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Fred K. Weigel
United States Army, fred-weigel@us.army.mil

R. Kelly Rainer Jr.

Benjamin T. Hazen

Casey G. Cegielski

F. Nelson Ford

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Fred K. Weigel

Army-Baylor Graduate Program in Health and Business Administration, Baylor University

fred-weigel@us.army.mil

R. Kelly Rainer, Jr.

Department of Supply Chain and Information Systems Management, Auburn University

Benjamin T. Hazen

Department of Supply Chain and Information Systems Management, Auburn University

Casey G. Cegielski

Department of Supply Chain and Information Systems Management, Auburn University

F. Nelson Ford

Department of Supply Chain and Information Systems Management, Auburn University

Abstract:

With rapid improvements in technology, the ever-pressing need to reduce healthcare costs, and continuing legislation emphasizing medical reforms, the demand for research within the healthcare/information systems interface is growing. In this study, we ascertain the prevalent themes from the extant medical informatics literature in an effort to motivate research beyond the traditional domain of health information technology research so information systems scholars can better understand where their expertise might contribute to advancements in healthcare. We used a quantitative content analysis method to systematically explore 2,188 article texts from journals in medical informatics, medicine, and MIS published over a ten-year period. Texts were analyzed using centering resonance analysis and factor analysis and the following themes emerged from the literature: Analytics; Healthcare Operations and Standards (with sub-themes: Operations, Project Management, and Information Assurance); Knowledge Transfer/Communication (with sub-themes: Extending beyond the Organization, Internal to the Organization, and Patient-Provider); Perceptions and Managing Expectations of Information Technology; Advancements in Research; and Software as a Service. In this article, we discuss these themes in greater detail and offer directions for future research.

Keywords: medical informatics; content analysis; centering resonance analysis

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I. INTRODUCTION

Providing adequate healthcare to the populace is an increasingly difficult task. Healthcare providers contend with an array of issues, such as ever-increasing costs, restrictive regulations, and medical identity theft. Other unique challenges include patient access to a virtually limitless supply of frequently contradictory medical information available via the Internet [Damman, 2010] and minimal standardization across healthcare facilities [Weigel, Landrum and Hall, 2009]. Healthcare professionals, government agencies, and other entities recognize that much of healthcare providers' time is increasingly spent on activities related to the use of information systems (IS) [Jones, Heaton, Rudin and Schneider, 2012; Shortliffe, Perreault, Widerhold and Fagan, 2001]. Herein lies the field of medical informatics, which is positioned at the intersection of healthcare and IS. Medical informatics is a field that some suggest struggles with its identity; some scholars question where in science medical informatics should be positioned while others question whether it should be considered a distinct field at all [DeShazo, LaVallie and Wolf, 2009]. In this study, we are not concerned with how medical informatics is received or where in science it belongs. Rather, we recognize that there is a dire need for timely, high-quality research within the interface of IS and healthcare.

Current research within this cross-functional interface is focused largely on what has been termed "health information technology (HIT)," which is generally concerned with health records and data exchange [Blumenthal and Glaser, 2007]. Unfortunately, a review of the management information systems (MIS) literature indicates that the recent contributions of IS scholars are focused largely on just this one facet of healthcare [Anderson and Agarwal, 2011; Angst and Agarwal, 2009; Burkhard, Schooley, Dawson and Horan, 2009; Goh, Gao and Agarwal, 2011; Ilie, Van Slyke, Parikh and Courtney, 2009; Oborn, Barrett and Davidson, 2011; Ozdemir, Barron and Bandyopadyay, 2011; Venkatesh, Zhang and Sykes, 2011]. Although investigating both the implementation and impact of HIT is surely an important area of current and future research, we concur with literature that suggests the need for extending the realm of HIT research, and thus, the purview of the IS researcher [Agarwal, Gao, DesRoches and Jha, 2010]. Some areas previously identified as being in need of further research include the implications of the Internet and investigating issues from the healthcare patient perspective [Agarwal et al., 2010]. However, we believe that there is a great deal more that IS scholars may contribute to the world of medicine.

In this study, we conduct a systematic screening of the major academic sources of medical informatics literature in order to establish a baseline perspective of the extant research. The purpose of this article is to motivate cross-disciplinary scholarship in healthcare by creating a typology of topics that might be used as the basis for future investigation. To achieve this purpose, the remainder of this article is structured as follows. We begin with a review of literature and related typology studies. In hopes of also contributing to the literature in the area of content analysis methodology development [Jung, Pawlowski and Wiley-Patton, 2009; Templeton, Lee and Snyder, 2006], we then describe our quantitative content analysis method in great detail. The article concludes with a discussion of the identified research themes and implications for IS scholars who are interested in pursuing such themes.

II. THE INFORMATION SYSTEMS—HEALTHCARE INTERFACE

At its most general level, medical informatics can be described as the fusion of medicine and IS applied to enhance patient care. Anderson, Gremy, and Pages [1974] and Collen [1986] provide some of the earliest mentions of the term "medical informatics," borrowing from the French term *informatique*, a term frequently used regarding medical information science. Medical informatics is thought to include medical computing, medical data processing, medical information processing, medical computer science, medical information science, medical information systems, healthcare information systems, computer hardware and software, computer and information technology, applications of computers and data processing to the health services, and basic concepts of computer science fundamental to medicine [Collen, 1986, p. 779].

