Mapping the Electronic Health Record: A Method to Study Display Fragmentation

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Abstract

Electronic health records have often been criticized for poor interaction design. One major problem is the ‘display fragmentation problem’ i.e. the fact that conventional EHRs require the user to view many screens and retain information in memory or external tools rather than being able to view all relevant information together, increasing cognitive load and the possibility of errors and inefficiency. We describe a method for evaluating and depicting the extent of display fragmentation and discuss its potential uses in comparing systems, identifying navigation pathways and information juxtaposition, and improving EHR interaction design.

Keywords:
Electronic Health Records; User-Computer Interface; Computer Graphics.

Introduction

Healthcare information technology (‘health IT’) and electronic health records (EHRs) have great promise to improve care, reduce costs, and create a ‘learning healthcare system’ in which continuous improvement is possible by using data to analyze which treatments are most effective. However, optimal interaction design of such software has proven difficult, with the potential for health IT to introduce safety concerns.

The Institute of Medicine 2011 report identifies several concerns related to fragmented displays and the conventional interaction approach in which information location is fixed by the programmer and users navigate through menus. These concerns include the mismatch between programmer assumptions and actual work environment and the mismatch between developer and clinician backgrounds, resulting in unmet needs. Current displays may not reflect clinical reasoning performance and other aspects of clinical cognition. Addressing the display fragmentation problem is therefore an important task in redesigning clinical information systems for better efficiency and cognitive support.

Prior work reveals conventional EHRs have an approximate six-fold greater number of clicks and screen transitions required to obtain complete information than systems in which the relevant information for a task can be included on one screen. Conversely, appropriate information juxtaposition can foster insight, creativity, sensemaking, and problem-solving.

Modular composable systems

Because the display fragmentation problem arises partly from the fact that information location is typically fixed by the programmer, one means of addressing it is to by making systems a) modular (i.e. pieces can be rearranged and reassembled flexibly according to different needs, like a Lego set), and b) composable by the end user clinician. Removing the requirement for a programmer to reconfigure displays and giving the clinician the ability to assemble any desired elements together on the same screen can allow patient-specific display of all relevant information on the same page, reducing cognitive load and respecting clinicians’ deep medical expertise in their choice of elements. Ease of use can mean that drag/drop assembly of ‘objects’ is a simple means of providing this functionality. Some other domains in which user expertise and security/reliability are important have also used this approach; NASA mission control tools are an example.

MedWISER system

Our experimental system, MedWISER, implements a modular composable architecture, in which elements are backed by a controlled vocabulary. Separation of the display elements and back-end data queries allows for a javascript framework which permits the end user to specify display of chosen elements (such as a lab value, note or note fragment, mashup of lab plots, RSS feed) in movable rectangular widgets. These can also be opened to large-screen size, collapsed with only a header showing, colored, retitled, and have other modifications which affect display. This gives the end user considerable power to select and arrange information elements.

More advanced features are not discussed in this paper. By permitting choice and assembly of any elements by the clinician, these can be gathered on the same page before or during clinical review of the patient case. This then avoids the fragmentation problem, as repeated navigation to and viewing of other screens is no longer necessary (or minimally necessary). This should avoid the consequent cognitive load, forgetting, navigation inefficiencies and other problems inherent in our current conventional fixed systems. These typically

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present the user with a series of tabs, left-hand menus, drop-down lists or other affordances allowing the user to find and view different pieces of information configured as a hierarchical tree, with higher level menus providing access to more granular information as the tree is traversed. One way to study and compare systems is to map the locations of the major information elements as they occur according to the navigation structure of the EHRs. This can help us understand the fragmentation problem, suggest design solutions, and compare systems. Here we describe a method of doing this, with a few examples.

Methods

Modified Cognitive Walkthrough

Cognitive walkthrough is an expert-based, usability evaluation method for identifying usability issues. The expert steps through a typical task, noting all navigation actions, system responses, and potential problems, according to well-established heuristics and expert knowledge. We make use of this basic technique to map information locations, creating the navigation tree by walking through each step from the top of the navigation tree (typically the selection of the specific patient from a patient list) [8]. An example of a map subsection appears below.

Sunburst Visualization

Many different visualizations of hierarchical structures exist with advantages and disadvantages. In this technique we have leveraged advantages of the sunburst visualization. This visualization displays tree structures in a circular fashion (as if the spine of the tree were wrapped around in a circle), facilitating display of entire trees in a single page, with drill down (in interactive versions) to details of leaves. This facilitates apprehension of the relationships between different regions, and makes it easier to show navigation pathways in relation to the overall navigation structures. It also addresses the problem that as the number of leaves expands more space is needed, since the deeper levels furthest from the trunk appear in the outer concentric circles, using the greater available space.

Microsoft Excel 2016 and other tools generate such displays from spreadsheets or hierarchical text documents. See Figure 1. Figure 1 (b) shows the sunburst visualization for the tree section shown in Figure 1 (a).

We use as an example the general information review that clinicians undertake when reviewing a comprehensive patient case, in one of the major commercial inpatient systems (Figures 2 and 3). This generally involves the following types of information: admission notes, laboratory results, orders, study reports (e.g. of imaging or other studies), images (if available), discharge summaries, primary care provider notes, medications, demographic and insurance data, and nursing notes (if available) as well as automated data from devices, if applicable.

