VOOGLE: A Query-Based Visualization Application to Support Clinician Cognition During EHR Access

David Eibling MD FACS
Department of Otolaryngology, University of Pittsburgh and VA Pittsburgh
Augie Turano PhD
Office of Information, Veterans Health Administration

Abstract: Physicians and other healthcare providers need rapid access to patient data in an informative and visual format that maximizes cognitive functioning at the point of care. Patient data is available in all electronic health record (EHR) systems but most require the provider to navigate a myriad of menus, usurping cognitive resources needed for patient care. Voogle is an application designed to directly support queries in natural language that delivers data quickly and in a format defined by the user. Voogle supports direct queries and “knows” where the data elements are. It supports direct queries such as “show the last PSA test for patient:xyz”. The goal of the prototype program is to give a healthcare provider exactly the information they need on demand, in a format they desire, while minimizing cognitive requirements for information access, aggregation, and interpretation.

INTRODUCTION

The introduction of computerized electronic health records (EHRs) into clinical practice has been shown to exact an adverse effect on clinical workflow, team communication, provider cognition, and patient safety. (Ash 2004, Weiner 2007, Koppel 2005, Embi 2004) A 2008 analysis by the National Research Council of deployed EHRs (Stead 2008) noted that of the 8 systems studied (including VistA, the system utilized in VHA facilities) none appeared to have been designed with the intent of supporting provider cognitive function. To quote the report: “IT applications appear designed largely to automate tasks or business processes. . . and provide little support for the cognitive tasks of clinicians or the workflow of the people who must actually use the system . . . The committee saw virtually no effective computer-based support of an integrated view of patient data.” The “Carayon-Karsh Report” examined the impact of EHR implementation on clinical workflow in a large number of published studies. Among other findings, the authors noted that increased provider workload universally accompanied EHR implementation. (Carayon 2010) A recently released Institute of Medicine Report (IOM 2012) reviewed and highlighted the risks to patient safety posed by EHR software utilized in healthcare delivery.

Commercial EHR systems have focused primarily on strategies to facilitate comprehensive documentation and “meaningful use” due to the economic and bureaucratic pressures facing US healthcare. With nearly 25 years of active data accrued on nearly 25 million veterans, the Veterans Health Administration EHR system, VistA, contains enormous quantities of patient-specific data. The quantity of information available for a single patient presents users with many challenges. Among these are the daunting task of finding and aggregating clinically pertinent information previously digitally captured and stored within the system. Few, if any, EHR systems are capable of generating information displays that are congruent with the mental models of health and disease utilized by providers in decision-making, such as reconstructing time-based narratives of disease processes. We are not the first to note this difficulty. (Stead 2008, Smith 2005) Personal experience and formal published studies note that the effort required to access, aggregate, and process information for decision-making at the point of care is substantial and may impair provider cognitive functioning.

VOOGLE APPLICATION

Overview

This report details the current status of “Voogle,” a secure, web-based prototype application designed to facilitate rapid access to VA patient data with the goal of reducing provider cognitive burden. Voogle utilizes an interface similar to the widely recognized search engine Google™, and “interprets” natural language queries and applies the request directly to VistA data. User input is parsed, analyzed, and constructs a query or series of queries that retrieves patient-specific information within the VistA Cache’ (MUMPS) database. The analyzed user input generates a lookup in a knowledge base and formats both the query and the visualization method(s) for the data to be delivered to the provider at the point of care. The application is web-based and secure, utilizing standard web security strategies with VistA standard login and role based access security access mechanisms. The web-based design facilitates remote access on a wide variety of devices with no unique client software required. Voogle enables user-defined aggregated views of complex
information, employing a number of commercially available graphic controls. The client is coded in Microsoft Silverlight™ and C# and uses standard SOAP (Simple Object Application Protocol) calls to communicate with the VistA host. The wide variety of commercially available controls enables the use of novel displays such as radar charts, timelines, line charts, etc. that may facilitate improved provider interpretation of related information. Raw text is converted to PDF format and is searchable. User-defined data groups facilitate single word command access to multiple data fields and display types, similar to a “macro.” Complex but frequently recurring queries can be saved, used and recalled for future sessions. We have not performed usability testing, however we believe that training requirements will be minimal since the search format is well recognized by users. Since Voogle is “read only,” and does not write to the database, learning can occur during user exploration in a “safe” environment.