Collen's [1986] conceptualization of medical informatics and extensions thereof has endured throughout the literature [Haux, 2010; Hersh, 2009; Ronczka, 2012]. In addition, it should be noted that the context is not confined to the patient-provider relationship. Rather, medical informatics concerns the processing of data, information, and knowledge in all facets of medicine and healthcare, to include managing the healthcare enterprise and facilitating medical research and training [Haux, 2010]. In short, medical informatics addresses the application of information science and technology to any facet of medicine [Greenes and Siegel, 1987]. Considering this information, we define "medical informatics" in this article as the discipline dedicated to the systematic processing, analysis, and dissemination of health-related data through the application of digital information systems (computers) to various aspects of healthcare, research, and medicine.

Despite the almost thirty years that have passed since the first use of the term “medical informatics,” discussion regarding how to effectively study the interplay between IS and medicine continues [Haux, 2010; Hersh, 2002]. In a paper presented at the first International Conference on Information Systems, Keen [1980] explained the importance of the emerging field of MIS and its development as a standard field of scientific research. Although directed toward the MIS discipline, his exhortations readily apply to the field of medical informatics because they suggest questions in which any burgeoning discipline that lacks identity should seek answers, such as: What research themes do we see emerging? In what directions do we see the field heading? What follows is a review of literature that seeks to answer these questions.

Past Typology Studies

Past research has sought to assess and understand the structure of the medical informatics field. Limiting their analysis to medical informatics journals, Morris and McCain [1998] used cluster analysis and multidimensional scaling to identify five unified groupings of research. The five emerging themes were: (a) general medical informatics, (b) decision making, (c) biomedical computing, (d) computing in biomedical engineering, and (e) education. The education grouping was found to be relatively isolated from the other four, which, unfortunately, suggests a clear distinction between research and practice.

Additional study of the medical informatics literature has investigated authors as units of analysis in order to uncover which topics these influential scholars address [Andrews, 2003; Eggers et al., 2005; Sittig and Kaalaas-Sittig, 1995]. Considering both citations and literature content from the years 1994–2003, Eggers et al. [2005] identified prominent authors, primary topics in the field, and the relationships among them using a mix of basic analysis, content map analysis, and citation network analysis. Andrews [2003] suggested that future research might include a look at medical informatics literature as an interdisciplinary perspective—not relying solely on the medical informatics journals, but including other disciplines’ publications to explore and share knowledge across fields. As such, unlike some earlier works, Eggers et al. [2005] expanded their analysis somewhat beyond the confines of the medical informatics literature.

In an attempt to identify trends in the medical informatics literature over the previous ten-year period, Eggers et al. [2005] segregated the literature into three time periods: 1994–1997, 1998–2000, and 2001–2003. Using the Arizona Noun Phraser software to extract medical noun phrases, the content maps of the topics derived for each year group were constructed and compared. Newly emerging topics were discovered (e.g., human genome, medical imaging, neural networks, etc.) and those areas of the literature with declining growth rates (e.g., hospital information systems) were uncovered. This research identified many pattern changes among the three content maps, supporting earlier research about the fast growth and change in the medical informatics discipline.

More recently, DeShazo et al. [2009] analyzed 77,023 articles over the twenty-year period from 1987 to 2006 and performed frequency counts and citation analyses. They found that the literature base was expanding at an average growth rate of 12 percent each year. Their results suggest that medical informatics topics are found in both medical informatics-specific publications and non-medical informatics-specific publications [DeShazo et al., 2009]. While this finding may seem obvious, the relevance is that DeShazo et al. [2009] found little evidence of clearly demarcated lines between medical informatics literature and non-medical informatics literature. In addition, DeShazo et al. [2009] found that a substantial number of articles are published in journals not typically identified as publishing medical informatics research. For example, they found that over 100 journals publish at least twenty medical informatics-indexed articles per year—a stark contrast to the twenty publications Morris and McCain [1998] identified as core medical informatics publications two decades earlier.

Schuemie, Talmon, Moorman, and Kors [2009] chose a semantic approach in their investigation into the medical informatics discipline. They extracted n-grams from the combined titles and abstracts of all 6,000,000 records in the MEDLINE database for the years 1993–2008. N-grams are sequences of words that occur in the text, and often include one word (unigrams), two word (bigrams), and three word (trigrams) sequences. Upon extracting n-grams and creating profiles of the document sets for the purpose of categorization, Schuemie et al. [2009] cluster analyzed the n-grams and generated a two-dimensional depiction of the clusters’ journal titles, with the distance between journals indicating approximate dissimilarity between the n-gram profiles of each of the journals. The results of their analysis indicated a distinct set of the top sixteen journals that publish medical informatics research. Using these top journal publications, Schuemie et al. [2009] used cluster analysis to identify three predominant categories within the medical informatics domain: (a) the organization, application, and evaluation of health information systems, (b) medical knowledge representation, and (c) signal and data analysis. Using the clusters of journals they extracted in the earlier phase of the study, Schuemie et al. [2009] categorized the article counts over five three-year time periods. Basing their conclusions on this categorization and in contradiction to earlier studies, their results suggested that the topic covered in the medical informatics literature has remained relatively stable over the fifteen-year period of their study sample.

