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Communications of the Association for Information Systems

INFORMATION SYSTEMS AND HEALTHCARE XXII: CHARACTERIZING AND VISUALIZING THE QUALITY OF HEALTH INFORMATION

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ABSTRACT

We all need ways to assess the quality of the information we look for, but this task is critically important when we are seeking health information. Healthcare consumers increasingly seek and use health information to address their health concerns. However, many health consumers lack the time and expertise required to make solid judgments about the quality of health information they encounter. A full range of quality appraisal methods for health information offer help, yet health consumers use those methods infrequently. Health consumers need better support to overcome barriers to efficiency, scalability, and transparency often associated with this breadth of valuable methods. Furthermore, they need ways to assess the quality of health information they find in the context of their own, individually situated needs. Our goals were to investigate the concept of health information quality and to explore how we can provide health consumers with better support by highlighting, rather than hiding, important aspects of health information quality. First, by reviewing and synthesizing criteria used by a broad range of quality appraisal methods for health information, we identified four focal characteristics of health information quality: content, reference, authorship, and publisher. Together, these four characteristics of intrinsic quality provide an organizing framework for health consumers to assess the quality of health information along multiple dimensions according to their own needs. Next, we used a user-center approach to design a prototype tool that concretely illustrates our framework by allowing the user to highlight multiple dimensions of health information quality. We present a usage case example of this illustrative tool, which visualizes the quality of MEDLINE search results. Our work provides a new perspective on health information quality by acknowledging and supporting consumers' needs for transparency and flexibility as they take a prominent role in health information quality assessment.

Keywords: consumer health informatics, health information, information quality, model formulation, information visualization, consumer-centered technology

I. INTRODUCTION

Healthcare consumers seek a variety of health information resources to learn about health topics, make informed medical decisions, and play active roles in their health care. A significant number of consumers now turn to the Internet to access this information [Pew Internet and American Life 2005], and those who use high-quality online health information could improve their health outcomes and the physician-patient relationship [Murray et al. 2003].

Unfortunately, consumers are likely to encounter poor-quality health information on the Internet due to its high prevalence [Berland et al. 2001]. The rate of growth in online health information and its variation in quality requires that consumers assess the quality of information they find. However, many consumers lack the time and expertise required to make solid judgments about the quality of health information they encounter. For example, some consumers overrate the quality of health information they find online [Diaz et al. 2002], lack concern for information trustworthiness [Pew Internet and American Life 2003], and overlook available health information quality indicators and tools [Eysenbach and Kohler 2002; Adams et al. 2006]. Furthermore, consumers assess quality within the context of dynamic and divergent, yet individually situated needs [Anderson et al. 2003] and established search routines [Adams et al. 2006]. These findings indicate that quality appraisal can be a significant challenge for health consumers. Helping consumers use available methods for appraising the quality of health information in more transparent, efficient, and individually tailored ways could remove many of these barriers. A fresh perspective that acknowledges consumers' needs as individually situated and context-dependent might lead to the development of more flexible techniques, which highlight, rather than hide, telling aspects of health information quality. Such techniques could assist the user in taking a more central role in aligning those aspects of quality most critical to their own specific situation.

A wide range of methods, including health information trust marks [Health on the Net Foundation 2004; MedCERTAIN Consortium 2001], automated filtering and Web metrics [Price and Hersh 1999; Wang and Liu 2007; Hernandez-Borges 1999], user-guided checklists [Charnock et al. 1999; National Library of Medicine 2006], and manual quality assessment guidelines [Cochrane Consumer Network 1998; Silberg et al. 1997; Oxford Centre for Evidence-Based Medicine 2001] can assist consumers in discerning the quality of online health information [Wilson 2002]. Many of these quality appraisal methods for health information rest on principled standards of medical information quality that encompass provision of authorship information, proper attribution, appropriate disclosure, and indication of currency [Silberg et al., 1997]. Other methods incorporate additional criteria, including accuracy, completeness, authority of source, readability, and Web site design [Eysenbach et al. 2002; Kim et al. 1999].

Quality appraisal methods for health information have been applied to the assessment of information resources ranging from informal health Web pages to scientific medical literature. For example, questions from MedlinePlus' user-guided checklist [National Library of Medicine 2006] provide consumers with guidance in their own appraisal of information available from informal health Web sites (Table 1). In contrast, indicated validity of scientific evidence underlying medical advice can be graded according to Oxford Centre for Evidence–Based Medicine's "Levels of Evidence" framework [Oxford Centre for Evidence-Based Medicine 2001]. In this framework, the research design underlying a piece of scientific evidence is assigned a "level" between 1 (i.e., strong designs, such as a systematic review of randomized controlled trials) and 5 (i.e. weaker designs, such as expert opinion), The level is then mapped to a "grade of recommendation" between A (i.e., highest recommendation for designs consistent with Level 1 evidence) and D (i.e., lowest recommendation for designs consistent with Level 5 evidence, or with studies showing inconsistent or inconclusive findings). Although traditionally the "levels of evidence" framework has been used in the context of evaluating the validity of medical advice in the clinical setting, its use could be extended to support consumers in their evaluation of online health information.