VistA

The Veterans Health Administration (VHA) is the largest integrated healthcare system in the United States, currently providing care to nearly 9 million veterans. Its EHR system was authored in-house by a small team of pioneer developers in the late 1970’s and early 1980’s. Coding was in Massachusetts General Hospital Utility Multi Programming System (MUMPS) which had been established in the 1960’s and had several attributes (such as scalability) and string handling which was unique at the time. VistA was authored in multiple (over 120) packages in open source fashion entirely by VA personnel, with care taken to assure program standardization. MUMPS is widely utilized in EHR infrastructure, not only by VistA but other commercially available systems, and is distributed and supported as Cache™ by Intersystems Inc. (Cambridge Massachusetts). There is also an open source version of Mumps (M) which runs with a compiler (GT.M) developed by Greystone Technologies and supported by Fidelity Information Services (Jacksonville FL) a financial data services company. VistA has been dramatically improved over the past 30 years, with new packages such as a linked picture archiving system (Vista Imaging), linkages to commercial software add-ons, web access to other VistA systems (Vista Web) and most notably the graphical interface CPRS (Computerized Patient Record System), now in use for more than a decade. VistA (and linked packages) accessed through CPRS is utilized in all VHA healthcare facilities, and more than half of all practicing physicians in the United States trained since 1995 are familiar with its capabilities (and quirks). The total investment by the VA can be measured in the billions of dollars, and there is no doubt that much of the ascendency of the VHA over the past 15 years as a model integrated healthcare system is due to its implementation. As public domain software, VistA is exportable, and versions of VistA such as GT.M are employed by a number of healthcare systems, both within the US as well as around the world.

Role of VA Innovation Office

Despite its many attributes, CPRS, like essentially every other EHR, has not been seamlessly integrated into clinical workflow. The reasons for this are many, and relate to essentially every aspect of EHR interaction, whether it be documentation, communication, order entry, data interoperability, or data access. (Stead 2009, Carayon 2010, IOM 2012) These as well as other reports illuminated the challenges EHR interaction poses for all providers, including VA clinicians. In response, the VHA Office of Information Technology (VHA OIT) established a program to fund innovation projects proposed by small teams of investigators willing to address recognized challenges. This report will detail the current status of one such funded project, Greenfield #78 Voogle.

DEVELOPMENT STRATEGY

An experienced VHA academic physician-educator (DE) and an experienced computer software architect (AT) developed a list of desirable characteristics (Table 1) of an information system engineered to meet provider needs. It was elected to design to meet these goals utilizing a strategy based on the ubiquitous search engine Google™, off-loading the search/retrieval task from the provider to the information system. Like its namesake, Voogle is a “read only” application intended to be employed by providers seeking rapid, nearly effortless access to desired information, bypassing the standard menu-based system employed universally. A key difference between Voogle and Google™ is that Voogle accesses the curated VistA patient database. We anticipate that future enhancements will enable wider searches for patient-related information from many external sources. We elected not to address EHR data entry requirements for clinical documentation or entry of orders, alerts, or other patient-specific information. Voogle is intended to support the information goals of the provider, not the business, financial, or regulatory goals of the healthcare enterprise.

Natural Language Queries

Natural language queries assist in facilitating rapid information access in that providers are not required to know the data structure or menu hierarchy. They can expend their cognitive resources for decision making rather than playing “Where’s Waldo?” in the search for information. (Hartzband
Features such as auto-complete, retained prior query history, (similar to that of Google™) and the enabling of single-command user-defined groupings of complex data elements, reduce, but do not eliminate keyboarding requirements. Current development is focused on enabling voice commands, which may be able to dramatically reduce provider-keyboard interaction. Employment of UMLS (United Medical Language System, available at www.nlm.nih.gov) - defined synonyms reduce vocabulary limitations. A parts-of-speech (POS) parser was first used to interpret the natural language input then build the query. However we found that a semantic pattern analyzer yielded similar results with much greater speed. Once the query is generated from the user input the program executes the query and retrieves the requested data. Full support for common synonyms is currently incorporated.

