoperability are so relevant to the topic of healthcare databases. Particularly, there is a widespread lack of centralized data sharing across such databases, which forces hospital staff across organizations to rely on unsafe and inefficient methods of sharing information (Iroju et al., 2013). Medical staff have reported having to use fax, snail mail, email, and even records on CD-ROMs shipped via FedEx just to deliver information. Hence, lack of interoperability in the healthcare domain leads to increase in costs and an increase in medical errors at hospitals (Zeinali et al., 2016). In fact, according to a 1999 statistic, up to 98,000 people pass away each year in hospitals due to errors that cost almost $29 billion annually, with almost 75% of these errors being implicated, in some way, by the lack of proper implementation of interoperability procedures (Folmer & Verhoosel, 2011).

Figure 1

Levels of Interoperability



Note. This figure was provided by Iroju et al. 2013, and it summarizes the different levels of interoperability. Reprinted from "Interoperability in Healthcare: Benefits, Challenges and Resolutions", by Iroju, Iroju & Soriyan, Abimbola & Gambo, Ishaya & Olaleke, J., 2016, *International Journal of Innovation and Applied Studies*.

There are four different levels of interoperability – technical, syntactic, semantic, and organization -- as summarized in Figure 1. For the purposes of this paper, I shall be focusing on merely semantic interoperability. Semantic interoperability refers to enabling different healthcare systems to interpret the information being exchanged. Interoperability at this level implies that a common, agreed upon set of protocols and standards for data sharing exists among these disparate healthcare systems. This level of interoperability provides the simplest definition for interoperability amongst disparate hospital systems. However, it is beneficial to keep in mind

that success of interoperability at all levels – from technical to organizational – is the most ideal scenario.

According to Iroju et al. (2013), there are a variety of means through which interoperability can be improved. To start with, there are a few basic criteria that must be met for interoperability to be considered successful. These include facilitating easier access to patient records, enabling easier comprehension of medical terms shared amongst different organizations participating in data sharing, significantly reducing medical errors (as interoperability of the overall system ensures data is stored/shared in accurate and consistent formats), and reducing overall healthcare costs. It should also successfully integrate health-related records into the system. Additionally, an interoperable system should also lead to enhanced support for the management of chronic diseases; it should make it easier for patients to find information relating that would help them prevent such conditions, as oftentimes these conditions are easily preventable with the right information and treatment given at the right particular times. Nonetheless, Iroju et al. identify that there still exist a number of barriers that prevent all this from happening so easily. These barriers include (but not limited to) complexity of the healthcare domain, issues/politics surrounding standardization in healthcare, use of incompatible clinical ontologies/terminologies that differ from one organization to the next, and general resistance to change (Iroju et al., 2013).

It is evident from most of these studies that researchers tend to attribute most of the shortcomings of the technological side of the healthcare domain to issues rooted in organizational politics/semantics and lack of proper technological infrastructure. However, this viewpoint leaves out critical analysis of how the design and development of these database systems oftentimes fail to take the needs/concerns of users, which in this case is external hospital

organizations who need to participate in data sharing. I will analyze how failures in designing these systems for users is a major component that drives lack of interoperability and lack of usability of these complex technological systems in healthcare in order to argue for a need to reform these systems, for both users and hospitals.

STS Conceptual Framework and Analysis

The science, technology, and society (STS) framework of user configuration allows us to properly analyze the factors that underpin failings of electronic healthcare database systems, particularly the lack of interoperability. With this framework, these issues can be contextualized within the realm of just how users interact with such vast systems. The design of any technological system should organically account for the needs and abilities for all of its users. The idea of user configuration covers the processes of developing user identities as well as defining and constraining user behavior within reasonable measures in relation to a particular technology. At its crux, it's a sum analysis for the relationship between system and user, and the design process behind these novel interactions. I will elaborate upon Steve Woolgar's idea of User Configuration to analyze the shortcomings of healthcare database systems, and how these can affect each of its different user classes.

