

A Biomedical Informatics Perspective on Human Factors:

The Necessity of Consistent Evaluation Procedures to Design the Future and not Impair the Present

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Summary

Objectives: to select and summarize excellent research published during 2011 in the study of human factors in bio-medical informatics.

Methods: we attempt to derive a synthetic overview of the activity and new trends in this field, from a wide selection of worldwide research papers published during 2011.

Results: We selected four papers. The first one presents an international effort aiming to design a guideline for good evaluation practice in health informatics (GEP-HI) [2]. The second reviews medical errors taxonomies from a human factor perspective [3]. The third one advocates the need to systematically perform a deep evaluation process after all healthcare information technologies project deployment [4]. The fourth one explores exit strategies performed by clinician using health record system and how/why we need to anticipate them [5].

Conclusions: This papers selection will provide our readers with valuable evidences on past and existing research in the specific field of human factors in healthcare informatics. It can also act as a foundation for stakeholders in the healthcare industry that emphasize the significance of human factors and ergonomics in designing healthcare information systems of the future.

Keywords

Medical informatics, International Medical Informatics Association, yearbook, human factors

Yearb Med Inform 2012;65-9

Introduction

Last year's papers selection clearly addressed different aspects of healthcare information technologies (HIT) adoption issues and how this adoption could become successful, or not [1]. This year's selection is mainly focused on the evaluation of HIT systems with a human factor perspective. Evaluation is the means to assess the quality, value, effects and impacts of IT in the healthcare environment [2,3]. This implies the act of measuring or exploring properties of a health information system in planning, development, implementation, or operation. Results of this exploration will facilitate decision to be made concerning that system in a specific context [4]. We live in a political context urging to implement meaningful HIT solutions [5-8]. However, rushing HIT deployment could lead to inappropriate specifications, unreliable systems, user pain, clinical workflows issues, processes failures and global organization mayhem [9].

Best Paper Selection

The four papers selected this year are clearly focused on evaluation procedures and how these evaluations should be performed. The first paper, published in *IJMI* by Pirkko Nykänen *et al.* [10], presents the result of a decade of international efforts to design an exhaustive guideline regarding

evaluation of HIT projects. They succeeded to create a tool that will consistently enhance the quality and results of any evaluation study within our field. The second paper, published in *Safety Science* by Ibrahim Adam Taib *et al.* [11], acknowledges the fact that, in order to design a robust or error tolerant healthcare system, knowledge about potential medical errors within the system is required. This knowledge can only be supported by well-designed error taxonomies: 26 such taxonomies were reviewed and led to an clear understanding of what these should integrate and provide. The third paper, published in *IJIE* by Richard J. Holden *et al.* [12], demonstrates how the application of a human factors approach can help modeling the way HIT influences healthcare outcomes. The human factors model specifies that HIT implementations have a chain reaction effect. When transforming the work system it also transforms the process of care, which in turn transforms the outcome of care. The knowledge and tools amassed in the field of human factors engineering/psychology is consistent enough to ease the measurement and design of work system and process transformations. The fourth paper was published in the *JAMIA* by Kai Zheng *et al.* [13]. It deals with exit strategies in healthcare information systems, providing insight on how to avoid severe disruption to the clinical work by implementing systems capable of neatly handle exceptions in clinical care. The overall exit strategy utilization rates

were low during the study period and usage patterns can help tailoring very effective training strategies for distinct healthcare information system user groups.

