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Important Ingredients for Health Adaptive Information Systems

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Abstract: Healthcare information systems frequently do not truly meet clinician needs, due to the complexity, variability, and rapid change in medical contexts. Recently the internet world has been transformed by approaches commonly termed 'Web 2.0'. This paper proposes a Web 2.0 model for a healthcare adaptive architecture. The vision includes creating modular, user-composable systems which aim to make all necessary information from multiple internal and external sources available via a platform, for the user to use, arrange, recombine, author, and share at will, using rich interfaces where advisable. Clinicians can create a set of 'widgets' and 'views' which can transform data, reflect their domain knowledge and cater to their needs, using simple drag and drop interfaces without the intervention of programmers. We have built an example system, MedWISE, embodying the user-facing parts of the model. This approach to HIS is expected to have several advantages, including greater suitability to user needs (reflecting clinician rather than programmer concepts and priorities), incorporation of multiple information sources, agile reconfiguration to meet emerging situations and new treatment deployment, capture of user domain expertise and tacit knowledge, efficiencies due to workflow and human-computer interaction improvements, and greater user acceptance.

Keywords. healthcare Web 2.0, collaboration, human-computer interaction, user configurability, architecture of participation, MedWISE.

1. Introduction

Current healthcare information systems suffer from numerous difficult problems, in part due to the high variability of medical information needs, the difficulty of addressing rapidly changing or emergent conditions, the highly collaborative, social, and high-stakes nature of the work, limitations of human cognition and current human-computer interaction paradigms, and other factors. These contribute to the lack of acceptance of EHRs by clinicians [1, 2, 3].

Therefore we created a new model for healthcare information systems, embodied in MedWISE, a widget-based EHR platform we have built, based on 'web 2.0' philosophies and technical approaches, which include emphasis on user control, participation, and communication. This paper puts forth a vision of how these might solve problems in healthcare, with implications at multiple levels, from small individual user cognitive effects to large sociotechnical changes in the way healthcare information systems are designed and built. We present a model for discussion, and a

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clinical practice scenario[2]. The discussion covers implications and areas for further inquiry. Our belief is that only a scientific approach (i.e. testing such systems in controlled conditions) will resolve some of the potentially controversial issues. MedWISE embodies some parts of the model.[2]

2. Web 2.0 Model for a Healthcare Adaptive Architecture

Figure 1 presents a model schematic showing information flow within a worldwide system and the authoring and distribution process. A description of model components follows.

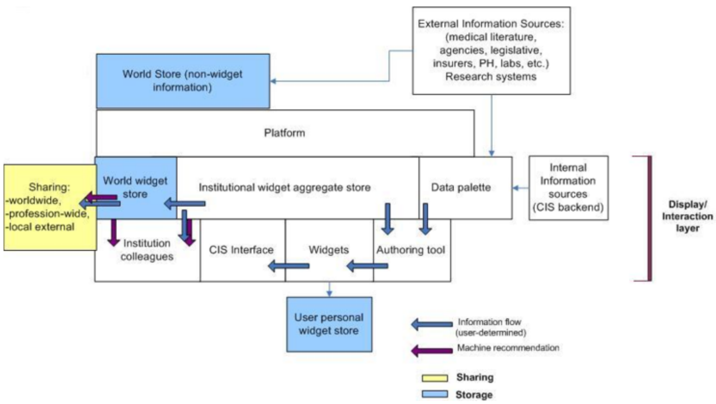

Figure 1. Model diagram.

2.1. Model Description:

Essential components of our Web 2.0 model for adaptation in health care include *a standards-based platform* supporting the following functions:

- *A back-end service-oriented architecture (SOA)* that permits applications to incorporate information from diverse within-hospital, external clinical, other data stores and applications, (e.g. HL7 and medical RSS feeds, notes, alerts).
- *A display/interaction layer* that allows users, individually and col-laboratively, to recombine this information in unanticipated ways via drag/drop assembly using a palette of data and formatting options**.** This includes programming, data visualization and transformation, rich interfaces. This must be as effortless and transparent as possible such as by saving objects from the viewing history as a template.
- *Self-describing widgets* that enable annotation and incorporation into larger collections, with facility for the output of one process to become the input of another.
- *Means to store, share, and aggregate widgets and views* that supports future use, repurposing, and sharing with others at multiple levels, e.g., specialty, institution, national, international. Machine learning applied to aggregations of

[2] More detailed information on MedWISE and web 2.0 is available at http://www.ehr2.org, in a paper by Cheung et al [4.], and at http://www.ncbi.nlm.nih.gov/pubmed?term=senathirajah . http://tinyurl.com/ehr2scenario contains an illustrative scenario.

widgets and views would enable dynamic suggestions of elements for viewing or authoring (much as Amazon suggests books). Eventually this aggregation would form a large collection embodying clinicians' tacit or explicit expertise and institutional knowledge, allowing for insights based on group wisdom.
- *Explicit communication and collaboration* features for collegial communication & group authoring.