Table 1. Questions from MedlinePlus' User-Guided Checklist for Evaluating the Quality of Internet Health Information

Provider
Who is in charge of the Web site?
Why are they providing the site?
Can you contact them?
Funding
Where does the money to support the site come from?
Does the site have advertisements? Are they labeled?
Information quality
Where does the information on the site come from?
How is it selected?
Do experts review the information that goes on the site?
Does the site avoid unbelievable or emotional claims?
Is it up to date?
Privacy
Does the site ask you for personal information?
Do they tell you how it will be used?
Are you comfortable with how it will be used?

The diverse range of quality criteria used among health information quality appraisal methods reflects the complexity and breadth that surround the construct of health information quality as well as the variation in individual users' needs. It also reflects the difficult nature of building consensus around an operational definition of quality and valid criteria by which health information might be judged [Eysenbach et al. 2002; Gagliardi and Jadad 2002; Anderson et al. 2003]. These ongoing tensions align closely with information quality issues addressed in more general contexts. For example, insight into dealing with the complexity among a diverse range of quality criteria can be gained by differentiating quality characteristics in reference to intrinsic properties of information resources (e.g., accuracy, reputation, completeness) from extrinsic properties associated with information use and the effects of information systems on users (e.g., accessibility, clarity of representation, contextual relevance to user's task) [Wand and Wang 1996; Wang and Strong 1996]. Furthermore, grounding our understanding of information quality from multiple angles can be gained by contrasting research results among different approaches to information quality inquiry, including identification of quality attributes based on intuition, theoretical reviews, or empirical studies [Wang and Strong 1996], such as understanding users' needs from survey research and direct observation [Eysenbach and Kohler 2002; Fogg et al. 2003; Adams et al. 2006]. Insights from inquiry into information quality in more general contexts could provide guidance for addressing challenges surrounding health information quality appraisal methods explicitly.

Although health information quality-appraisal methods can help consumers identify high quality health information, many place a heavy burden on these users [Bernstam et al. 2005]. They

require that consumers take the time and have the motivation to check the quality of health information they find against an often unfamiliar and lengthy criterion code, checklist, or questionnaire [Bernstam et al. 2005], become familiar with the meaning of a quality label, or understand the mechanisms by which an automated system selects and ranks the quality of health information resources. Several methods include extrinsic evaluation criteria, such as ease of Web site use and design aesthetics, which can influence consumers' use of a Web site but do not necessarily reflect the intrinsic quality of the content provided by that Web site. Many methods conceptualize quality from a singular perspective to meet a perceived uniformity in consumers' needs [Anderson et al. 2003]. Quality criteria used by a number of methods are inaccessible to consumers because they are not publicly disclosed [Gagliardi and Jadad, 2002; Bernstam et al. 2005]. Although existing methods provide a range of valuable quality criteria, their existing implementations pose several challenges for consumer use due to inefficiencies, poor scalability, and lack of transparency.

These challenges indicate the need for tools that help consumers assess the quality of health information clearly and easily. Variation in consumers' health information needs, search purposes, backgrounds, and preferences necessitate tools that represent health information quality in ways that are responsive to these individual variations. As our understanding of the strategies consumers currently use to assess health information grows [Adams et al. 2006; Eysenbach and Kohler 2002], development of such tools will require a robust framework that can represent those various aspects of health information quality. The construct of quality encompasses multiple features (e.g., validity, accuracy, credibility, impact, authority, attribution, prestige, influence, merit), and can be examined from a number of different reference points. Therefore, a one-size-fits-all marker of health information quality is insufficient [Martin 1996; Anderson et al. 2003]. Our approach to quality appraisal, given this multidimensional nature of quality, is to provide consumers with multiple quality indicators which they themselves can match to their own specific needs, purposes, and characteristics. Their confidence in the reliability of health information could build with convergent findings among multiple quality indicators, while incongruent findings could spark investigation [Kostoff 1997].

Each health information quality appraisal method contributes valuable quality criteria from a unique perspective. We speculated that a synthesis of criteria from among those methods could identify focal quality characteristics associated with health information that capture these various perspectives within a robust representational framework. New consumer health informatics tools could implement such a framework by describing and comparing health information resources along these focal characteristics to reveal quality in multiple ways. Such a tool might better meet the needs of consumers than existing appraisal methods by providing more flexible and less burdensome support for discriminating quality.

II. APPROACH

We explored the construct of health information quality and its relationship to the design of new tools for consumer use. Our goals were first to identify focal characteristics of health information quality, and then to explore the design of an example tool that can help the user to highlight those focal characteristics given a set of health information resources. We met these goals through a two-step process. We first developed a multidimensional framework of health information quality (i.e., "Framework Development") based on a theoretical review of health information quality appraisal methods. Then, we employed a user-centered approach to design a prototype that provides a concrete illustration of our framework (i.e., "Prototype Design").

FRAMEWORK DEVELOPMENT

Our first goal was to identify focal characteristics of health information quality. Using a theoretical approach [Wang and Strong 1996], we reviewed a range of available methods for assessing the quality of health information to identify focal aspects of quality, which we expressed as dimensions within a multidimensional framework.

We focused our review on capturing focal quality characteristics across a breadth of different types of health information quality appraisal methods, including manual review processes and guidelines, trust marks, user-guided checklists, and automated filters and Web metrics in the health context. As we discussed in the Section I, these methods have been applied to the appraisal of information resources ranging from informal health Web pages to scientific medical literature. We examined 31 methods discussed in the literature related to health information quality for which explicit quality criteria could be directly accessed from either peer-reviewed studies or from tool descriptions available online (Table 2).