Conclusion and Outlook

Even if all implementation hazards are surmounted, HIT may still be ill-functioning or inefficient in certain areas potentially leading to iatrogenic injuries or patient deaths [9, 14-16]. A 2008 review showed that the overall incidence of detected hospital adverse events was 9.2%, with a median percentage of preventability of 43.5%; 7.4% were lethal [17]. Knowing that errors cannot be completely prevented, the HIS has to be robust and error tolerant [18]. HIS are operated by human beings who are by nature not that unpredictable [19, 20] but they interact in complex environments/organizations with complex tools to perform complex tasks. The relationships of all these factors achieve at some point a certain level of stability that any changes may undo. To think that HIT will automatically and directly improve this precarious balance is a fallacy [21]. HIT success in closely linked to the way in which it fits with and transforms the work system. It is no longer “an appendage to ordinary work” [12, 22] and can no longer be of simplistic design [13]. This is where the need for deep HIT evaluation studies has become inevitable. And these evaluations have to be neatly performed before, during and after the deployment steps. This years’ best papers selection supports the criticality of evaluation. We also advocate the reading by all HIT professional of the Innsbruck’s Declaration: “Health Information Systems are intended to improve the functioning of health professionals and organizations in managing health and delivering healthcare. Given the significance of this type of intervention, and the intended beneficial effect on patients and professionals, it is morally impera-

Table 1 Best paper selection of articles for the IMIA Yearbook of Medical Informatics 2010 in the section ‘Human Factors’. The articles are listed in alphabetical order of the first author’s surname.

Section
Human Factors
<ul style="list-style-type: none"> ▪ Holden RJ, Brown RL, Alper SJ, Scanlon MC, Patel NR, Karsh B-T. That’s nice, but what does IT do? <i>Int J Ind Ergon</i> 2011;41:370e379. ▪ Nykänen P, Brender J, Talmon J, de Keizer N, Rigby M, Beuscart-Zephir M-C, Ammenwerth E. Guideline for good evaluation practice in health informatics (GEP-HI). <i>Int J Med Inform</i> 2011;80:815-27. ▪ Taib IA, McIntosh AS, Caponecchia C, Baysari MT. A review of medical error taxonomies: A human factors perspective. <i>Safety Science</i> 2011;49:607-15. ▪ Zheng K, Hanauer DA, Padman R, Johnson MP, Hussain AA, Ye W, Zhou X, Diamond HS. Handling anticipated exceptions in clinical care: investigating clinician use of ‘exit strategies’ in an electronic health records system. <i>J Am Med Inform Assoc</i> 2011;18:883-9

tive to ensure that the optimum results are achieved, and any unanticipated outcomes identified. The necessary process is evaluation, and this should be considered an essential adjunct to design and implementation of information systems” [23].

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References:

1. Meyer R. A Biomedical Informatics Perspective on Human Factors - How Human Factors Influence Information Technology Adoption. *Yearb Med Inform* 2011;6(1):58-62.
2. Moehr JR. Evaluation of health information systems: beyond efficiency and effectiveness. *Comput Biol Med* 2002;32(3):111-2.
3. Brender J. *Handbook of Evaluation Methods for Health Informatics*. New York: Academic Press; 2006.
4. Ammenwerth E, Brender J, Nykänen P, Prokosch HU, Rigby M, Talmon J. Visions and strategies to improve evaluation of health information systems. Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. *Int J Med Inform* 2004;73:479-91.
5. Commission of the European Communities. COM 356: Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: e-Health—making health care better for European citizens: An action plan for a European e-Health Area. Brussels; 2004.
6. European Commission: ICT for Health & i2010 - Transforming the European Healthcare Landscape—

Towards a Strategy for ICT for Health, June 2006, Office for Official Publications of the European Communities: Luxembourg; 2006.

