eHEALTH
Transporting Information to Transform Health Care

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Abstract: The 'e' in eBusiness, eCommerce, eGovernment, and eHealth represents the transformation of the traditional domains by the current ability to transport information using information and communication technologies. In this paper we present an ontological analysis of the transformation of health care by eHealth. The five dimensions of the ontology are derived by parsing the definition of eHealth as 'transporting information to transform health care'. They are: (a) information, (b) spatial transportation, (c) temporal transportation, (d) semiotic transportation, and (e) health care. Each dimension is defined by a taxonomy. Each sentence, formed by concatenating categories across the five dimensions using appropriate conjunctive words and phrases, is a natural language descriptor of eHealth. The set of all such sentences is a closed description of eHealth.

1 INTRODUCTION

Health care, at its core, is information intensive. For example, the physician-patient encounter (Ramaprasad and Johnson 2000), Magnetic Resonance Imaging (MRI), modern genetic research (Ambrose, Ramaprasad et al. 2003), and the administration of health care benefits require rich and voluminous information exchange. Not surprisingly, information and communication technologies have transformed health care and continue to do so. They hold the promise of transforming it even more radically in the near future. eHealth is the application of these technologies to transport information to transform health care to make it more efficient and effective (Eng, Maxfield et al. 1998; Weber 1999; Johnson, Kumar et al. 2000; U.S. Department of Health and Human Services 2000; Eng 2001; U.S. Department of Commerce 2002; Ortiz and Clancy 2003; Boulos 2004; Oh, Rizo et al. 2005; Valenta, Brooks et al. 2007).

The research and practitioner literature on eHealth is vast and growing rapidly (Oh, Rizo et al. 2005). Its size and the rate of growth attest to eHealth's importance. However, they also make it difficult to systematically synthesize, interpret, and apply it to the design and development of eHealth systems. We address the complexity using an ontology derived by parsing the definition of eHealth as 'transporting information to transform health care.' We synthesize (a) the extant academic and practitioner literature on eHealth, and (b) insights from an industry-university forum on the topic conducted in 2005 over a six-month period, using the ontology.

In the following we will first present the ontology derived by parsing our definition of eHealth. Then, we will discuss the topics corresponding to the ontology in the following sequence: (a) transporting personal, medical, and business information; (b) transporting information spatially, temporally, and semiotically; (c) transforming health care outcomes, quality, management, and knowledge use; and (d) transporting information to transform health care.

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2 ONTOLOGY

The ontology we use for the analysis of eHealth has five dimensions, namely: (a) information, (b) spatial transportation, (c) temporal transportation, (d) semiotic transportation, and (e) health care. The logic of the derivation of the dimensions from the definition of 'transporting information to transform health care' should be intuitively clear. We have deconstructed transportation into three dimensions: (a) spatial transportation, (b) temporal transportation, and (c) semiotic transportation. Information and health care have been retained as such.

The five dimensions and their corresponding taxonomies are shown in Figure 1 above and discussed below. The alternative conjunctive words to concatenate two adjacent columns are shown between the columns. The right word makes the concatenations across dimensions natural and understandable. Five illustrative combinations are shown at the bottom of the figure. The ontology as presented can be expanded into 7*8*6*5*8 = 13,440 combinations. The above representation is a concise way of representing them and analyzing them systematically. A listing of all the combinations would likely take more than 200 pages.

3 TRANSPORTING PERSONAL, MEDICAL, AND BUSINESS INFORMATION

In keeping with the actuality (Cicmil, Williams et al. 2006) of eHealth we have chosen a very simple and practical two-level taxonomy of information. It has three categories: (a) personal, (b) medical, and (c) business information. Personal information is categorized as health related and non-health related; medical information as care related and research related; and business information as financial, administrative, and regulatory.

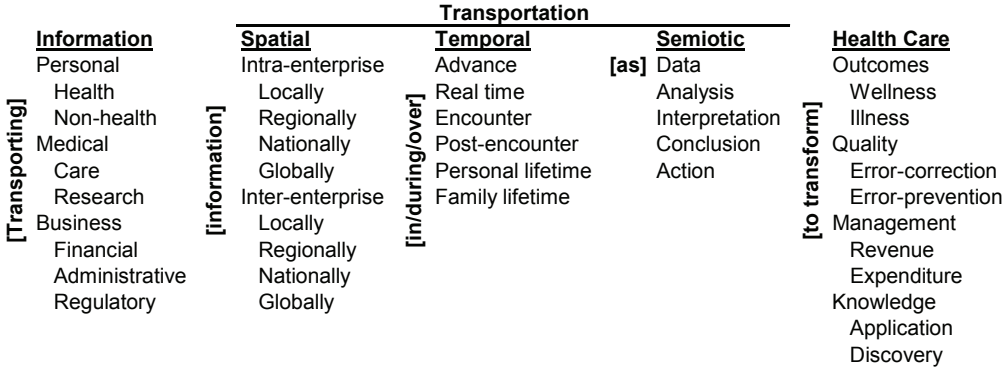
Personal information pertains to individuals whose health care is the object of eHealth. It is information possessed, owned, stored, and managed by the individual. At a minimum it consists of information to uniquely identify the individual; at the maximum it is a complete personal health and non-health record of the individual over his or her lifetime.