Table 2. Quality Appraisal Methods Reviewed during Framework Development

	Content	Reference	Authorship	Publisher
Manual review processes and guidelines				
Levels of Evidence [Oxford Centre for Evidence-based Medicine 2001]	X			
ACP Journal Club Criteria and Star Rating [American College of Physicians 1991]	X	X		
Faculty of 1000 Medicine Evaluation System [Faculty of 1000 2007]	X	X		
CCNet Consumer Review Process [Cochrane Consumer Network 1998]	X			
MedlinePlus Quality Guidelines [National Library of Medicine 2004]	X		X	X
HON Code of Conduct [Health on the Net Foundation 1997]	X		X	X
Hi-Ethics Principles [Health Internet Ethics Inc. 2000]	X		X	X
eHealth Code of Ethics [Internet Healthcare Coalition 2000]	X			X
AMA Guidelines [American Medical Association 2000]	X			X
JAMA Benchmarks [Silberg et al. 1997]	X		X	X
Trust marks				
URAC Accreditation Seal [URAC 2004]	X		X	X
HONcode Accreditation Certificate [Health on the Net Foundation 2004]	X		X	X
MedCERTAIN Transparency Mark [MedCERTAIN Consortium 2001]	X			X
User guided checklists				
Information Quality Tool [Mitretek Systems 2001]	X		X	X
DISCERN [Charnock et al. 1999]	X			X
Bomba and Land Consumer Health Web Site Rating Index [Bomba 2005]	X		X	X
MedlinePlus checklist [National library of Medicine 2006]	X		X	X
OMNI Evaluation Steps [OMNI 2002]	X	X	X	X
NetScoring [Centre Hospitalier Universataire de Rouen 2001]	X	X	X	X
Quality Information Checklist [HDA and CHIQ 2000]	X		X	X

Automated filters and Web metrics				
Automated Filtering Tool [Price and Hersh 1999]	X		X	
PubMed Clinical Queries [National Library of Medicine 2005b]	X			
HIDDEL [MedCIRCLE Collaboration 2003]	X		X	X
Automated Filtering [Eysenbach and Diepgan 1998]	X	X	X	
Citation Indexing [Garfield 1955]		X		
Journal Citation Patterns [Garfield 1972]				X
Journal Impact Factor Institute for Scientific Information 2007]		X		
Web Statistics [Brin and Page, 1998; Kleinberg, 1999, Lawrence et al. 1999]		X		
Super-Site Hypertext Linking [Aguillo 2000]		X		
Web Statistics Hernandez-Borges et al. 1999, 2001, 2003]		X		
Author Impact Factor [Hernandez-Borges 1999]			X	

For each of these 31 methods, we extracted and listed the criteria used to assess health information quality. We selected criteria from each method that related to the intrinsic quality of an information resource.[1] Next, we identified focal characteristics of health information quality by grouping selected criteria that describe common properties of information resources into thematic categories (i.e., "dimensions"). Throughout this process, we discussed discrepancies in our categorization of criteria until we reached agreement.

Four focal dimensions emerged from our review and synthesis of quality appraisal methods for health information, revealing that the intrinsic quality of health information is a multidimensional construct that can be characterized by four primary dimensions: content quality, reference quality, authorship quality, and publisher quality. Table 2 shows the health information quality appraisal methods that we reviewed, categorized by method type. Table 2 also indicates the division of quality criteria for each method among each of the four dimensions in our framework. Next we provide descriptions of the underlying quality appraisal methods for each of the four dimensions that together form the basis of our multidimensional framework of health information quality.

Content Quality Dimension

The content quality dimension characterizes the degree to which information present within a health-related document is scientifically rigorous, free of bias, and current. Scientific rigor of published medical studies can be assessed using details about study methodology, such as randomization, sample size, and the use of a control group. Text terms or metadata that indicate publication type, venue, or potential bias show quality of informal health resource content. Date of publication or last update can indicate information currency. Methods for determining content

[1] Although we agree that extrinsic characteristics of health information quality (e.g., criteria related to context of use, representation, and accessibility of information, such as web site design, usability, and resource readability) are necessary for understanding information needs and use by a target user [Wang and Strong, 1996], we chose an intrinsic focus as a first step exploration in the development of our framework. For example, we selected the criteria *balanced and unbiased presentation* because this characteristic influences the quality of content contained in an information resource. However, we did not select *easily navigable site* because this characteristic reflects more closely the ease of web site usability, rather than intrinsic quality of the content the web site provides.

quality fall into two general categories: manual content evaluation and automated content evaluation.

Manual approaches often rely on expert evaluation through an authoritative review process, such as traditional peer review applied to scientific medical literature, post-publication editorial processes used by many gateways, or reviews of informal health Web pages. Authoritative review processes rely on domain experts or other authoritative bodies to evaluate the validity, accuracy, proper attribution, and fairness of a document's content based on their in-depth experience in a relevant subject area. These processes often rely on established guidelines, such as the HON Code of Conduct [Health on the Net Foundation 1997], Hi-Ethics principles [Health Internet Ethics 2000], eHealth Code of Ethics [Internet Healthcare Coalition 2000], AMA guidelines [American Medical Association 2000], or JAMA benchmarks [Silberg et al. 1997].