3. Discussion

3.1. Advantages

Increased Information availability: integration of more information sources and meaningful display tools, at the point of decision, via self-updating feeds,

C*apture of tacit knowledge*: Expert-created 'views' would appeal to colleagues, facilitating adoption (prestige bias) [5], and could inform novices [6], capturing on the fly what specific clinicians considered important. Views encompassing institutional policies could capture knowledge which is often currently tacit.

Information display & visualization: Flexible placement of elements allows grouping those which should be viewed together. Juxtaposition can foster insight [7-8], and constitute decision support, serving as a reminder. Custom alerts (geared to the individual patient) delivered to various devices, could assist with error avoidance. Displays involving direct perception rather than calculation, can assist safety. User-composable tools may facilitate more reflective understanding of the relationship of data to patient care and ultimately, better design.

HCI and Workflow Advantages: Distributed cognition theory states that people use tools to decrease the cognitive load (internal mental processing) in their tasks, freeing up finite cognitive resources (perception, attention, memory) for the main task. An example is writing something down instead of keeping it in memory. Mitigation of the keyhole effect[3] is another result, since the user can assemble together highly relevant elements in the scarce screen space [9]. This may substitute for usual actions of workers in high-reliability, high-stress environments, who often workaround computers [10] using easily manipulable supplementary objects (e.g. paper) [10, 11, 12].

Workflow facilitation: team members could contribute widgets pertaining to their own roles, and highly local needs accommodated. (e.g., mashup of admission data and dialysis chair locations for amputee dialysis patients could meet fire regulations mandating staff assistance for evacuation).

Reduced and accumulated work due to decreased search and material re-use. Sharing created interfaces reduces total work, since subsequent users need not do the same search and retrieval, resulting in substantial time savings over a population of users and patient records. Complete views also serve as a reminder system [13, 14].

Sociotechnical change: *Communication/collaboration:*, Hospital workers prefer synchronous communication [15], leading to an interrupt-driven environment with high cognitive costs in terms of memory failure, and errors [15]. Care interfaces with Web 2.0 rapid communication tools may help minimize this cost. Shareable user-customized displays also provide 'common ground' for consults or handoffs.

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[3] 'Keyhole effect' refers to the problem in computer system design that the user must access a vast array of data elements through a small screen, as if viewing a large room through a keyhole.

Rapid reconfigurability: since system change does not require programmers, emerging needs such as public health emergencies or new treatment deployment could be addressed more rapidly. Public health elements are easily incorporated.

3.2. Disadvantages

Foremost is the concern that excess variability or omissions could lead to errors (e.g diagnosis momentum [16]). We believe a situation of equipoise with respect to current systems exists. Currently, aside from attested notes there is no real monitoring of which user views what data (this is highly variable [17], and lost as a search sequence)[4]. Our study did not find substantial diagnosis momentum errors. Decision support to enforce viewing of complete element sets can be built in.

There are perhaps three levels of concern. 1) Widgets which merely rearrange pre-existing data close to their usual form, 2) widgets which reformat, perform calculations, or otherwise fallibly change the data representation, and 3) widgets which implement more sophisticated decision support. The latter is the most concerning and would require careful oversight, e.g. a vetting system involving clinical experts, administration, and IT. Default configurations and conventions (e.g. for format, layout, display) can be used to foster consistency important for usability.

Will sufficient numbers of users want to adopt and use the system to create their own interfaces? HIS users have high levels of education, numeracy, algorithmic thinking, computer savvy, and great interest in improving care effectiveness. Younger users already create and share content online. Our studies show great user enthusiasm, skill and engagement in using MedWISE features to solve problems and fit different contexts and needs. It is not necessary that a majority embrace it; in fact we expect that a small proportion of users will create many complex tools, which their colleagues will adopt, along with widespread use of the simpler functions.

4. Conclusion

Further laboratory study and controlled deployments are needed to resolve issues of concern. Implementation of such systems is likely to open up new avenues for research, in HCI and efficiency, tacit knowledge, technology acceptance/adoption, new evaluation methods, and data mining on a vast library of user-created tools. The different mode of software creation has implications for tool development in other complex, critical environments in which user expertise is paramount.

We believe this approach can facilitate evolutionary development of HIS and improve task-technology fit. This would allow users to make software reflect and fit their mental models, domain knowledge, collaborations, and emerging needs, reversing the need for the user to fit herself to the software instead of the software fitting the domain and user. It makes domain knowledge paramount. We hope this may allow the full potential of computing to leverage human creativity and knowledge in health care to better meet the full requirements of this most complex and critical of domains.

[4] In MedWISE the usual CIS is simultaneously available, so there is no functional penalty for incorporating the Web 2.0 interface.

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