Considering studies such as those previously mentioned, Haux [2010] provides a subjective overview of the medical informatics literature. He asserts that the field is defined by its methodology and technology, its application domain, and its practical aims [Haux, 2010]. Previous research suggests that three methodological categories comprise the majority of the medical informatics literature: decision modeling, engineering modeling, and communication processes [Hasman and Haux, 2006, 2007]. These results conflict with those found in Schuemie et al. [2009], although Haux offered a caveat that "communication as well as decision processes may primarily be in research on the organization, application, and evaluation of health information systems" [2010, p. 604]. Further categorizing the literature based on the 2006 International Medical Informatics Association Yearbook of Medical Informatics, Haux offered that the application sub-domains of medical informatics can be categorized as: (a) contributing to good medicine and good health for the individual, (b) contributing to good medical and health knowledge, and (c) contributing to well-organized healthcare. In praxis, medical informatics should seek to contribute to progress in the sciences and to high-quality, efficient healthcare [Haux, 2010].

Of all of the aforementioned studies, none serve to guide scholars from outside the medical informatics field to contribute to the study of IS in healthcare or offer advice as to what topics to pursue and how to do so. Although Haux [2010] dissected the informatics literature into three overarching themes, the findings were subjective in nature and did not consider literature outside the realm of traditional medical informatics journals. Similarly, the former is also a shortcoming of Schuemie et al.'s [2009] research. Other typology studies, although useful for their intended purpose, do not offer clear insight into how researchers in the field of IS and related disciplines may contribute to the medical informatics field. Thus, the method employed in this study was chosen to fill the gaps from previous studies and offer guidance to scholars regarding research opportunities within the area of medical informatics.

III. DATA COLLECTION METHOD

The research method we chose for the study is content analysis–a data reduction technique often used with textual data to make the text more manageable for inference and analysis [Krippendorff, 2004; Weber, 1990]. Content analysis has been used in past research aimed at creating typologies or examining research directions [Tangpong, Michalisin and Melcher, 2008; Zhao, Flynn and Roth, 2007]. One of the key concepts behind content analysis is that large bodies of text are grouped into a relatively small number of categories based on some criteria so that the large bodies of text can be managed and understood. We synthesized the procedures outlined in content analysis methods literature to establish the content analysis process we performed [Corman, Kuhn, McPhee and Dooley, 2002; Krippendorff, 2004; Neuendorf, 2002]. In this section, we describe each step of this procedure.

Sampling

This study uses seven publications from which article abstracts from the period of 2002–2011 were drawn for analysis. To arrive at the sample of articles—the sampling units—we used several criteria. To determine which mainstream medical informatics journals to include in the sample, we consulted previous journal-ranking articles. Considering the work of Morris and McCain [1998], Eggers et al. [2005], DeShazo et al. [2009], and Schuemie et al. [2009], we found that the following journals were consistently given high rankings: the *Journal of the American Medical Informatics Association* (*JAMIA*) and the *International Journal of Medical Informatics* (*IJMI*). Likewise, both *JAMIA* and *IJMI* consistently receive high impact factors [LeRouge and De Leo, 2010; Wilson and Lankton, 2004]. Because these publications are part of the core medical informatics literature, all articles for the ten-year period from these journals are included in the data set.

Based on the repeated calls for analysis that extend beyond the core medical informatics journals (e.g., Andrews, 2003), our study includes articles from the medical and MIS fields. For the medical journals, we chose the *Journal of the American Medical Association* (*JAMA*) and the *New England Journal of Medicine* (*NEJM*). Using *JAMA* and *NEJM* extends the data set into the medical discipline to gain a perspective of the medical field's discussion about medical informatics. These international, peer-reviewed medical journals are some of the most widely circulated and respected medical journals in the world. In its journal, *JAMA* provides a specific section, Informatics/Internet Medicine, from which all article citation, abstract, and text information was collected for the ten-year period. *NEJM* does not have a distinct section for medical informatics research like that found at *JAMA*. Therefore, we employed an advanced query using medical informatics-related terms in Thompson Reuter's Institute for Scientific Information (ISI) Web of Science to identify articles. The ISI Web of Science provides for simultaneous searching of the Science Citation Index–Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index databases.

Management Information Systems Quarterly (*MISQ*), *Information Systems Research* (*ISR*), and *Communications of the ACM* (*CACM*) are consistently recognized as top MIS publications [Katerattanakul, Han and Hong, 2003; Lowry, Romans and Curtis, 2004; Peffers and Tang, 2003; Rainer and Miller, 2005]. Including these journals in the study provides a solid basis for understanding the MIS discipline's perspective on medical informatics. For each of the MIS publications, a query method similar to that used for the *NEJM* was employed to identify and extract articles related to healthcare and medicine.

Observational and Recording Units

While recording units are generally the smallest units of analysis in a content analysis study, the observational units range in size depending on the content being analyzed. The observational unit should be determined to achieve a balance between making it large enough to provide adequate meaning and, hence, validity, while being as small as is possible to maintain reliability. For the purpose of this study, the entire article abstract text satisfies this balance and is therefore adopted as our unit of observation.

Within these observational units, we chose an appropriate recording unit. Noun phrases are the subject or object of sentences and are comprised of at least one noun and, potentially, additional adjectives or nouns [Corman et al., 2002]. Although verb phrases, another linguistic model, provide the action in texts or conversation, the noun phrases are the only elements that can be clearly classified as singular entities in discourse [Corman et al., 2002, p. 174]; therefore, we posit that noun phrases are of greater explanatory value than are verb phrases. As such, the noun phrases were chosen as our recording units.