The traditional peer-review process requires that content of a scientific work include appropriate study details, attribution, and a logical framework from which to determine validity. The rigor of this evaluative review process makes scientific medical content well suited for evaluation by evidence-based medicine's critical appraisal method [Oxford Centre for Evidence-Based Medicine 2001]. This method argues that appropriately selected and legitimately implemented methodology is associated with a high likelihood of validity. The critical appraisal method uses levels of evidence to rank content validity on the basis of study rigor using facts such as study design, sample characteristics, and appropriateness of methodology to study hypotheses. The peer-review process ensures that such content-oriented characteristics are present in published scientific medical literature.

Post-publication editorial processes are based on the same principles of traditional peer review. ACP Journal club [American College of Physicians 1991] and Faculty of 1000 Medicine [Faculty of 1000 2007] for example, are composed of experts who use rigorous standards to select and disseminate the highest quality published biomedical literature through their Web sites. Similarly, the Cochrane Consumer Network selects the highest quality evidence to produce consumer friendly systematic reviews of the medical literature [Cochrane Consumer Network 1998; White 2002]. Published content from informal Web pages undergoes an authoritative review process prior to dissemination from consumer-oriented health information gateways, such as the National Library of Medicine's MedlinePlus [National Library of Medicine 2004]. Health information accreditation organizations, such as URAC [URAC 2004], and third-party labeling services, such as that provided by the Health on the Net Foundation [Health on the Net foundation 2004], also use authoritative review processes to evaluate and disseminate Web-based health information.

In contrast, other manual approaches attempt to teach consumers to use authoritative review to perform their own quality evaluations (i.e., user-guided methods). A variety of questionnaires, checklists, and rating instruments has been developed to help consumers identify and assess content characteristics indicative of quality [Mitretek Systems 2001; Charnock et al., 1999; Bomba 2005, National Library of Medicine 2006; OMNI 2002, HDA and CHIQ 2000; Centre Hospitalier Universataire de Rouen 2001]. For example, DISCERN [Charnock et al. 1999] is a 16-question validated instrument that helps consumers judge the quality of medical treatment information. It was developed by an expert panel and provides hints to help consumers evaluate a number of key components of content, such as clarity, attribution, and balanced presentation.

The rigid requirements and reviewer expertise upon which manual content evaluation approaches derive allow authoritative reviews and user-guided methods to identify the highest quality online health information. However, this method is highly labor intensive. Therefore, scalability of manual approaches for coverage of the large and growing volume of online health information is impractical. Automated content evaluation approaches provide an alternative method with greater scalability.

Automated approaches rely on heuristics to identify predefined patterns in text or metadata, such as the word *double-blind*. Extracting these features from content has been used to indicate credibility or potential bias. For example, Price and Hersh [Price and Hersh 1999] developed an

automated quality-filtering tool that relies on a variety of quality indicators extracted from the text of health Web pages. This system eliminates Web pages containing the terms *Visa* or *MasterCard* with the assumption that such terms indicate a likelihood of commercial bias. The system also eliminates pages containing the term *miracle cure,* assuming its presence threatens credibility. As a marker of credibility, the system accepts Web pages that display the HONcode accreditation certificate [Health on the Net Foundation 2004].

Other automated content evaluation methods rely more heavily on metadata. For instance, PubMed Clinical Queries service [National Library of Medicine 2005b] uses both metadata in the form of MeSH terms [National Library of Medicine 2005a] and text terms to enhance retrieval of the most methodologically sound studies within the categories of therapy, diagnosis, etiology, and prognosis [Haynes et al. 1994]. These search strategies allow the user to emphasize either search sensitivity or specificity, which provides them with some control over the strictness of their search.

A flexible use of metadata for online health information quality appraisal is MedCIRCLE's Health Information Disclosure, Description, and Evaluation language ("HIDDEL") [MedCIRCLE Collaboration 2003]. HIDDEL is a vocabulary composed of both evaluative and descriptive metadata. It provides a language and format for information providers, users, and third parties to both provide and access descriptions of the quality of Web-based health information. Automatic filtering based on HIDDEL can complement the laborious process of manual peer review [Eysenbach and Diepgen 1998].

In summary, consumers need content evaluation methods to assess the information contained in health resources. Manual methods are labor intensive for both expert reviewers and consumer reviewers; thus, they have limited coverage. Automated systems can expedite the evaluation process, but are prone to a variety of problems, such as lack of metadata required for making quality evaluations [Shon and Musen 1999], technical difficulty of accurately extracting and processing text, and lack of universally upheld health information metadata standards. An intermediate approach is to identify and present the consumer with available content quality characteristics from text. This method might improve the efficiency with which consumers can use evidence-based critical appraisal and enable them to exercise greater control over their own quality judgments than automated filtering systems provide.

Reference Quality Dimension

The reference quality dimension indicates how a health information resource is cited or referenced by other information resources. Several reference-oriented quality indicators derive from bibliographic citation indexing [Garfield 1955], which signifies the rate at which information resources are cited. The Institute for Scientific Information, for example, estimates the influence of an article in the scientific literature, or its "impact," based on the rate at which other scientific articles reference it [Institute for Scientific Information 2007]. This method of quality evaluation by resource use rests on the assumption that as the number of citations to a resource increases, so does its likely impact, as well as its quality. Other reference-oriented indicators are provided through expert recommendations of health information. ACP Journal Club [American College of Physicians 1991], for example, uses a star rating system to indicate resource newsworthiness (e.g., Star ratings"). Similarly, Faculty of 1000 Medicine [Faculty of 1000 2007] indicates level of recommendation using the "F1000 factor."

