ABSTRACT
Health information systems have extremely complex, variable and changeable information requirements and vendor-controlled development has resulted in systems that frequently neither reflect clinical users’ domain knowledge nor meet their needs. ‘Web 2.0’ approaches have transformed the commercial/public internet world. Consequently we created MedWISE, a ‘web 2.0’ EHR interface which allows users to create, select, configure, and share information, displays and tools, via simple drag/drop interfaces, without programmers. Possible advantages include greater suitability to user needs, incorporation of multiple information sources, interoperability, agile reconfiguration, capture of user tacit knowledge, efficiencies due to workflow and Human-Computer Interaction (HCI) improvements, and greater user acceptance.

Categories and Subject Descriptors
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General Terms
Design, Human Factors

Keywords
Human-computer interaction, web 2.0 EHR, user-configurable EHR, user-configurable EMR.

1. MOTIVATION
The Ideal electronic health record remains elusive
In recent years increasing attention has been paid to the expansion of electronic records in healthcare. However despite years of research and deployment, the development and adoption of an ideal medical record remains elusive. Problems range from profound user dissatisfaction and lack of task-technology fit to inability to integrate public health elements or configure systems for response to emergency conditions. Despite the existence of the relevant technologies for decades, electronic health record (EHR) adoption in the United States remains at 41.5% (physicians reported using all or partial EHR systems (not including systems solely for billing) in their office-based practices of small practices) and a similar percentage for larger hospitals.

Healthcare is complex
Healthcare is characterized by extreme complexity(2-3) and the involvement of highly trained healthcare practitioners with extensive domain knowledge in perhaps the most information-intensive area of human endeavor. This information varies with patient, provider, practice system, and many other variables. The practitioner must aggregate and integrate snippets of information from multiple information sources (e.g. a laboratory test result, x-ray, paper, patient preference). Increasingly, complex multiplayer care of chronic conditions is involved.

It includes the possibility of emergent high-stakes problems (such as new epidemics or treatments, or economic change) which must be accommodated.

Current systems may not match clinician mental models
Characteristics of the current system in healthcare include a set of ad hoc systems which often follow silos instead of integrating information across institutions. The healthcare provider must learn the system, which may be complex, rigid, hard to learn, and cannot be easily adapted to different contexts. Systems are built by designers and programmers, and consequently may prioritize their concepts, not the complex domain knowledge of the healthcare professional. These facts are part of the reasons for underutilization or failed adoption of EHRs. In addition, the system complexity uses cognitive resources (perception, attention, and memory) which are then unavailable for the main diagnostic and treatment tasks(4). The system design may not follow user mental models, further complicating use and potentially causing errors.

In addition, an assumption underlying such systems is that users will follow the designer’s rationale and use the system in circumscribed ways foreseen by the designers. However our knowledge of real work situations show that users continually adapt tools to uses not foreseen by designers, in response to system inadequacy, difficulties or new situations(5). Current EHR systems often prevent this. Rigidity and lack of expressivity are some of the reasons for user dissatisfaction with current systems. Further, changing current EHR systems usually involves the vendor, time, consensus, and often, further cost. Users must view different parts of the medical record in sequence, taking different paths through the system. These may differ by specialty, role, and institution(6-7). This also often means in clinical work there is considerable repetitious navigation and information viewing during a session.
Web 2.0 technologies have transformed public internet world
At the same time the advent of modern (‘web 2.0’) technologies has transformed the public internet world, including commerce, political participation, journalism, scientific publication, service delivery, and many other areas. This set of approaches comprises both a core philosophy and a set of technical principles and practices, which emphasize user participation, content creation and sharing, repurposing of content as short snippets which are easily rearranged and further processed by machines or humans.

1. An emphasis on user control, participation, and creation, recombination, and exchange of information resources, often as small fragments (snippets) (e.g. viewing newspaper headlines in RSS readers, iGoogle, Netvibes).
2. Creation of frameworks or platforms and modular architectures (not monolithic applications), which allow the user to create, recombine, configure and share diverse user-selected resources as needed (e.g. rss, blogs, Google maps, mashups, wikis, digg, Mendeley).
3. Attention to the user experience, interactivity, and sophisticated rich information visualization.
4. Open standards, application programming interfaces (APIs), and free or open-source software (FOSS) if advisable.
5. Evolutionary approaches to software development, which make use of user participation. These may be active and deliberate (such as using user ratings for collaborative filtering) or passive (such as using mining of use statistics to deliver putatively relevant information). The value of these resources increases with participation, and evolutionary development based on thousands of user modifications, is the norm, but specific developments are unpredictable. (e.g. prioritization of problem solutions on programming help websites according to user voting).

Web 2.0 Approaches have potential for application in healthcare
Some of the properties of such systems are that by employing user-defined processes, they give rise to software that better reflects user domain knowledge. The service oriented architecture and use of technologies as RSS facilitate the integration of external and internal information. Multiple personnel throughout the healthcare organization as well as external to it can contribute; user participation can also ensure capture of tacit knowledge. User-created custom views can be created for different specialties, diagnoses, patients, or groups of providers or patients. Collaboration and team-based processes are possible in a way not common before. Finally, the use of modular architecture with elements that can be rapidly changed by users without programmers can facilitate the adaptation of the system to emergent healthcare needs, such as public health emergencies, incorporation of public health elements into the regularly used electronic health record, and new treatment deployment into practice (T2 translation).