Data Preparation and Cleaning

We used the freeware citation manager database Zotero [2012] in conjunction with the add-on SQLite Manager [2012] to catalog and prepare the data. Next, we screened each article for appropriateness. The exclusion criteria were defined as any article texts that were clearly unrelated to medical informatics—texts that did not meet this study's definition of medical informatics nor had both IS technology and healthcare-related content. Unless the text met the exclusion criteria, we included it for further analysis. Because we sought to capture all pertinent references and extend our analysis beyond the traditional medical informatics literature, we chose to err on the side of including articles when in doubt. Table 1 summarizes the number of articles that were retained for analysis.

Table 1: Summary of Articles Retained

	Number of articles from original query	Number of articles retained	Percent retained
International Journal of Medical Informatics	966	949	98.24
Journal of the American Medical Informatics Association	812	779	95.94
Communications of the ACM	70	52	74.29
Information Systems Research	10	10	100
MIS Quarterly	19	19	100
Journal of the American Medical Association	238	238	100
New England Journal of Medicine	200	141	70.5
Total	2,315	2,188	-

IV. ANALYSIS AND RESULTS

Our chosen data analysis method, centering resonance analysis, is purported to be a useful tool for analyzing large amounts of textual content [Gasiorek, Giles, Holtgraves and Robbins, 2012; Willis and Miertschin, 2010]. Centering resonance analysis is a means of text analysis based on noun phrases and has been used in studies across a variety of academic disciplines [Canary and Jennings, 2008; McLaren and Manatsa, 2011; Papacharissi and de Fatima Olivera, 2012; Rossetti, Handfield and Dooley, 2011]. A noun phrase is "a noun plus zero or more additional nouns and/or adjectives, which serves as the subject or object of a sentence" [Corman et al., 2002, p. 174]. Centering resonance analysis is grounded in centering theory, which derives its name from the concept that authors focus their written statements around centers—words or noun phrases that form the subjects of the discussion. These centers connect to previous centers and subsequent centers to form a cohesive network of speech. Centering resonance analysis identifies discursively important words and represents these words as a network. It then uses the structural properties of the network to index the importance of each word and draw comparisons across networks [Corman et al., 2002; Mcphee, Corman and Dooley, 2002]. The word networks created with centering resonance analysis illuminate influential words, which "facilitate the connection of meaning among many different words, across very different parts of the overall word network" [Mcphee et al., 2002, p. 278], and are "very rich data structures that preserve significantly more information about a text than keywords or word frequency statistics" [Corman et al., 2002, p. 172].

Using the Crawdad Text Analysis System [Corman and Dooley, 2006] software, we analyzed the article data files and extrapolated three statistics: nodes, density, and group influence. The node indicates the number of centering points, or noun and noun phrases the network contains; a "node" is a point of connection within a centering resonance analysis network. The density is a ratio of the number of network connections that exist among nodes compared to the number of network connections that could possibly exist and is an indicator of how tightly connected the network is. The group influence score is an indicator of how coherent the entire network is within itself. A high group influence score indicates that the network is highly focused and centralized. Additional information regarding these statistics and how they are derived can be found in Corman et al. [2002].

In addition, we collected the top fifty influential words. The more influential the word is, the more it facilitates meaning by tying other words together in the text network [Tate, Ellram and Kirchoff, 2010]. Influence scores range from zero to one; influence values of .01 or greater are considered significant, and influence values of .05 or greater are considered very significant [Corman and Dooley, 2006]. The influence values and the top influential words provide an overview of the general themes throughout each year and can provide a basis to identify consistency of themes over the years.

Noun Phrase Network Information

The results of our network analysis can be found in Table 2 (table limited to words with influence scores of .10 or greater). In sum, we identified 17,501 nodes. The density score was .0018 and the group influence score was .0596. Both the density and group influence scores are standardized measures with minimum scores of zero and maximum scores of one. Although there are no established heuristics to assess the density and group influence scores, the lower density and group influence scores suggest that the network of noun phrases among all publications is not tightly connected and the texts are not very coherent within the network (i.e., there is much diversity in the content of the journal article texts). Additionally, we examined the data for consistency across years and between journal categories via a series of t-tests; we found no significant differences at the .05 level.

Table 2: Noun Phrase Network Information

Nodes	17,501
Density	0.0018
Group Influence	0.0596
Word	Influence
Patient	0.06
System	0.059
Information	0.034
Health	0.033
Data	0.03
Use	0.026
Study	0.025
Medical	0.024
Clinical	0.02
Care	0.018
Physician	0.015
Hospital	0.015
Model	0.013
Method	0.013
Time	0.012
Disease	0.011
Technology	0.011
Analysis	0.01
Case	0.01
New	0.01
Group	0.01

Analysis of Influential Words

To assess the underlying thematic structure of the medical informatics literature, we performed an exploratory factor analysis (EFA). The fifty most influential words were the variables, and the influence values were score values for each of the corresponding variables. The EFA was performed using principal components analysis with varimax rotation. We retained factors based on a triangulation of Velicer's [1976] minimum average partial (MAP) analysis, Horn's [1965] parallel analysis, and Kaiser's [1960] eigenvalue greater than one criterion. The resulting factor solution included seventeen factors and explained 85.85 percent of the variance (Table 3). The rotated factor loadings provided a starting point for evaluating the themes (Table 4). By convention, loadings of less than .40 were not considered [Hair Jr., Black, Babin and Anderson, 2010; Kline, 2011].