Web statistics, such as hyperlink structure, are an extension of citation indexing methods that have become a popular means for evaluating online resources [Kleinberg 1999; Brin and Page 1998]. Web statistics can identify authoritative Web pages based on the number and characteristics of links associated with Web pages. For example, Aguillo [Aguillo 2000] proposed an approach, which used hypertext linking to and from a controlled sample of known high-quality medical super-sites to indicate the quality of resources residing outside this sample. Context of use can be partially deduced by examining the location from which inward bound links arrive. For example, Web-based search engines, such as the CiteSeer Digital library [Lawrence et al. 1999]

and Google [Google, Inc. 2007] inform quality by communicating the context of use when they present users with portions of text surrounding citations.

The use of Web statistics for evaluating the quality of online health information has been an integral part of several proposals and evaluations. Eysenbach and Diepgen [Eysenbach and Diepgan 1998] promote Web statistics as promising indirect quality indicators that have good potential for use in automatic and semiautomatic quality assessment schemes. Hernandez-Borges and colleagues [Hernandez-Borges et al. 1999] evaluated the efficacy of using Web statistics to identify high-quality pediatric health Web sites. They found that both the number of daily visits and the characteristics of outbound hyperlinks associated with a Web site correlated with the site's positive evaluation by three prominent online health information rating systems. Later, Hernandez-Borges and colleagues extended these findings by showing a correlation between the number of inbound links to a pediatric health Web page and the page's compliance with health information quality criteria advocated by three prominent international organizations, including the Health on the Net Foundation [Hernandez-Borges et al. 2001; Hernandez-Borges et al. 2003]. Furthermore, user-guided checklists, such as OMNI [OMNI 2002] and NetScoring [Centre Hospitalier Universataire de Rouen 2001], encourage users to investigate Web metrics and other usage statistics (e.g., bibliometrics and press releases) to find out if an information resource is heavily used in the community.

Incorporation of reference characteristics, such as citation indexing, Web statistics, or indicators of newsworthiness is a promising approach for indicating quality based on citation frequency and context. Web statistics-based quality evaluation is a comparatively new innovation, thus it warrants further evaluation. In addition, consumers must be aware that not all citations should be treated equally. Authors cite for a variety of reasons, including self-promotion or discrediting others, and these varied contexts of citations pose potential reliability problems. It can, therefore, be misleading and unreasonable to base quality evaluation on citation rate alone [Baird and Oppenheim 1994].

Authorship Quality Dimension

The authorship quality dimension shows the merit of reputations, credentials, and competing interests of authors, contributors, and their affiliations. Methods for appraising authorship quality identify authorship descriptions, such as author qualifications, institutions, affiliations, or presence of financial or other bias. These approaches fall into two general categories: user-guided authorship evaluation (e.g., questionnaires and checklists) and automated authorship evaluation (e.g., filtering tools and author impact factors).

User-guided authorship appraisal approaches promote consumers' self-evaluation of health information authorship. Several of these methods are consistent with guidelines and authoritative review processes that attend to authorship characteristics [National Library of Medicine 2004; Health on the Net Foundation 1997; Health Internet Ethics Inc. 2000; Silberg et al. 1997]. For example, Mitretek System's Information Quality Tool [Mitretek Systems 2001] is a user-guided questionnaire that devotes nearly one-third of questions to authorship-oriented characteristics, such as presence of credentials, subjective judgment of author's experience as relevant to topic, and presence of explanation for financial conflict or bias. A host of user-guided checklists similarly highlight the importance of consumer evaluation of authorship [Bomba 2005; National Library of Medicine 2006; HDA and CHIQ 2000; OMNI 2002; Centre Hospitalier Universataire de Rouen 2001]. Although such methods rightfully urge consumers to attend critically to authorship, they can be burdensome for consumers who are not familiar with the names of well-respected authors in a given domain.

In contrast, automated systems, such as Price and Hersh's automated quality-filtering tool [Price and Hersh 1999], judge likely credibility by inspecting site URL and other authorship information. Other filtering methods rely on metadata to automate evaluation of authorship [MedCIRCLE Collaboration 2003; Eysenbach and Diepgan 1998]. Hernandez-Borges and colleagues' [Hernandez-Borges 1999] approach for evaluating authorship provides a metric for automated

authorship evaluation. This group generated an author impact factor for authors of pediatric health Web sites by aggregating the journal impact scores associated with the author's work published in MEDLINE. Although this metric did not correlate with positive evaluation by prominent online health information rating systems, it is nonetheless an engaging attempt to automate quality indication based on authorship.