### Table 1

<table>
<thead>
<tr>
<th>Desirable Characteristics for Provider Information Access from an EHR</th>
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<tr>
<td>1. Accurate – information is accurate. Data quality must not degrade during transfer from system to system.</td>
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<td>2. Comprehensive – all available information must be available for presentation, without gaps. Information on auxiliary packages must be secured and reformatted if necessary</td>
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<td>3. Rapid – Prior studies have demonstrated that cognitive function of providers degrade when information access delays are longer than one second.</td>
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<td>4. Aggregated – Linked information should be displayed on a single display. Combining information from multiple screens requires use of scarce short term memory resources, and degrades further in critical, complex, and time-sensitive settings.</td>
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<td>5. Time linked – Health and disease reside on a trajectory linked by time. Time-linked information displays facilitate interpretation of trajectories, enabling comprehension of the disease narrative.</td>
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<td>6. Explicit notification of unavailable information – If information is not available it should be indicated explicitly to avoid prolonged searches for information that does not exist.</td>
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<td>7. Use visualizations – Well designed visual displays facilitate efficient viewing of complex information, reducing impact on provider cognitive resources.</td>
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<td>8. Minimal or no training required</td>
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<td>9. Minimize or eliminate menus</td>
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<td>10. Minimize or eliminate dialog boxes</td>
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<td>11. Graduated Alerts – Not all contain equally critical information</td>
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<td>12. Eliminate display of excess or useless information not required for patient care</td>
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<td>13. If unable to display requested information, Indicate presence of available related information</td>
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<td>14. Minimize navigation tasks – Provider cognitive resources should not be wasted searching for information</td>
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<td>15. Reduce access time to 1/8 second for any single data element</td>
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<td>16. Enable durable end-user customization</td>
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<td>17. High level information security – Concerns regarding Patient Privacy have been highlighted by recent data losses by the VHA as well as other healthcare organizations.</td>
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<td>18. Web-based – The ubiquity of the web enables point-of-care information access on any number of devices, as well as facilitate expansion to additional users as the need arises.</td>
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<td>19. Seamlessly obtain non-patient specific information from within the application – Information needs often develop during patient care that are not available within the patient record (such as lists of medication adverse effects). The application should facilitate seamless search of linked databases or even the open web.</td>
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Avoiding data overload

CPRS will attempt to load large data objects such as clinical notes stored in VistA that may exceed available client memory. Providers must learn strategies to limit retrieval to required notes for patients with lengthy or complex medical histories, utilizing complex filters in order to avoid missing critical information. (Smith 2005) Date-based filters will inevitably load large quantities of text information that address administrative or regulatory requirements, within which...
critical information may be “hidden.” Although the current Voogle prototype employs only rudimentary text search ability accessing a limited test database, the basic structure of the data calls will enable this attribute in future versions. Other VA innovation groups are adapting Lucene (Java-based open source search engine supported by Apache™ www.lucene.apache.org) to index VistA text notes. Future version of Voogle will likely use those methods. For example, future versions of Voogle will be able to filter and display text notes containing defined words or text strings such as “display notes containing thyroid” – with qualifiers like “Limit to ENT notes”.

Information Aggregation

A well-recognized limitation of CPRS is its inability to display more than one open window at a time which impairs information aggregation. Data for some displays is aggregated from several sources. The CPRS cover sheet and the graphing function facilitate user-defined aggregation, but is is restricted to these screens. This limitation impacts provider cognition by usurping valuable human memory resources that could be better employed in decision-making. VA clinicians have learned a variety of work-arounds to address this limitation, such as opening more than one instance of CPRS or setting up templates that load multiple objects into a new progress note. This latter strategy generates the well-recognized phenomenon of note bloat as well as “copy and paste,” behavior, a strategy often employed by providers to aggregate information from multiple sources on a single screen. The high speed and asynchronous data calls of Voogle facilitate generation of aggregated views of requested information and the web-based nature permits remote access. Large screen displays will likely enable broader visualizations of aggregated information, further reducing provider cognitive load.

Voogle Knowledge Base

Key to the functionality of Voogle is an integrated knowledge base that serves several critical functions. VistA database structures vary slightly from facility to facility, hence Voogle relies on its knowledge base that that has previously registered the locations of requested data at each individual site. Voogle installs itself on each unique VistA system, utilizing “spiders” that crawl through the database, “learning” the data structures. In this way, the application, not the user, “learns” how to conform with individual VistA data configuration paradigms. The knowledge base can be configured with a more globally oriented data locator that not only enables access to VistA, but can be configured to identify the location of data not within VistA. The Voogle prototype includes functionality to retrieve documents stored on other accessible databases, or perform complex calculations with non-Mumps programs of any variety. Examples include “display expense report” or “calculate Easter for 2015.” Voogle will automatically redirect queries to other sources, even to the World Wide Web if so configured. For example, providers could utilize the Voogle query box to directly access recent publications through PubMed or other web services if the knowledge base was so configured. Since the knowledge base “knows” the data structure, if the specific requested information is not available within VistA, Voogle will inform the user, avoiding the well-recognized situation of searching within the CPRS menu structure for data that does not exist.