Table 3: Factor Analysis Results

Component	% of Variance	Cumulative %
1	9.64	9.64
2	6.8	16.43
3	6.61	23.04
4	5.91	28.95
5	5.83	34.78
6	5.71	40.49
7	5.66	46.15
8	5.3	51.45
9	4.43	55.88
10	4.08	59.96
11	4.03	63.99
12	3.91	67.89
13	3.87	71.76
14	3.86	75.62
15	3.85	79.47
16	3.52	82.99
17	2.86	85.85

Table 4: Factor Loadings after Rotation

Factor	Component	Loading		Factor	Component	Loading
1	Confidentiality	0.983		2	Maker	0.979
	Surveillance	0.982			HIT	0.968
	Protocol	0.965			Process	0.744
	Provider	0.781			Research	0.735
	Time	0.725		4	Computing	0.87
	Disease	0.551			Computer	0.743
3	Service	0.929			Health	0.615
	User	0.911			Medical	0.590
	Technology	0.801		6	Quality	0.873
	Risk*	0.540			Physician	0.735
5	Peer	0.956			Hospital	0.702
	Internet	0.935			Care	0.514
	Individual	0.841			Medical*	0.493
7	CT	0.778			Clinical	0.422
	Risk	0.612		8	Firm	0.951
	Method	0.562			IT	0.888
	System	0.540			Knowledge	0.651
	Patient*	0.543		10	Attitude	0.929
	Disease*	0.507			Information	0.699
	Use	0.499			Individual*	0.401
9	Result	0.842		12	Case	0.924
	Study	0.492			Process*	0.566
	Analysis*	0.434			Project*	0.564
11	Conference	0.801		14	Communication	0.856
	Data	0.796			Patient	0.582
13	Performance	0.833			Provider*	0.542
	Analysis	0.774		16	Trust	0.890
	Knowledge*	0.423			Research*	0.423
15	Management	0.973		17	Community	0.855
	Project	0.739			Use*	0.448
	Knowledge*	0.412				

Note: * indicates cross-loading; influential words “biology” and “new” did not load.

Final Theme Solution

While the EFA provides a good foundation for developing themes from the factors identified, some scholars suggest a further step—latent coding—to refine the themes [Tate et al., 2010]. Centering resonance analysis develops networks of words—specifically, nouns and noun phrases—and not networks of theoretical constructs or concepts. Secondary latent coding analysis can connect words to themes in a logical manner to strengthen the face validity of the theme [Tate et al., 2010, p. 25]. Starting with the rotated factor solution, we re-read texts from the data set that referenced the influential words in each of the factors. Based on a thorough reading of the article texts and an examination of the factor loadings, the two data sources were synthesized to express the themes of the literature. The final theme solution and the factors for each theme are presented in Table 5. In the remainder of this article, we describe these themes in greater detail and offer suggestions for future research within each.

Table 5: Final Theme Solution

Theme	Factors
Analytics	12, 13
Healthcare Operations and Standards: Operations	6
Healthcare Operations and Standards: Project Management	15
Healthcare Operations and Standards: Information Assurance	1
Advancements in Research	2, 7, 9, 16
Knowledge Transfer/Communication: Extending Beyond the Organization	11
Knowledge Transfer/Communication: Internal to the Organization	8
Knowledge Transfer/Communication: Patient-Provider	5, 14
Perceptions and Managing Expectations of Information Technology	10, 17
Software as a Service	3, 4

V. DISCUSSION

Considering Moore's law and other factors that affect the rate of technology growth, it is difficult to determine what the future holds for medical informatics. However, our analysis of the extant literature might offer some insight into areas that may be of value to investigate in the future. The medical informatics themes that emerge from the literature evaluated in our study can be categorized into the following general areas: Analytics, Healthcare Operations and Standards, Advancements in Research, Knowledge Transfer/Communication, Perceptions and Managing Expectations of Information Technology, and Software as a Service. We discuss each of these themes and their constituent sub-themes in greater detail in this section.

Healthcare Operations and Standards: Operations

Healthcare Operations and Standards can be further sub-divided to delineate the areas of Operations, Project Management, and Information Assurance. The Operations sub-category focuses on the literature that discusses the use of IS in the functions of day-to-day operations at the micro-level of patient healthcare as opposed to the organizational level. Aronsky and colleagues provide us with an example of a study involving Healthcare Operations and Standards: Operations, in their work evaluating the use of a computerized emergency department census board, a central location for patient and operational information, as a replacement for a non-digital dry erase board [Aronsky, Jones, Lanaghan and Slovis, 2008]. Other research in this area has examined how IS can be used to reduce medical errors [Aron, Dutta, Janakiraman and Pathak, 2011] or to facilitate capacity planning [Bretthauer and Cote, 1998; Smith-Daniels, Schweikhart and Smith-Daniels, 1988]. Indeed, there are many IS uses within the operational levels of the medical field. Future research can evaluate adoption of such IS as well as performance outcomes.

Healthcare Operations and Standards: Project Management

Considering the rate of technology turnover, it is not unexpected to see the necessity of professional project management in developing and implementing IS projects in the healthcare environment. The sub-theme Project Management that has emerged in the Healthcare Operations and Standards area is an indicator of this greater need. While implementing tools and services in any aspect of the healthcare process can be daunting, the rate of technology growth, concerns about information security, patient safety, patient privacy, and healthcare provider/patient relations are a few factors that exacerbate the problem for IS professionals. Indeed, as in other applications of IS, resistance to technology and adoption of systems is a key issue in this area [Kane and Labianca, 2011]. Research regarding proper project management techniques can assist in reducing the problems associated with health IS adoption and implementation [Ludwick and Doucette, 2009].