Authorship is a difficult and time-consuming characteristic to evaluate, especially for people who are not familiar with a given subject area. Yet, user-guided systems often place this burden on the consumer. Systems that perform automated authorship evaluation are an improvement, although they might not provide the consumer with enough information about the basis of automated judgments. Both methods can be problematic for consumers who do not know how to make or trust such assessments without supplementary knowledge. A system that identifies and flags information resources authored by well-respected individuals might better support consumers. Potential methods to achieve this goal include identification of authors affiliated with highly ranked educational programs [U.S. News and World Report 2007] or named in the Institute for Scientific Information's highlycited.com database [Institute for Scientific Information 2007] or in the COS Expertise Database [Community of Science 2007]. Other potential methods for supporting consumers' authorship evaluation include extracting and presenting authors' credentials or aggregating resources authored by a common source to indicate extent and breadth of an author's contribution to a subject area.

Publisher Quality Dimension

The publisher quality dimension communicates quality using the reputation, practices, and extent of experience of an information resource's publishing body. Data associated with a document, such as its publishing venue, the history and procedures of its publisher, the editorial or review board of its publisher, its sources of sponsorship, and its publisher's perceived impact (e.g., journal impact factor [Institute for Scientific Information 2007], readership rate) provide insight into a publisher's merit and endurance. Identification of these publisher-oriented sponsorship and ownership details is a component of several user-guided checklists [Mitretek Systems 2001; Charnock et al. 1999; Bomba 2005; National Library of Medicine 2006; OMNI 2002; Centre Hospitalier Universataire de Rouen 2001] and automated filters [MedCircle Collaboration 2003]. Presence of information on a reputable scientific or consumer-oriented health information portal and publisher impact factors are indicative of publisher quality.

Publisher-oriented characteristics provide reassurance of quality for information authored by less-well-known authors. Identification of source sponsorship can reveal potential conflicts of interest, and identification of publishing venue can be indicative of quality. Generally, higher quality health information is published on more authoritative sites, such as institution-supported health information portals, as opposed to less authoritative sites.

Without a required review process, health information published on the World Wide Web has no inherent method of quality control. Therefore, a number of online health information publishers ensure the quality of health information they disseminate by requiring authoritative review. Many authoritative review guidelines recommend disclosure of publisher-oriented ownership and sponsorship details [Health Internet Ethics 2000; Internet Healthcare Coalition 2000; American Medical Association 2000; Silberg et. al. 1997]. Publishers who require authoritative review as part of their editorial process are more likely to publish high quality health information. Examples of such publishers include scientific literature portals, such as MEDLINE [National Library of Medicine 1996], ACP Journal Club [American College of Physicians 1991], and Faculty of 1000 Medicine [Faculty of 1000 2007], as well as consumer-oriented health information portals, such as MedlinePlus [National Library of Medicine 2004], URAC [URAC 2004], and Health on the Net Foundation [Health on the Net Foundation 1997].

Impact factors associated with publishing bodies provide an alternative method for evaluating publisher quality. The Institute for Scientific Information's journal impact factor [Institute for Scientific Information 2007] is a metric by which to judge the prestige of a scientific journal, and

thus the likely quality of an article appearing in that journal. A journal's impact factor is the average number of citations that papers published in that journal have received over the previous two years [Garfield 1972]. The quantitative nature of the impact factor calculation assumes that all citations appearing in a journal are contextually equivalent and distributed normally; a fact we know to be less than true [Baird and Oppenheim 1994]. Citation characteristics do not vary systematically between articles published within a journal, among journals, or across fields. Therefore, the reliability of this metric for individual articles is often questioned [Seglen 1997]. Although controversial, the journal impact factor tends to correlate with the esteem of published scientific work [Baird and Oppenheim 1994] and could be a reasonable quality predictor of health information published in scientific journals. Like the journal impact factor for scientific information, merit of online publishers could be evaluated based on corresponding factors, such as readership or Web site reputation.

In summary, consumers need informative facts about publishing bodies to help them evaluate health information quality. Presence of health information on a respected health information portal shows a certain caliber of quality. However, few tools assist consumers in differentiating quality among the various documents these portals distribute. The journal impact factor is such a tool, although it has been met with some controversy and resistance. Use of hyperlinked trust marks, such as the HONcode accreditation certificate [Health on the Net Foundation 2004] or the MedCERTAIN transparency mark [MedCERTAIN Consortium 2001]), to differentiate resources published by authoritative portals could provide a reasonable approach if consumers understand the meaning of these labels and know how to use them. However, the volume of accessible online health information makes widespread use of this manual approach an ambitious goal.

PROTOTYPE DESIGN

Our design goal was to develop a prototype consumer tool that highlights quality characteristics of online health information according to the four dimensions expressed in our multidimensional framework of health information quality: content, reference, authorship, and publisher. We believe our framework can be used to develop new kinds of consumer tools that reveal different aspects of quality associated with health information resources. Our framework's multidimensional perspective provides flexibility for alternative approaches to interaction design for search and result presentation. In addition to the traditional ranked list, creative interface approaches, such as information visualization or interactive dialog techniques, can use multiple quality indicators to provide consumers with new ways to examine the quality of health information resources they find online. We were motivated to explore design as a means to illustrate one concrete implementation of our framework.

In our prototype design process, we implemented our multidimensional framework through an informal, user-centered approach, which explored the design of a new consumer tool that visually highlights multiple aspects of health information quality. First, we identified a range of potential Web-based indicators that could be used as proxies for quality within the context of our framework. Using a selection of those indicators, we created several initial design alternatives centered on the scenario of finding high quality health information from MEDLINE [National Library of Medicine 1996]. Next, we solicited feedback and design recommendations from two health consumers using select design alternatives over three user-driven design iterations. We used participants' feedback and recommendations to arrive at a final design. Finally, we implemented this final design using an open source tool that provided the necessary functionality recommended by our participants.