According to Steve Woolgar (1991), user configuration involves defining the identities of putative users and setting reasonable constraints on their probable future actions via conscious design of a given technological artifact. As a result, the machine in question can be defined by its relationship with its users. Woolgar highlights the importance of usability trials in discerning and delimiting boundaries for both the machine and its users, and as a result, configuring both the user and the machine in the process. According to Lindsay (2003), while the real-life users

matter immensely in the design of technology, the designers' ideas about a systems' users or – more simply put – user representations are as equally important in crafting the relationships between users and technology. Woolgar states how human behavior will oftentimes be unpredictable, so trying to cover for every possible usability case is mentally taxing for the designer. As a result, setting constraints on user behavior should always be a guarantee while designing any type of technology.

Achieving the perfect balance between setting user constraints and meeting user needs is always a challenge for anyone designing a piece of technology. Hence, it should intuitively follow that this problem is only exacerbated by the increasing complexity of the technological artifact in question, which is undeniably the case for healthcare database systems. However, I argue that for the case of these particular systems, current issues arise from a surprising lack of proper, in depth analysis and consideration of user needs while developing and implementing these systems -- insufficient for the complexity of healthcare database systems. This leads to improper and oftentimes imprecise user and technological configurations. In the analysis that follows, I will attempt to explain how such is the case for two different user classes of such technologies: medical professionals and external hospital systems.

User Case 1: Medical Professionals

Implementing successful healthcare database systems requires expertise from both non-medical and medical professionals. Non-medical professionals, such as hospitals administrative officials and IT personnel, are required to oversee that the implementation and integration of such complicated systems happens as successfully and as seamlessly as possible. Medical professionals, such as doctors and nurses, are needed to provide their input and opinions

on the systems (that they will mostly be using) as well as participate in usability testing; in fact, medical professionals are vital as it is their very concerns and needs that the systems being implemented should strive to account for (Sittig & Singh, 2010).

However, as stated prior, system designers and implementers often fail to involve these vital concerns of the medical professionals into the systems they are implementing. This boils down to a matter of failure to properly orient and configure medical professionals to the database systems. According to Staggers et al. (2018), a variety of medical experts ranging from nurses to nursing researchers have identified a number of user experience pain points and usability issues when it comes to using these systems in hospital settings. For example, there is a general consensus that current electronic database designs, particularly the designs of electronic health records, do not support or mimic the workflows that caregivers are accustomed to – a viewpoint similarly expressed in the Ahmadian et al. study previously mentioned.

Most nurses in long-term care units are assigned groups of patients that they need to care for, but most of the health record systems they use are only designed for "single patient views in a linear workflow model," according to Staggers et al., which usually forces these nurses to utilize additional resources to support their work, such as paper or memory. Needless to say, usage of paper or memory in a technical setting is grossly inappropriate and highlights rampant issues with the system in play. One can assume that the designers of these systems perhaps did not properly orient nurses and other medical professionals to successfully using their systems, otherwise they would not have to rely on paper and memory. The reason for such failures, in general, can be due to the fact that most of those in charge of designing and implementing these systems, such as the hospital administrative officials, are usually concerned with limiting cost and improving efficiency of these systems (Amaechi et al., 2018). As a result (either

intentionally or unintentionally), they end up designing a system that limits user behavior to the point where the users themselves could not even consider the system wholly functional for their particular needs. This problem could have been easily averted had input from the nurses who would be using these systems were properly heeded and accounted for during the design and implementation process, such as through proper usability testing, and with better training/orientation to these systems – remarks that the nurses in this particular study had expressed.

User Case 2: External Hospital Systems

In the United States, there is no concrete federal legislation that mandates how hospitals can set up their databases (Iroju et al., 2013). As a result, administrative officials running these hospitals feel empowered to choose their own database system designs and interfaces, which can differ greatly from one hospital to the next. From this arises the problem of lack of interoperability across these disparate organizations, as stated previously. This is responsible for a number of issues, including significant gaps in care coordination from one hospital to the next and inefficient processes (Iroju et al., 2013; Samal et al., 2016).

The question arises why external hospital systems should be considered a user class in this instance. Since most hospitals do depend on data being shared with them from other health institutions, their respective organizational behaviors are in ways limited by how the institutions they depend on choose to design and set up their database systems and health record formats. Hence, in a sense, the behaviors of these disparate organizations are constantly being configured by one another so that the immense amount of data that can be shared amongst all of them; in this more macroscopic sense, hospital systems can act as both the designer as well as the user.