Healthcare Operations and Standards: Information Assurance

The factors that increase challenges for implementation—patient privacy, patient safety, and information security—also are factors in the area of Information Assurance, a subset of the Healthcare Operations and Standards theme. Information Assurance is defined by discussions related to the risks associated with transmitting, storing, and processing sensitive and non-sensitive healthcare data and information, and the management of said risks. Over the duration of a typical healthcare process, some hundreds of people, both direct patient care providers and non-care providers, may have access to a patient's personal digital medical information [Cannoy and Salam, 2010], thus, creating a risk of breach of patient privacy. The Health Information Portability and Accountability Act (HIPAA) established some provisions and requirements for addressing information assurance risks [Mercuri, 2004]. Georgetown University Medical Center provides another example of the Information Assurance theme emerging in their use of a self-directed risk assessment method to comply with the information security provisions of HIPAA [Collmann, Alaoui, Nguyen and Lindisch, 2005].

An additional concern for information assurance experts comes from the pervasive communications tools available to both patients and providers. How do the information assurance specialists ensure patient data and privacy security when patients and providers establish communications through the myriad of means available in today's environment of cell phones, instant messaging, email, and so on? Although this area is being addressed by IS researchers, in part, via investigation of healthcare records, this challenging area will likely remain in the forefront of medical informatics research for years to come.

Knowledge Transfer/Communication: Extending Beyond the Organization

As with the general Healthcare Operations and Standards theme, the Knowledge Transfer/Communication theme further subdivides. The inherent idea in the sub-theme Extending Beyond the Organization is that of passing information between people, groups, or elements within a healthcare organization to those outside the organization. The information transfer is usually, but not necessarily, two-way and it may be synchronous or asynchronous [Wilson, 2003]. The emergence of this theme is attributed, in part, to the spread of newer and cheaper communications technologies such as cellular/smart telephones, social media, and health/healthcare information exchanges [Shachak and Jadad, 2010]. Indeed, the effect of social media alone is so great that the American Medical Association has issued a policy statement on healthcare provider professionalism when using social media [Chretien, Azar and Kind, 2011]. Although smartphones and instant messaging are tools that provide greater access for patients to healthcare administrators and providers than has existed in the past, they also provide more complex challenges in managing the information risks [Bønes, Hasvold, Henriksen and Strandenæs, 2007; Nguyen, Fuhrer and Pasquier-Rocha, 2009]. Despite the risks, the communications technologies are great tools for including the patient more in his or her own care and we encourage more discussion of them in the medical informatics literature.

The capability to transfer patient care data electronically among various healthcare organizations is known as health information exchange (HIE). Again, current IS literature appears to address some aspects of HIE; however, with greater governmental and commercial interest in sharing data, HIE is a sought after technology in the healthcare community and there are ample indications that HIE will continue to fuel the research in this area. For instance, some recent literature addresses facets of the healthcare supply chain [Ross and Jayaraman, 2009; Shah, Goldstein, Unger and Henry, 2008; Sinha and Kohnke, 2009]; however, less literature covers the movement of information alongside the goods and services that are channeled throughout the supply chain. This area presents an opportunity for research within the interface between IS and supply chain management in a healthcare context.

Knowledge Transfer/Communication: Internal to the Organization

The second subdivision in the major theme Knowledge Transfer/Communication lies in the conveyance of information among people, groups, and other elements within an organization. While there is some overlap with Knowledge Transfer/Communication: Extending Beyond the Organization—information that has traversed the boundaries of an organization often has made the rounds within the organization—Knowledge Transfer/Communication: Internal to the Organization is a theme evident in the literature. This Internal to the Organization theme can, like the previous theme, include instant messaging, social media, and smartphones. Nevertheless, it can also include messaging designed into the electronic medical records, other healthcare systems, and other similar technologies. The effect that communications technologies has on continuity of patient care is the subject of some concern, in that while one might expect the improved technology to improve continuity of care that is not necessarily the case [Horwitz and Detsky, 2011]. Research about medical knowledge centers, repositories of medical knowledge available to assist with providers' educational and research needs, is another area that resides in the Internal to the Organization theme [Haux, Ammenwerth, Herzog and Knaup, 2002]. With continued rapid advances in communication technology, IS scholars may realize a wide variety of opportunities for research in intra-organizational knowledge transfer and communication.

Knowledge Transfer/Communication: Patient-Provider

While Patient-Provider communication as a sub-theme of Knowledge Transfer/Communication could nestle within the Knowledge Transfer/Communication: Extending Beyond the Organization theme, there was adequate literature to support the separation. As mentioned in the previous Information Assurance discussion, communications tools abound. With this abundance, research opportunities are plentiful for the medical informatics scholar. Many research questions arise such as: What are the professionally acceptable means of communication between patient-provider? How does communication method affect the patient-provider relationship? What medical knowledge can/should the provider share with the patient and how? Obviously, some topics have already been addressed—hence, the emergence of the Patient-Provider theme in the first place. These topics include whether a secure Internet-based electronic messaging system is effective for augmenting patient care in general practices [Bergmo, Kummervold, Gammon and Dahl, 2005], and investigations of patient-controlled health records, which afford patients direct access—usually via the Internet—to their health data [Bourgeois, Taylor, Emans, Nigrin and Mandl, 2008]. The use of video conferencing between patients in their homes and healthcare providers has been documented and investigated for effectiveness in patient care, thus providing another example of the extent of the Knowledge Transfer/Communication: Patient-Provider theme [Bakken et al., 2006].