Web-based Quality Indicators and Design Alternatives

We began our design process by identifying Web-based indicators that could be used as proxies for each dimension of our multidimensional framework of health information quality (Table 3). These indicators comprise both our own novel ideas as well as previously reported indicators used in the health information quality appraisal methods we reviewed. We selected and fit each indicator to a corresponding dimension of quality in our framework through discussion and mutual

Table 3. Web-Based Quality Indicators by Dimension

Dimension	**Quality Indicator**
Content	Key term search (e.g., “miracle cure” or “double blind”)
	HIDDEL metadata
	Third-party label (e.g., trust mark)
	Publication type
	Match to MEDLINE Clinical query
	Date posted or updated
	Expert or peer reviewed
	Evidence level
	Publication date
	Presence of editorial board
Reference	Resource citation rate
	Web statistics (e.g. number of hits, number of inbound links)
	Newsworthiness
	Context of use information
Authorship	Key term search for credentials (e.g., “MD”)
	Author affiliation with high ranking institution
	Presence of author in prestigious database
	Aggregation of author’s documents
	Author impact factor
Publisher	Site authoritativeness
	Publisher requiring authoritative review
	Number of hits to publishing site
	Readership rate
	Journal impact factor
	Respected portal (e.g., MedlinePlus)
	Inspect URL (e.g., “.gov” or “.org” versus “.com” or “.net”)
	Site venue

agreement. Indicators could be selected from this list and incorporated into the design of search tools in creative ways. For example, the traditional relevance ranked list could incorporate quality indicators as document descriptors that allow consumers to sort or filter search results based on one or more indicator. Techniques of information visualization [Card et al. 1999] are well suited to

represent the multivariate data our framework is likely to provide. Depending on the specific indicators one selects, alternatives for presenting search results could include the use of scatter plots, maps, parallel coordinate plots, star plots, or mosaic plots [Spence 2001]. In addition, interactive dialog techniques could use a system wizard that asks the user to identify and prioritize quality dimensions by importance, and then returns search results corresponding to this request [Hearst 1999]. Form-based or menu-based requests could provide similar user-customization. These creative design ideas could provide the consumer with new and flexible ways to gain overviews of the quality characteristics of the documents contained in their search results.

Once we identified a range of Web-based indicators, we used them to explore interface design for an example tool that illustrates our multidimensional framework concretely. To scope our work, we focused the development of our initial design alternatives on a specific scenario in which a health consumer is searching MEDLINE [National Library of Medicine 1996] for health information using queries, such as <"heart attack" AND "blood pressure">. We speculated that this focus could be a productive first step for design because MEDLINE provides a homogenous set of online health resources for which several of the quality indicators we identified are readily available on the World Wide Web. Furthermore, consumers are turning to MEDLINE as a source for health information at an increasing rate [Lacroix and Mehnert 2002]. Thus, development of a prototype tool that strives to facilitate consumers' access to health information from MEDLINE is a reasonable objective.

Guided by this scenario, we selected a small subset of quality indicators from the existing Web-based indicators in Table 3 with which to work. Our selection of this subset of quality indicators for MEDLINE documents was informed by factors, such as indicator accessibility and capacity for representing the general essence of a dimension. The subset we selected to work with during our design process, including a description for each indicator, is shown in Table 4. In this initial design step, we used the indicators shown in Table 4 to design a range of low-fidelity mockups for presenting search results from consumer-oriented MEDLINE queries, such as <"heart attack" AND "blood pressure">.

A selection of these initial design alternatives is shown in Figures 1 through 6 of the appendix and includes, a bi-directional bar chart, star plot, synthesized bar chart, bar chart with quadrants, spatial plot, and a date-ranked list with forward categorization.

User-Driven Design Iterations

The goal of our user-driven design iterations was to arrive at a final design by making iterative improvements to our initial design alternatives using feedback and recommendations from members of our target population of health consumers. We conducted three half-hour sessions each with two participants to solicit feedback and recommendations on successive designs.

We recruited two individuals to provide feedback and design recommendations that could guide improvements to our initial design alternatives to a final design for implementation. These participants, one male, one female, and both graduate students in biomedical informatics, brought specialized knowledge to bear on the design problem. However, both also identified themselves as health consumers with personal interest in the goals of the project.

Next, we selected two of our initial design alternatives to begin the design process. We paired these designs for comparison during the first session with each participant. We chose the synthesized bar chart (Appendix, Figure 3) and the bar chart with quadrants (Appendix, Figure 4). These alternatives were appealing for two reasons. First, health consumers have shown both preference for [Fortin, et al. 2001] and improved interpretation accuracy using bar charts over other common types of visual presentation formats [Lipkus and Hollands 1999; Schapira et al. 2001]. Second, although both of these initial design alternatives represent the same quality indicators, they use different approaches. The bar chart with quadrants separates quality indicators across documents into distinct groups according to quality dimension, whereas the

synthesized bar chart integrates those indicators at the level of the document. We speculated that pairing these two alternatives could bring insight into participants' perceptions of these different approaches and indicate potential directions for design iterations.