The availability of timely, reliable, and valid personal information can significantly affect health care outcomes and quality. An eHealth system should ideally help transport the right personal information to the right place at the right time. An eHealth system should ideally help transport the right medical information to the right place at the right time (Ambrose, Ramaprasad et al. 2003).

Medical care information, in contrast to personal health information, can be defined as "the clinician's record of patient encounter-related information … which is managed by the clinician and/or health care institution." (Tang, Ash et al. 2006, p. 122) Over time there may be considerable overlap between the two. Ideally with eHealth there should be "an environment in which health information about an individual can flow seamlessly among systems used by authorized health professionals, caregivers, and the patient, when the patient authorizes such sharing." (Tang, Ash et al. 2006, p.122)

Medical research information pertains to the research relevant to the health of the person. The rapid advances in medical research and the advent of evidence-based medicine (Rosenberg and Donald 1995; Elstein 2004) make the transportation of medical research critical for health care. "Evidence based medicine is the process of systematically finding, appraising, and using contemporaneous research findings as the basis for clinical decisions." (Rosenberg and Donald 1995, p.1122) The accessibility of medical research information to the public through the internet (Weber 1999; Tufts Managed Care Institute 2001; U.S. Department of Commerce 2002) is also major motivator for transporting such information. At the same time, in the spirit of becoming informed patients (Detmer, P.D.Singleton et al. 2003; Henwood, Wyatt et al. 2003), many people are informing themselves about illnesses, their characteristics, causes, and cures through publicly accessible information and consequently changing the dynamics of the interaction between the health care receivers(patients, their family and friends, etc.) and the health care providers (physicians, nurses, social workers, etc.). The transportation of current research information to health care providers in remote areas without easy access to libraries is also playing an important role in reducing the gap between the care in rich and poor locations within a country and among countries.

Business information includes financial, regulatory, and administrative information related to health care. These three categories of information are particularly important for managing the revenues and expenditures and the overall quality of care. Examples of the three categories of information are: (a) billing information, (b) Medicare/Medicaid



Illustrative combinations

Transporting personal health information intra-enterprise locally in real time as data to transform outcomes of wellness.
Transporting medical research information inter-enterprise nationally in advance as action to transform outcomes of illness.
Transporting business financial intra-enterprise regionally in real time as data to transform management of revenue.
Transporting personal health information inter-enterprise globally in personal lifetime as knowledge to transform quality through error-prevention.
Transporting medical care information inter-enterprise nationally post-episode as data to transform knowledge application.

Figure 1: eHealth Ontology.

regulations, and (c) appointments scheduling information, respectively. Multiple stakeholders are responsible for the generation and dissipation of this information. Thus transportation of the information across the network of stakeholders is critical to the success of health care.

4 TRANSPORTING INFORMATION SPATIALLY, TEMPORALLY, AND SEMIOTICALLY

Transportation usually connotes spatial movement – from one location to another. In addition, in eHealth it is necessary to consider temporal and semiotic transportation. In the following we discuss the three transportation dimensions.

4.1 Spatial Transportation

Spatial transportation, as the name suggests, is the movement of information over physical distances. It is essential for eHealth because the individuals receiving care, the providers, employers, insurers, regulators, and suppliers are geographically distributed. Today, with the internet there is a rising expectation of services to be provided 'anytime, anywhere'. The spatial dimension addresses the 'anywhere' expectation of health care services. Progression along the spatial dimension can be viewed as local, regional, national, and global or based on the enterprise as intra-enterprise and inter-enterprise.

The broad presumption of movement along the spatial dimension is to reduce the location dependence of health care services(Ambrose, Ramaprasad et al. 2003). Not only should the consumer be able to avail of the services 'anywhere', but any health care facility in the geographical domain should be able to deliver the services 'anywhere'. Moreover, broader geographic domains can improve the effectiveness of sentinel public health systems for recognizing epidemic outbreaks or terror attacks. For example, RFID tags are being used for injured soldiers during Iraq war as a way of storing personal health information and transporting the same to the military base hospital (even before the soldiers are transported there) (Chaiken 2004).