Perceptions and Managing Expectations of Information Technology

Addressing user Perceptions and Managing Expectations of Information Technology is not a new theme in medical informatics or MIS. However, as technology continues to change and improve at a rapid pace, managing user perceptions and expectations becomes increasingly complex. Healthcare workers expect more from the technology they use and expect systems implementations to be performed without affecting other work. Other aspects play into the increased challenges for information managers in managing expectations of information technology. For example, the aforementioned Internet-based patient-controlled healthcare records and patient-provider messaging add a new facet: the expectations of the patients. In the past, the focus was on those within the healthcare organization—providers and staff. With more complex systems and a greater level of technology integration and communication, IS experts have to adapt to the myriad customer base. No longer is it acceptable to approach all customers with the same IT product [Bakker and Hammond, 2003]. Although this theme is established, more research is required in determining how IS managers balance the perceived needs of healthcare employees and patients themselves.

Analytics

The Analytics theme has, at its foundation, a focus on the analysis and management of medical health knowledge ideas, insights, and experiences. Aspects of the theme include healthcare applications of data mining, managing clinical information, and business intelligence approaches. With the advent of increasingly cheap data storage and the push toward electronic health data, the amount of electronic medical data available is greater than our ability to use it to maximum effectiveness in improving clinical care and operations [Ferranti, Langman, Tanaka, McCall and Ahmad, 2010]. Continued reflection and growth is necessary in the Analytics area to overcome the overwhelming volume of data available and put it to good use.

The medical informatics community has been researching methods of information retrieval for several years and we can expect that research to grow in the future [Baud and Ruch, 2002]. One such research study gave perspective on the Mayo Clinic's "Enterprise Data Trust," a collection of data to support business intelligence [Chute, Beck, Fisk and Mohr, 2010]. Another study provided a view of a hospital's transition to a new health information system with a focus on, among other things, data mining and reporting [Haug, Rocha and Evans, 2003]. The Analytic theme includes Web-based and open source tools as well [Liu, Marenco and Miller, 2006]. As long as rapid innovation continues to push down the prices for data storage and governmental and organizational entities continue the drive toward electronic health data, it is likely that scholars from several areas of the decision sciences may find ample opportunities for research within the Analytics theme.

Software as a Service

The migration of software applications from residing on the desktop computer toward residing on an in-house server or an Internet-based server is an integral aspect of the Software as a Service theme. The computing evolution cycle is reverting back toward its initial stages, when mainframes housed the applications and users used "dumb" terminals (terminals with little to no computing power) to access the mainframe. Now, the terms "thin client" and "zero client" have replaced "dumb terminal" and, with the improvement of data transfer speeds, it is becoming more efficient to manage software update and security requirements hosted on an organization's server that provides virtual software desktops to the thin clients. An extension of the server owned and managed by an organization is found in current approaches toward Internet-based hosting—the organization leases server computing resources from another organization using the Internet for access to the resources.

While centralized health data and applications are not new in health organizations, there has been a recent emergence in Internet-based, health-related software such as Microsoft's HealthVault and Google's recently discontinued Google Health [Bergmann, Bott, Pretschner and Haux, 2007; Haas, Wohlgemuth, Echizen, Sonehara and Müller, 2011; Mandl and Kohane, 2008; Simborg, 2009]. While Microsoft's and Google's offerings are primarily patient-focused, Practice Fusion, a free Web-based electronic health record, focuses on providing software as a service to healthcare providers. The growing emphasis of government and commercial entities toward electronic health data and applications, combined with improvements in computing and communications technology, suggest continued relevance of Software as a Service as a topic for IS research.

Advancements in Research

The Advancements in Research theme encompasses IS research that supports additional research within the healthcare domain. Government influence on healthcare, through regulations such as HIPAA and laws such as the recently enacted American Recovery and Reinvestment Act of 2009 (ARRA), with its specific focus on health information technology, provide ample stimulation for IS advancements in several facets of healthcare-related research [Blumenthal, 2009]. For instance, the $17 billion from the United States government to incentivize HIT will most certainly trickle down to the research community [Blumenthal, 2009]. We can expect IS scholars to continue to provide research contributions such as those provided by members of the State Networks of Colorado Ambulatory Practices and Partners (SNOCAP), in their investigation of missing clinical information [Smith et al., 2005]. In addition, IS scholars may investigate newer statistical methods such as hierarchical linear modeling or structural equation modeling and the application of these methods in healthcare research [Gagnon et al., 2003; Ko and Dennis, 2011]. Overall, further examining the ways in which healthcare research is conducted and supported by information technologies is a research theme that will likely continue to remain relevant in the future.

Limitations and Additional Research

As with many archival research methods, limitation of this inquiry lies in the sampling procedure. Although we believe that the sampling procedure employed in this study was appropriate, we recognize that the procedure limited the scope of our study. The fields chosen to be included were medical informatics, medicine, and MIS. Because the study focuses on medical informatics, the inclusion of texts from medical informatics is apparent. Based on calls for extending medical informatics research beyond the boundaries of medical informatics, the closely related fields of MIS and medicine were included. However, the two fields are not the sole disciplines that are closely associated with medical informatics. This study could have benefited from the inclusion of publications in other closely related fields, such as computer science and nursing. Likewise, the inclusion of disciplines that are less closely related but surely relevant, such as operations, decision-making, electrical engineering, and organizational behavior, may have shed additional light on the field of medical informatics. Future studies may benefit from increasing the scope to include such disciplines.