7. United States Congress. American Recovery and Reinvestment Act of 2009. Washington DC: United States Government Printing Office; 2009.
8. Sittig DF, Classen DC. Safe electronic health record use requires a comprehensive monitoring and evaluation framework. *JAMA* 2010;303(5):450-1.
9. Ammenwerth E, Shaw N. Bad health informatics can kill - is evaluation the answer. *Editorial. Methods Inf Med* 2005;44:1-3.
10. Nykänen P, Brender J, Talmon J, de Keizer N, Rigby M, Beuscart-Zephir MC, et al. Guideline for good evaluation practice in health informatics (GEP-HI). *Int J Med Inform* 2011;80:815-27.
11. Taib IA, McIntosh AS, Caponecchia C, Baysari MT. A review of medical error taxonomies: A human factors perspective. *Safety Science* 2011;49:607-15.
12. Holden RJ, Brown RL, Alper SJ, Scanlon MC, Patel NR, Karsh BT. That’s nice, but what does IT do? *Int J Ind Ergon* 2011;41:370-9.
13. Zheng K, Hanauer DA, Padman R, Johnson MP, Hussain AA, Ye W, et al. Handling anticipated exceptions in clinical care: investigating clinician use of ‘exit strategies’ in an electronic health records system. *J Am Med Inform Assoc* 2011;18:883-9.
14. Veterans given wrong drug doses due to glitch, *Health care at msnbc.com*, <http://www.msnbc.msn.com/id/28655104> (accessed 06.03.12).
15. Han YY, Carcillo JA, Venkataraman ST, Clark RSB, Watson RS, Nguyen TC, et al. Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. *Pediatrics* 2005;116(6):1506-12.
16. Ekeland AG, Bowes A, Flottorp S. Effectiveness of telemedicine: a systematic review of reviews. *Int J Med Inform* 2010;79:736-71.
17. de Vries EN, Ramrattan MA, Smorenburg MA, Gouma DJ, Boermeester MA. The incidence and nature of in-hospital adverse events: a systematic review. *Qual Saf Health Care* 2008;17:216-23.
18. Christofferson K, Woods DD. How complex human-machine systems fail: putting “human error”

- in context. In: Karwowski W, Marraas WS, editors. *The Occupational Ergonomics Handbook*. Boca Raton: CRC Press; 1999. p. 585–600.
19. Reason J. Human error: models and management. *BMJ* 2000;320:768-70.
 20. Carayon P, Schoofs Hundt A, Karsh B, Gurses AP, Alvarado CJ, Smith M, et al. Work system design for patient safety: the SEIPS model. *Qual Saf Health Care* 2006;15:50-8.
 21. Karsh BT, Weinger MB, Abbott PA, Wears RL. Health information technology: fallacies and sober realities. *J Am Med Inform Assoc* 2010;17:617-23.
 22. Perry SJ, Wears RL, Cook RI. The role of automation in complex system failures. *J Patient Saf* 2005;1:56-61.
 23. Declaration of Innsbruck - Results from the European Science Foundation sponsored Workshop on Systematic Evaluation of Health Information Systems (HIS-EVAL), April 4–6th, 2003, <http://iig.uit.at/dokumente/r16.pdf> (accessed 04.06.12).

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Appendix: Content Summary of Selected Best Papers for the IMIA Yearbook 2012, Section Human Factors*

Nykänen P, Brender J, Talmon J, de Keizer N, Rigby M, Beuscart-Zephir M-C, Ammenwerth E

Guideline for good evaluation practice in health informatics (GEP-HI)

Int J Med Inform 2011;80:815–27

In this work the authors develop an exhaustive guideline regarding the evaluation within health informatics' domain. A deep review to identify a wide range of issues usually found in evaluation studies was performed, and data regarding guidance and experi-

ences reported by key players was collected. These guidelines were then closely examined and discussed by a larger group of experts from EFMI and IMIA working groups during meetings, mail exchanges and web networks based comments. The authors came up with a list of sixty relevant issues in six main categories: preliminary outline, study design, operationalization of methods, project planning, execution and completion of the evaluation study. All these chapters are carefully described and cover all phases of a state of the art planning, implementation and execution evaluation study in the health informatics domain. This guideline for good evaluation practice in health informatics (GEP-HI) also covers issues regarding risk management and project control as well as reporting and publication of the evaluation results. The strengths and weaknesses of the guideline itself and of the guideline application are of course discussed. The main conclusion of this huge collective work is that the implementation of this powerful tool has the potential to enhance the quality and results of any evaluation study. This should help our community to perform another important step towards evidence-based health informatics.