2. SPECIFIC PURPOSES OF THE SYSTEM
Recent studies underline the importance of interfaces for effectiveness and adoption. An ongoing problem in the use of healthcare information systems is the lack of fit between users’ medical concepts and systems developed by programmers. These systems may not adequately address the great complexity of user needs nor accommodate rapid change, nor meet unforeseen emerging needs. Typically system change requires vendor involvement, time, consensus, and cost. The ‘keyhole effect’ which results from the need to view thousands of data elements sequentially via a small screen, compounds the scarcity of cognitive resources (perception, attention, memory). available for diagnosis/treatment cognitive functions.

Healthcare’s highly collaborative practice requires the aggregation, integration, sense-making and sharing of pieces of information from diverse sources.

Consequently the creation of a system which allows users to gather whatever pieces of information they deem relevant on the same screen allows the software to parallel the main mental process, allowing externalization of information usually kept in short-term memory. It also permits the creation of custom resources and a much more granular level, dynamically, than is possible with more conventional approaches.

Innovative features include the facility for users to create, save and share custom widgets and tabs with colleagues and to a central repository; assemble information from multiple internal and external sources on the same page; and create mashups of clinical data as well as custom sophisticated visualization and display types. This includes timelines for data overview and drill-down, medication timelines, user-determined plotting of test results with other data, and user creation of widgets for
calculation and creation of new entities. It allows much greater flexibility and sharing than other EHR interfaces to date. It also facilitates the capture of user medical domain knowledge, and tacit knowledge (e.g. institutional procedures) to form a library of user-created and practice-based innovations and tools. The widget-based architecture eases incorporation of new technologies, data, and workflows, and allows independent client-side scripting for each widget.

3. SYSTEM ARCHITECTURE
The system was built as a middleware layer drawing on the usual hospital clinical databases but providing a separate database back-end for storing user-derived combinations of data elements, formatting, display specifications, widget specifications, and administrative functions; it includes no identified health information. This architecture allowed flexibility in changing the interface system while still drawing on the hospital data stores. In order to create the mashup editor on-the-fly query generation as the user completes the mashup forms takes place, returning information in a JSON-like or xml format which can be further manipulated for specific visualizations.

Figure 4. Clinical data summary timeline. The three lower tracks are zoomed-out views showing that the patient had three hospital visits in 2009. The 2nd row intermediate view shows the dates more precisely, with the locations of orders. The top (detailed) track shows order titles.

Figure 5. Dynamic multiaxis plotting of multiple laboratory test values. Dragging the blue overview rectangle at bottom right allows panning over the entire range. The patient experienced a drop in calcium and rise in creatinine (a measure of decreased kidney function) and went into kidney failure (the wild fluctuations in the latter half of 2006). The APTT spike reflects treatment monitoring during a heart attack. Plotting all four measures together allows one to see events and fluctuations in related measures and distinguish patterns and/or effects of treatments.
Figure 5. Mashup editor. Users check off different parts of the record, and can insert filtering and output parameters, with logic, in the form below. The system retrieves the relevant patient data and gives the desired output and formatting. This system was tested with a study of rapid configurability for clinician decision support for clinicians treating patients with possible H1N1.

4. RESEARCH STUDIES

Our research studies with clinician users show that a majority find the ability to control some of the design of their EHR interfaces to be highly useful, timesaving, and easy to learn. Clinician users quickly realized and stated new use cases for which the flexibility and configurability of MedWISE would be useful. These included specific healthcare contexts such as clinic work in which they are in charge of 100 patients and could configure custom tabs for each patient, allow rapid review of the record before and during visits, handoff, new treatment adoption, team collaboration and communication both for routine clinical uses and special tasks, and the creation of myriad self-updating templates for rapid clinician orientation to the current state of the patient.

Typical clinical users from medicine and nephrology departments were asked to use the system to review real patient cases and found that use of the system assisted their mental processes, including diagnostic reflection about the case and incorporation of comprehensive information. It reduced repetitious navigation, and provoked reflection on interface design and note writing. In addition it facilitated their creation of different arrangements and procedures for note writing, which will be discussed in the presentation.

5. DEMO SCENARIO

After a short introductory slide presentation about the principles and motivation behind the work, we will demonstrate the system live (over the internet). There would also be short de-identified videos of clinician users and how they use the system to solve real patient cases.

With this system we would also make available a ‘dummy’ version populated with dummy patient data, to allow attendees to interact with the system for many of the basic functions. This would be supplemented with a set of walk-through exercises which attendees could optionally execute, to allow them to acquire familiarity with most functions of the system and how these might be employed in clinical cases.

In the case of low connectivity, we would use the ‘dummy’ system running locally on our presentation laptop, as well as video clips.

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6. REFERENCES