Next, aside from a small amount of latent coding, the majority of our research was automated and, thus, completely objective. While objectivity is a desired quality in research, there may have been topics and ideas that were not adequately captured by our process. Another extension of this study could include a manual coding analysis, which could be performed using full texts of articles similar to those collected for the current study, but with a limited stratified randomized sample of articles from each publication. Limiting the number of articles included would minimize coding fatigue without severely affecting the outcome of the investigation. Performing manual coding would contribute the insights and experiences of the coders in a way unavailable through the automated coding of centering resonance analysis.

The results of this analysis are based in the literature and suggest a direction for future research in the realm of practice. An interesting perspective on the themes would be found in an action-based or grounded theory approach. Direct observation of aspects of medical informatics in practice is essential in expanding the understanding of the discipline and in maximizing the benefits that medical informatics practitioners offer. Using the themes found in this study as guiding principles, subsequent analysis in a healthcare facility would enrich the discipline.

VI. CONCLUSION

In this study, we used the content analysis method of centering resonance analysis to evaluate 2,188 article texts from journals in medical informatics, medicine, and MIS published over a ten-year period. We found ten themes that emerged from the extant literature, which may be used as a roadmap to guide future research efforts. These themes are Analytics; Healthcare Operations and Standards (with sub-themes: Operations, Project Management, and Information Assurance); Knowledge Transfer/Communication (with sub-themes: Extending Beyond the Organization, Internal to the Organization, and Patient-Provider); Perceptions and Managing Expectations of Information Technology; Advancements in Research; and Software as a Service. Although the discussion section of this article details several specific areas for future research within each of the aforementioned themes, the primary areas for future research may be summarized as follows:

- Enhancing operational effectiveness of healthcare processes
- Improving IS implementations from a people and organizational perspective (i.e., technology acceptance, diffusion, and project management)
- Understanding how to disseminate (securely, effectively, and efficiently) information within, between, and beyond healthcare organizations
- Determining how to better manage IT expectations, perceptions, and needs of healthcare employees and patients
- Refining analytics techniques to make sense of the large volume of emerging healthcare data
- Investigating implications and operationalization of cloud technologies
- Examining the use of IS in support of additional healthcare research

While it may be cliché in stating that the future is bright for IS research in the medical field, it is not an understatement. With continuing legislation emphasizing digital health records, dramatic and rapid improvements in technology, and the ever-pressing need to reduce healthcare costs, the demand for high-quality research in this area is growing. The area of medical informatics provides a synthesis of IS, healthcare, supply chain, operations, and research–and it does so in a manner unlike any other field. Although this area is relatively young, we can expect to see persistent growth and maturity in the field as scholars, practitioners, and researchers continue to provide value to advance knowledge in the area of healthcare.

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Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the article on the Web can gain direct access to these linked references. Readers are warned, however, that:

1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
2. The contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. The author(s) of the Web pages, not AIS, is (are) responsible for the accuracy of their content.
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ABOUT THE AUTHORS

Fred K. Weigel is an active duty Army biomedical information systems officer, aviation officer, and Assistant Professor for the Army-Baylor Graduate Program in Health and Business Administration, Fort Sam Houston, Texas. His research interests lie in diffusion of innovations, information security and forensics, and medical informatics. He earned his AA in Business Administration from Brookdale Community College, BS in Professional Aeronautics from Embry-Riddle Aeronautical University, and PhD in Management Information Systems from Auburn University. The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Army, Department of Defense, or the U.S. Government.

R. Kelly Rainer, Jr. is the George Phillips Privett Professor of Management Information Systems at Auburn University, Auburn, Alabama. He received his BS in Mathematics from Auburn University, his DMD from the University of Alabama in Birmingham, and his PhD from the University of Georgia. He has published several articles in scholarly journals and is co-author, with Efrain Turban and Richard Potter, of *Introduction to Information Technology* (3rd edition), Wiley.

Benjamin T. Hazen is a recent PhD graduate of the Department of Supply Chain and Information Systems Management at Auburn University and an active duty U.S. Air Force maintenance officer. His research interests include innovation, information systems, reverse logistics, and sustainability. His research has appeared in several journals, including *International Journal of Production Economics, International Journal of Logistics Management*, and *International Journal of Physical Distribution and Logistics Management*. He earned his MBA from the California State University at Dominguez Hills, his MA in Organisational Leadership from Gonzaga University, and his BS in Business Administration from Colorado Christian University. The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

Casey G. Cegielski is an Associate Professor of Management Information Systems and former KPMG Faculty Fellow in the College of Business on the faculty of Auburn University in Auburn, Alabama. His current research interests are in the areas of innovation diffusion, emerging information technology, information security, and the strategic use of information technology. His research has appeared in several international information systems journals including *Communications of the ACM, Information & Management, Decision Support Systems,* and the *Information Systems Journal*. Additionally, Casey has more than fifteen years of professional experience within the domain of information technology. He has served as a Senior Executive and an Executive Consultant in the financial, healthcare, and manufacturing sectors.

F. Nelson Ford is an Associate Professor of Management Information Systems at Auburn University, Auburn, Alabama. He has published in journals such as *MIS Quarterly, Journal of Management Information Systems,* and *Information & Management*. His research interests include decision support systems and the principles of scholarship.

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