Taib IA, McIntosh AS, Caponecchia C, Baysari MT

A review of medical error taxonomies: A human factors perspective

Safety Science 2011;49:607–15

Errors in healthcare, or medical errors, have led to a large number of iatrogenic injuries or patient deaths. In addition to these iatrogenic injuries and deaths, medical errors also burden the economy by causing additional healthcare costs and loss of income. Database of healthcare errors can be obtained by collating information about those that have already happened. Analyzing this database can then reveal patterns in how medical errors occur in the hospital. Once the patterns are understood, the system can be enhanced

to expect and prepare for those inevitable medical errors. But, if a healthcare information system management team wants to build an efficient database, they will have to implement the best medical error taxonomy to organize systematically and classify collected information. The authors believe that it is critical that taxonomies contain categories that incorporate the entire range of contributing factors associated with an incident to provide crucial managing errors information. Incomplete taxonomies result in a limited incidents understanding and so limit the recommendations that can be made. What is new and important in this paper is that the authors did not focus on the usual topic found in literature regarding the issue of non-standardized 'terminology' of the categories found in medical error taxonomies. To address this issue the world alliance for patient safety alliance of the World Health Organization is developing the International Classification for Patient Safety (ICPS). The authors advocate that "while standardizing language is important for interactions between organizations, from a human factors perspective, it is also critical that medical error taxonomies provide useful information by classifying the system's role in medical errors and using theoretical error concepts as the basis for their classifications. To date, no systematic comparison has been performed on medical error taxonomies to determine if these two attributes are present in the taxonomies". This paper reviews 26 medical error taxonomies to see if they classified systemic factors of medical errors and if they classified medical errors based on underlying theoretical error concepts. They adopted Kirwan's method of grouping error taxonomy categories into EEM, PEM, or PSF. EEMs (external error modes) are concerned with errors that are visibly observable, such as a healthcare worker administering the wrong medication. PEMs (psychological error mechanisms) are concerned with the psychological mechanism of an error's occurrence, for example

* The complete papers can be accessed in the Yearbook's full electronic version, provided that the article is freely accessible or that your institution has access to the respective journal.

memory failure may have led to a failure to check the dose of the medication administered. PSFs (performance shaping factors) relate to how components of the system affected the occurrence of the error, for example time pressure may have affected a healthcare worker's ability to administer medication safely. Taxonomies that have categories grouped into EEM are taxonomies that classify the observable features of medical errors. Taxonomies that have categories grouped into PSF are taxonomies that classify systemic factors of medical errors. Taxonomies that have categories grouped into PEM are taxonomies that classify medical errors based on underlying cognitive mechanisms. The authors also determined if the medical error taxonomies utilized any theoretical error concepts for error classification. This was determined by noting any reported usage of human error-related theories or classification systems derived from such theories during the taxonomy's development or the presence of these theories in its structure. Their results are inspiring. Out of the 26 medical error taxonomies reviewed, about two-thirds classified systemic factors of medical errors. The remaining one-third of medical error taxonomies fail to take into account systemic factors, such as issues of workload or staffing. The consequence is that analyses and interventions based on such classifications may only focus on the person who made the error missing many other aspects, thus highlighting that it is crucial for medical error taxonomies to include systemic factors in their error classifications. Their results also tends to indicate that medical error taxonomies that used theoretical error concepts were more likely to be generic than domain-specific. The discussion of this paper is a must-read and leads to the conclusion that any medical error database should benefits of using medical error taxonomies that use theoretical error concepts. The integration of such taxonomies increases the likelihood that systemic factors, cognitive mechanisms, and cause of medi-

cal errors are better classified. This leads to the need of more in-depth studies on how differences between medical error taxonomies can affect medical error management and subsequent field or information system interventions.

Holden RJ, Brown RL, Alper SJ, Scanlon MC, Patel NR, Karsh B-T

That's nice, but what does IT do?