Silverlight™ Controls

Data returned in XML format is displayed using Silverlight™ (free downloadable browser add-on) control. Default controls for specific data fields are pre-defined within the knowledge base and can be user-assigned to specific data elements. The current prototype employs a number of standard controls such as traditional tables, data grids, graphs, and text reports, as well as novel displays such as radar plots and expandable timelines. (Figure 2) Numerous commercial Silverlight™ libraries are available, and only a few of these have been investigated for use in Voogle at this time. The platform is supported by Microsoft™ and there are many vendors that supply commercial, royalty free Silverlight controls, so that new and improved displays should become available in time. Voogle users can easily define displays using the simple “define:” command which is similar to Macro creation. (see next paragraph).
spoken when voice recognition is active) to retrieve all the requested data. The format for “macro” creation is: [Define:eiblab as Chem4, glucose, BUN HBA1c]. Once defined typing “eiblab” into the query box will call and display all data in the format defined by the knowledge base. As noted earlier, user-defined displays can also be specified by including them in the definition string: […notes as timeline] (Figure 3).

Text data
Voogle can present text in several formats including PDF files which can be displayed via typical PDF readers, with standard manipulation including text search. As noted earlier, although the current Voogle prototype does not support user-defined text searches from the query line, the feasibility of this strategy has been demonstrated. Text data can also be placed in book form and paged through graphically similar to many online magazines with “page-turn” graphics (Figure 4).

Keyword box
Voogle employs the common auto-complete function of other search engines to minimize keyboarding tasks. The auto-complete functionality of CPRS was inactivated several years ago due to risk identified in order-entry dialogue. This risk is sharply reduced or eliminated in Voogle since the application is read-only. We elected to position this functionality in a separate box from the standard query so that the drop-down would not overlay the patient photograph. Similar to standard auto-complete functionality in other applications, entering the first 3 letters activates the function, enabling the user to pick from a drop-down list. The current Voogle prototype utilizes drop-down lists unique to each user including user-defined group labels.

Patient ID Photographs and other images
Many commercial, and some VistA installations, employ a patient photograph to help assure correct patient identification. Voogle has elected to display the patient photograph on all screens, avoiding errors in ID that can easily accompany workflow interruptions particularly during periods of intense cognitive multi-tasking. The Voogle prototype recalls photographs from a dedicated web service. It is anticipated that future versions will access the most recent patient photograph uploaded into VistA Imaging. Although the functionality does not exist on the Voogle prototype, access to other information uploaded into VistA Imaging or similar packages should be accessible. This might include clinical images and scanned text reports from commercial vendor packages and non-VA facilities. These would be accessible via Voogle queries in future versions with proper external API calls to those packages.

Security
Voogle is a web-based application, hence security is paramount to assure protection of private patient health information. Moreover, it is understood that not all users should be granted equal access to this information. Hence, Voogle employs a novel security system in which each data element is assigned a security level from 1 to 100. Each user is assigned a level as well. Upon receiving a request for information, Voogle compares the security level of the data element requested with that of the requester. If the user has an equal or higher number, access is granted. Each instance of Voogle log-in assigns a unique token to the user, which is encrypted along with the call and the data return from the client to server and back. Single Socket Layer (SSL) encryption is planned, but not yet incorporated since current operation already occurs behind the VA firewall.

Conclusion
The burgeoning information complexity on which modern healthcare delivery depends exacts an ever-increasing cognitive demand on providers. These demands are greatest at times of peak workflow when critical information is most needed at the point-of-care. The cognitive effort required for information access and aggregation unavoidably impairs decision-making for patient care at these most critical times. Voogle promises to reduce the cognitive load required for information access through the use of natural language queries
and user-defined displays of aggregated information. The read-only characteristics of the application support user-directed exploration in a safe environment without the requirement for extensive user training. We propose that Voogle be deployed as an additional VistA overlay in order to permit users the opportunity to explore its capabilities while simultaneously accessing information through the standard CPRS interface. No one interface satisfies every need; this prototype was created to offer a supplement to normal physician – computer interaction beyond what is available in the VistA system. This strategy would insure the highest levels of patient safety as well as provide a widespread test environment for the application while enhancing patient care.

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