The key issues associated with spatial transportation are of connectivity, interoperability, security, and legality. They are a combination of technological, organizational, and policy issues. The emergence of HIEs (Health Information Exchange) and RHIOs (Regional Health Information Organization) is an example of the progression, at least in concept, along the geographical domain. On the other hand, countries such as the UK are establishing a national domain.

Another key component in the transformation of health care is the shift in locus of care: where and when the care is delivered. Homes, for example have become significant locus of postoperative recovery instead of extended hospital stays. They have also become important locus of chronic disease management and psychological counseling. Shopping malls, on the other hand, are emerging has locus of health checkups. The ability to transport information over geographical domains – between hospitals, clinics, laboratories, homes, pharmacies, and employers – is a key catalyst of the changing profile of the locus of health care. Thus consumers may soon expect that the care be centered on them, and that it be delivered wherever they are located, whenever they desire, and by whomever they chose based on performance – just as with travel services and books stores.

4.2 Temporal Transportation

In spatial transportation time is a factor only in terms of measuring the speed of the movement. In eHealth it is not enough to consider time simply as the denominator for measuring the rate of spatial movement. It is necessary to consider temporal transportation as a separate dimension to explicitly incorporate the longitudinal characteristics of health care and the associated transportation of information over time. Personal history, family history, treatment history, a disease epidemic, the presentation of a disease, etc. are all longitudinal. They occur over time and many subsequent events are likely to be related to or dependent upon preceding events. Without reliable, valid, and timely information about the past the care of a person's health can be adversely affected.

Temporal transportation, as the label suggests, is the movement of information over time. The temporal dimension of the information may range from advance information, real time information, encounter information, post-encounter information, personal lifetime information, to the family lifetime information. In the near future it may stretch to ancestral information. The problem of temporal transportation is to continuously incorporate current data in a life-cycle record, and to ensure that the latter is always complete, accurate, and accessible.

The temporality of the information available at the time of service can have a significant impact upon its outcomes and quality. It is generally assumed that 'larger the temporal domain the better', both for prevention and treatment of serious conditions. A paramedic at the scene of an accident has information only about the current state; his performance can be improved significantly if he or she can access the patient's history remotely from the scene or by reading off a smart-card carried by the victim.

4.3 Semiotic Transportation

Last, but not the least, the process of extracting value from health care information (personal, medical, and business) and using it to improve health care is semiotic. It is the process of discovering relationships, interpreting their meaning, framing it in a particular context, and translating into action. The transportation of information across the semiotic layers (morphology, syntax, semantics, and pragmatics) is semiotic transportation (Ramaprasad and Rai 1996; Ramaprasad and Ambrose 1999; Ambrose, Ramaprasad et al. 2003; Payne, Mendonca et al. 2007).

Semiotic transportation is the movement of information along the semiotic ladder to generate knowledge and action based on the data. Such transportation, for example, is embodied in the processes of data mining, knowledge discovery, clinical translation, and knowledge supply network (Mak and Ramaprasad 2003). It is the method of extracting knowledge- and action-value from data. The progression along the semiotic domain can be labeled as: (a) formalizing the data morphology, (b) discovering the relationships within the data, (c) interpreting the meaning of the relationships, (d) framing the meaning in context to generate knowledge, and (e) based on the knowledge determining the appropriate action. Thus information can be transported as data, analysis of the data, the interpretation of the analysis, conclusion based on the interpretation, or action recommendations based on the conclusion. The medium and the method of transporting at different semiotic levels can vary considerably. A journal article abstract may be sufficient to transport the conclusions and action; a high speed network may be needed to transport the raw data on medical research or business finances.

The heavy emphasis on data-driven practices such as evidence-based medicine, fact-based management, and balanced score-cards to ensure the quality of health care service have played a key role in the emergence of the importance of semiotic transportation. The availability of large volumes of data and the ability to transport them over space and time have also contributed to the increased value of

semiotic transportation. Many business and business units specialize in semiotic services.