They have to constantly adjust and adapt their data processing and sharing behaviors for each distinct hospital organization they have to interact with (Samal et al., 2016).

Hence, this often leads to mass confusions and hysteria on many different operating levels across all these participating private institutions, and usually, it's the nurses themselves who are essentially forced to become the human integrator among all these disparate systems (Staggers et al., 2018). The gross lack of interoperability results in highly fragmented systems that, once again, combine paper, electronics, and human memory, which is obviously prone to considerable rates of error and inaccuracies. Needless to say, all these issues dependent upon interoperability have led to lowered efficiency and efficacy of healthcare across every institution.

These widespread failures of interoperability can be attributed to faults in the way that the designers of each individual system define their user classes. Usually, hospital administrative officials and IT specialists in charge of creating and implementing these systems at each separate hospital limit their definition of user to all entities and personnel who are directly affiliated with the system, such as the medical professionals working there, and usually not officials and medical professionals working at other institutions. Much like issues surrounding usability of the database systems by medical professionals, there is clearly a disconnect between how designers think about the ideal users as opposed to who the actual, real users happen to be. Hence, not much forethought or investments (of time, effort, and money) is given during the actual design process towards developing/coordinating proper standards, technical infrastructure, and protocols for improving data sharing and consumption processes across these different organizations, usually termed as service-oriented architecture (Crichton, 2013).

In places like Australia and Europe, the opposite is true. Hospitals in these places utilize service-oriented architecture to solve these issues of interoperability, which has shown immense

improvements in the way healthcare functions in these places since implementation (Hägglund et al., 2007). One of the prime benefits of service-oriented architecture is that it still allows these different hospital systems to keep utilizing their different database system design formats, as this type of architecture refers to a common set of tools connecting the database systems of all participating institutions to ensure consistency and efficiency of data sharing. The lack of implementation of such architecture here in the United States reflects issues of how designers of these systems define their putative users (each other). This ultimately leads to these technical, semantic, and organizational issues with how external users configure their behaviors to ensure data sharing can still take place. Recognition of the collective need for service-oriented architecture across all these participating private institutions should rectify these issues, and in the process, potentially make the lives of both medical and non-medical professionals run more efficiently.

Conclusion

Electronic healthcare database systems have many benefits. Some of which include standardized protocol for patient data storage and reduced human errors from lack of legibility of notes and so forth. However, while replacing now archaic forms of data storage and processing, these systems have introduced novel issues that were previously unforeseen. Mainly, medical professionals across the board who don't have much technical experience have reported many pains and struggles with using these systems, which have in many cases, hindered their abilities to deliver proper medical care to their patients. A related issue that is experienced by non-medical professionals as well (such as administrative officials and IT personnel) is the topic of interoperability across disparate database systems – a vital requirement as the success of

almost every hospital depends on the continuous sharing and processing of data amongst all of them.

As multiple studies have indicated, these issues ultimately stem from faults in the ways that designers of such complicated systems think about their users. For both issues of usability and interoperability, there are alarming discrepancies between who the designers define their ideal users to be versus who the real-life, actual users of these systems happen to be. At the level of individual hospitals, usability issues stem from administrative officials and IT personnel in charge of developing and implementing the systems failing to involve medical professionals into the process. Across disparate hospital systems, interoperability issues stem from officials at individual healthcare systems failing to recognize professionals at external hospital systems as also being users of their systems, particularly of the data that each system stores. While it is true that these issues oftentimes stem from inter-organizational politics and lack of proper technological infrastructure, this is a narrow viewpoint. It fails to acknowledge the actual users of these systems and their various concerns and needs. Further research, reassessment, and redesign is needed to create and adopt solutions that will work for both medical professionals and hospital systems at large. One possibility could be putting a greater focus on service-oriented architecture as a way to improve the usability and interoperability of current technologies in place. With any technology being implemented, however, discussions of users and their needs/abilities should always be imperative in order to properly configure them – in hopes of improving healthcare across the board.

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