Int J Ind Ergon 2011;41:370e379

Improving key healthcare outcomes with the help of HIT is an objective widely researched especially when it comes to the patient safety area. This excellent work gives incentives on how the application of a human factors approach can help modeling how HIT might improve or worsen healthcare outcomes. The human factors model specifies that HIT implementation have a chain reaction effect. When transforming the work system it also transforms the process of care, which in turn transforms the outcome of care. In this study the authors examined the implementation of a bar coded medication administration (BCMA) and studied how it transformed the medication administration process in two large US pediatrics hospitals. They performed a survey within registered nurses teams before and after one of the hospitals implemented the BCMA, and measures using work system and process observations, interviews, observational medication error analyses, and surveys. Nurses' perceptions of the administration process changed at the hospital that implemented the BCMA, whereas perceptions of nurses at the control hospital did not. The new system was perceived has an improvement regarding the safety of the processes of matching medications to the medication administration record and checking patient identification. As another result they observed that the accuracy, usefulness, and consistency of checking patient identification improved as well. In contrast they also measured that nurses' perceptions of

the usefulness, time efficiency, and ease of the documentation process decreased post-BCMA. Nurses had to do extra documentation during high-workload periods using an unfamiliar software interface leading to this bad perception. In conclusion we can write that his study showed evidence of the process transformations that came out from new HIT hospital work system. Process changes were not uniformly desirable, but such work system transformations are measurable and also controllable through design. The knowledge and tools amassed in the field of human factors engineering/psychology will greatly inform and facilitate both the measurement and design/redesign aimed at controlling work system and process transformations.

Zheng K, Hanauer DA, Padman R, Johnson MP, Hussain AA, Ye W, Zhou X, Diamond HS

Handling anticipated exceptions in clinical care: investigating clinician use of 'exit strategies' in an electronic health records system

J Am Med Inform Assoc 2011;18:883-9

As the authors quote "exit strategy is a term commonly used in the military world to describe tactics for escaping from unfavorable situations". These exit strategies are commonly used when clinicians can no longer find their ways in the information system and choose to override what's expected from the computer to avoid the occurrence of a severe disruption to the clinical work. Modern HIS must avoid simplistic and linear designs. They have to incorporate theses exit strategies to be able to let the clinicians manage complex exception situations. In this paper, the authors aimed to analyze how end users utilized several exit strategies implemented in an ambulatory electronic health record (EHR) system. The study was conducted in an ambulatory primary care practice at the Western Pennsylvania Hospital, USA. The observed EHR system provides clinicians with electronic documentation and computerized decision support capabilities.

The research data collection lasted 12 months and involved 34 residents, 10 attending physicians, and 10 nurses and physician assistants. They focused on the exit strategies specifically designed to assist in clinicians' structured documentation of clinical data with International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM vol. 1&2), and Active Medications and Medication History based on FDA's National Drug Code Directory (NDC). They performed a statistical analysis and an expert review of the strategies used. What did they learned? The overall exit strategy utilization rates were low during the study period. It is reassuring because the provision of these exception handling procedures did not incline clinicians to overuse them as a speedy way of entering data. Clinicians' work, and their thought process, could have been interrupted if this exit strategy were not available. The reviewers found that most of the

exits could not be clinically justified, indicating that the clinician users either lacked a good understanding of the nature of medical coding or had difficulties in using the controlled medical vocabularies provided. Many data entries could have been properly documented according to recommended practice, yet were not, raising at some level a lack of system knowledge or a lack of good understanding of the nature of medical coding issues. They also noticed that different types of clinicians demonstrated distinct usage patterns. Residents were more likely to resort to exit strategies than attending physicians, and male users utilized medication exit strategies much more often than females. These findings suggest that EHR training strategies should be tailored based on the characteristics of users, in anticipation that certain behaviors might be particularly prominent among certain user groups, especially concerning work in

progress data. Finally regarding these data, this excellent paper raises four very important questions that not only human factors studying teams should focus on, but most certainly HIS developers. They could be quoted as follows: "(1) *Should data used by clinicians, of a clearly work-in-progress nature, be entered into EHRs which would then become part of the patient's legal medical record?* (2) *Should such data be recorded in the 'Current Problem List and Past Medical History' section or in another, perhaps more appropriate 'Transitory Information' section?* (3) *Should a deterministic, billable code be mandated, even if the clinical findings are not yet certain at the point of data entry?* (4) *Would a probabilistic scale allowing indication of the degree of uncertainty increase the value of codified data, and if so, how should it be implemented?*" We hope to read more soon about these universal interrogations.