In the sunburst, sections at the same navigation level appear in the same concentric circle; with leaves below toward the outer rim. Items viewable together on the same screen are included in the same block (with the names all written together in the same sector). Items not viewable together on the same screen.
but only sequentially as parts of separate screens accessed from the same menu level appear as separate sectors adjacent to each other, in the same colour as the higher menu level.

Figures 2 and 3 show the essential clinical elements coloured in black. Figure 3 shows the extent of display fragmentation; with each element in a separate sector if it must be navigated to separately, permitting analysis of the EHR structure and where elements are juxtaposed or not.

While figures shown here are relatively simple, visualization software is capable of rendering hierarchies with thousands of elements, with drill-down and expansion capabilities to facilitate examination of relationships between elements, pathway identification, and the study of subsections.

**Quantification of Display Fragmentation**

The fact that clinical elements appear in different subsections of the tree can be quantified, with respect to useful parameters such as the number of clicks or screen transitions required to access individual elements (starting from the top of the tree, or from intermediate points), as well as the likely numbers of clicks/screen transitions required for typical case review.

Derivation of an expression incorporating these parameters (including such things as requirements to scroll, or filtering functions) could allow comparison across commercial systems, and comparison of whether an interaction design improvement has successfully reduced the numbers of actions and fragmentation.
Results

Initial trials of this method revealed that a majority of end clinical elements (end leaves) of the navigation tree are located at least two levels below the top, and that consequently numbers of clicks and screens may reach dozens in order to view all relevant information. This echoes complaints by clinician organizations that ‘too many clicks’ are plaguing physicians in practice and delaying rather than hastening good use of the EHR and expected efficiencies [9,10].

Some systems attempt to reduce the problem by having pages for summaries, with varying degrees of success. Two problems identified in our preliminary work are the lack of inclusion of important clinical information in the summary, and the need for scrolling within elements in the summary, with uniform presentation of blocks of data regardless of whether the blocks are populated or not. This has the potential of wasting space and confusing the user, who may be unaware that the data exists elsewhere. The display fragmentation problem still exists where the user must take an action to view all the data on screen. Roman et al. describe the significance of within-page and between-page navigation as an important factor for EHR usability [11]. An example of the first problem is an outpatient system in which the clinical summary page includes demographic, billing, encounter and allergy data, but not other important clinical variables.

Discussion

Comparative studies across commercial and home-grown EHRs are under way, in order to identify the extent of fragmentation as a problem in general, and specific design
patterns which may contribute to it or conversely reduce fragmentation for specific tasks. The advent of mobile EHRs has also affected the fragmentation in both positive and negative ways. As mobile screens typically display less information, designers may have paid more attention to screen flow in order to ensure correct distribution of clinical values in a way meaningful and convenient to physicians. They are also able to make use of design patterns such as sequential tree menus to focus actions on immediate tasks without extraneous data. On the other hand, if poorly done, this can increase fragmentation, given the screen size limits and need to cater to finger- rather than mouse-driven interaction, which typically has smaller resolution.

The modified cognitive walkthrough method combined with sunburst display has several advantages for data collection. Cognitive walkthrough for the purpose of defining navigation structures is easy to teach, and easily grasped by non-researchers, allowing for others such as clinicians with access to systems to be data collectors. This can facilitate broader studies as specialized access need not be arranged. The use of Excel or similar spreadsheets is familiar to most people, and the branching structure, once explained, is also easy to understand. Automatic generation of sunburst as one of the new standard visualizations allows for easy experimentation. Formatting options allow manual coloring of subsectors. Some visualization tools generate the path from the top of the tree as a part of the legend, changing interactively as the user moves over different elements.

In preliminary studies, users are found to be mostly unfamiliar with the sunburst (unless their particular work requires it), but find it relatively simple to understand once its tree structure basis is explained. Prior empirical work on comparative information visualization of hierarchical structures has shown sunburst visualizations to be more efficient for tasks involving perception of the hierarchy [12], with a shorter learning curve.

**Interaction Design Implications and Other Use Cases**

Mapping can support composable approaches’ reduction of fragmentation, and assist creation of safer design patterns, such as replacements for extensive dropdowns or other undesirable interaction features. Radial menus, for example, leverage humans’ good capacity to distinguish small angles. Mapping of redesigns can provide a measure of progress. Multiple workflow paths could be overlaid on the map, as a way of specifying efficient transitions.

EHR display fragmentation maps have other uses besides research. Interactive sunburst visualizations can be used to convey the navigation paths to particular elements, facilitating instruction. It is conceivable that use of maps for comparison of different EHRs might be used for purchasing processes, as part of evaluation of whether the system flow can be made to match workflow needs. In some systems, changes do not propagate to all areas automatically, and a map could facilitate any manual changes necessary. Development uses include to inform creation of a user-configurable Web CIS interface, Methods Inf Med 50 (2011):337-348.

**Conclusions**

Display fragmentation is a critical problem for the usability of the electronic health record, and mapping EHR navigational structure with visualization presents useful ways to understand and address it. In addition such maps can be useful for related purposes such as instruction and software development. The method will allow comparison of fragmentation across EHRs, facilitating our understanding.

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**References**


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