Accompanying the shift in the locus of care described under spatial transportation but different from it is the shift in the locus of control. Control is being shifted increasingly from the care-giver to the care-receiver (Laine and Davidoff 1996; Bloche 2006). The physician, for example, has to help the patient make an informed decision, and not make the decision for the patient (Detmer, P.D.Singleton et al. 2003; Henwood, Wyatt et al. 2003; Elstein 2004). While the responsibility for informing the patient in the past rested primarily with the physician, patients today are assuming the responsibility themselves, and other stakeholders such as employers and payers are actively increasing their role in doing so. Thus at the core the locus of control is shifting from the care-giver to the care-receiver, aided by the concerted efforts of all the stakeholders to inform the care-receiver and reinforce the shift in the locus of control. They are being manifest in the Consumer Driven Health Care (CDHC), Health Service Accounts (HSAs), and patient empowerment. This shift mirrors the shift in other service industries, although not to the same extent – from 'full-service' to 'self-service' – you pump your own gas, conduct your own banking transactions, and book you own airline tickets. This shift has increased the importance of semiotic transportation required to inform the care-receivers about the problems, the treatments, the risks, and the outcomes. The emergence of web portals like WebMD to translate medical research and terminology for the lay person and to help them make decisions is an example of the emerging role of semiotic transportation in eHealth. Another example is the emergence of personal health information management tools such as Personal Health Records (PHRs) that enabled the patients to access and track their health records and be more informed about their diseases and conditions (Pratt, Unruh et al. 2006).

5 TRANSFORMING HEALTH CARE

Transforming the quality of care and the cost of care have become the Yin and Yang of health care. There is a symbiotic relationship between the two. The success of both transformations is dependent upon the efficient, effective, and error-free transportation of information – albeit different information spatially, temporally, and semiotically.

For quality, errors have to be eliminated, detected, prevented, or corrected. To eliminate an error is to design the system such that the error cannot occur. To prevent an error it has to be detected ahead of time; earlier the detection the greater the chance of prevention. The occurrence of an error is a failure of prevention. To correct an error it is best to detect it soon after it occurs; later the detection the lower the chance of correction. The absence of an error, it must be noted, may reflect effective prevention or ineffective detection.

To transform quality is to eliminate errors. Or, if they cannot be eliminated they have to be prevented. Further, if they cannot be prevented they have to be detected and corrected with minimum delay. To eliminate errors is also to learn from ones that have been corrected and prevented in the past and to eliminate them in the future. As with the other aspects of the transformation of health care the problem of transforming quality devolves to one of systematically managing complex information in a complex environment. One has to learn from the past, discovering knowledge from ones experience and others', and apply it to the future.

To manage health care cost is to manage information about the value of resources used to provide the service. Today's information systems provide the ability to monitor and control costs at a very micro level. The cost information also allows one to analyze and reengineer health care processes and therefore the cost structures. The transformation in the cost of health care will be catalyzed by the deep understanding of the micro cost structure and the consequent reengineering of the macro policies, procedures, and practices.

While the key components of the transformation of health care costs are known, the paucity of data is a significant barrier. Performance data on hospitals, individual physicians and on other health care providers are often unavailable in spite of the evidence that such data could lead to quality improvement (Marshall, Shekelle et al. 2000). Hospital costs, for example, are easier to obtain than ambulatory care costs. Employers, for example, have difficulty obtaining data about their employees. Consequently, acquisition of cost data at the greatest level of detail and transporting them among the entities and across the domains will be critical to transforming the cost of health care.

Ultimately to transform health care outcomes an organization has to be a learning organization – discovering knowledge from its own experience and others' and applying it to transforming its practices. This deliberate and conscious discovery and

application of knowledge can only be possible if there is an efficient and effective method for transporting personal, medical, and business information spatially, temporally, and semiotically. That is the challenge of eHealth.

6 TRANSPORTING INFORMATION TO TRANSFORM HEALTH CARE

Consider the five illustrative combinations at the bottom of Figure 1. They are natural language descriptions of the functions of eHealth. Although a little awkward grammatically, they make sense and can be related to specific requirements of ehealth. The first sentence relates to the need to obtain a person's health information in real time for ambulatory preventive care; the second to the need to disseminate medical research information on a disease nationally to all stakeholders to manage the outcomes of a potential epidemic; the third to revenue management in real time through collaboration between multiple branches of a health care organization in a region; the fourth to a person being able to obtain appropriate care globally without fear of errors due to ignorance of a person's medical history; and the fifth to monitor the effects of a new drug after it has been introduced in the market. The operational needs of eHealth mentioned above are not the only ones to which the five sentences apply. A sentence can connote many needs. There are 13,435 similar sentences which can be constructed from the ontology. Each of these sentences can connote a number of operational needs. No one system is likely to fulfill all the requirements connoted by all the sentences. On the other hand, a selection of sentences can be a high level description of the requirements of an eHealth system.

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