Table 4. Subset of Quality Indicators for MEDLINE Documents Used during Prototype Design

Dimension	**Quality Indicator and description**
Content	Publication Type[1] The publication type classification of the document identified in the "PT" field of the MEDLINE record (e.g., Review, Clinical Trial, etc.)
	Number of References[2] The number of references cited by the document identified in the "Cited References" field of the Web of Science record
	Publication Year[1] The year the document was published identified in the "PY" field of the MEDLINE record
	Date Ranked Position[1] Position in sorted list of MEDLINE records returned from a PubMed query to the MEDLINE database
	High-Level Evidence A Publication Type consistent with grades A or B (i.e., systematic review, randomized controlled trial, or controlled trial) of the Levels of Evidence and Grades of Recommendation system [Oxford Centre for Evidence-based Medicine 2001]
Reference	Number of Citations[2] The number of times the document has been cited identified in the "Times Cited" field of the Web of Science record
Authorship	Highly Reputable/Cited Author[2] The appearance of one or more author(s) of the document in the Institute for Scientific Information's HighlyCited.com database
	Highly Reputable Institution The appearance of one or more author-affiliated institution(s) in the U.S. News and World Report's "America's best colleges" report within 3 years of the document's publication date [U.S. News and World Report 2007]
Publisher	Journal Quality[2] The journal impact factor of the journal that published the document identified in the "impact factor" field of Institute for Scientific Information's Journal Citation Reports record

1. National Library of Medicine's MEDLINE database, http://www.ncbi.nlm.nih.gov/entrez/query.fcgi [National Library of Medicine 1996]
2. Institute for Scientific Information's Web of Science database, HighlyCited.com database, and Journal Citation Reports database, http://portal.isiknowledge.com/ [Institute for Scientific Information 2007]

We conducted three half-hour sessions with each participant. During each session, we presented the participant with paper mockups for two design alternatives, then asked them to comment on the reasonableness of the quality dimensions represented in each design, the fit of quality

indicators used in each design to the quality dimensions in our framework, the design alternative they preferred, advantages and disadvantages of each design, and their recommendations for making improvements to their preferred design. We were particularly interested in how well the designs helped participants to find and compare documents along multiple quality dimensions. During these sessions, we asked participants to consider the MEDLINE search scenario as their context while they provided feedback and recommendations. Following each session, we combined feedback and recommendations we received and used them to guide revisions into two new design alternatives for the next session. Paper mockups of these two new design alternatives were then presented to each participant in the subsequent session. All designs created through this iterative process used quality indicators from the subset we used during our initial design process (Table 4). In each design, we used these indicators to represent the quality of the first fifty MEDLINE records retrieved from the query <"heart attack" AND "blood pressure" AND test>.

Across the three sessions, both participants agreed on the reasonableness of the dimensions included in our framework for consumer assessment of health information quality. They also agreed on the appropriateness of fit between the quality indicators expressed in the designs and the quality dimensions of MEDLINE documents for health consumers. Both participants favored highlighting authorship quality by "highly cited author" rather than "highly reputable institution." They also favored highlighting content quality by "high-level evidence" rather than "publication type" or "number of references." Both felt that including "publication year" as a content quality indicator was helpful.

Throughout the three design iterations, major points of feedback and design recommendations from participants surrounded their ease of finding and comparing documents along multiple quality dimensions and their ability to interact with documents. For example, in the first session, both the participants thought that our initial bar chart design alternatives helped them to find individual documents scoring high on a single quality indicator. However, neither could easily find a document with a particular *set* of quality indicators nor easily make document comparisons along multiple quality indicators. Although both participants preferred the conciseness of the synthesized bar chart over the bar chart with quadrants, they found the x-axis of the synthesized bar chart to be difficult to interpret because it incorporated three different scales. Both participants wanted to be able to interact with the display by selecting and changing the axis to focus on a given scale of interest.

In response to the participants' feedback and recommendations, we moved from our initial bar chart representation to a scatter plot representation in our design revisions. We chose the scatter plot to help users find documents with a given *set* of quality indicators and to make document comparisons along multiple quality indicators simultaneously. An example of one scatter plot we created during our design iterations is shown in Figure 1. In this scatter plot, quality indicators are represented on axes and as glyph attributes. We used a single interval scale for each axis, which could be changed by the user with interactive pull down menus. Square glyphs represent individual documents. Each square contains a number that corresponds to the document's date ranked position in the underlying search results list. We added color and asterisk attributes to glyphs to represent additional quality indicators.

In the second session, both participants preferred the scatter plot design over our initial synthesized bar chart design. Across the second and third sessions, participants recommended several additional improvements to enhance interaction with the scatter plot design. For example, in the second session, one participant recommended adding shape as an attribute to differentiate different publication types. In the third session, both participants agreed that adding shape made the scatter plot overly busy and complex. In contrast, several recommendations proved to work well in iterative designs of the scatter plot. For example, participants recommended adding additional interactive features to the scatter plot, including a method for accessing additional documents details by clicking on a glyph associated with a document, as well as an interactive zoom method that would allow the user to enlarge an area of the graph. The participants disagreed about the usefulness of providing the date-ranked position as an attribute of document

glyphs and agreed that this information could instead be accessed along with other document details through a click on the document square. Alternatively, one participant recommended adding publication year as an additional option on the scatter plot's axes.

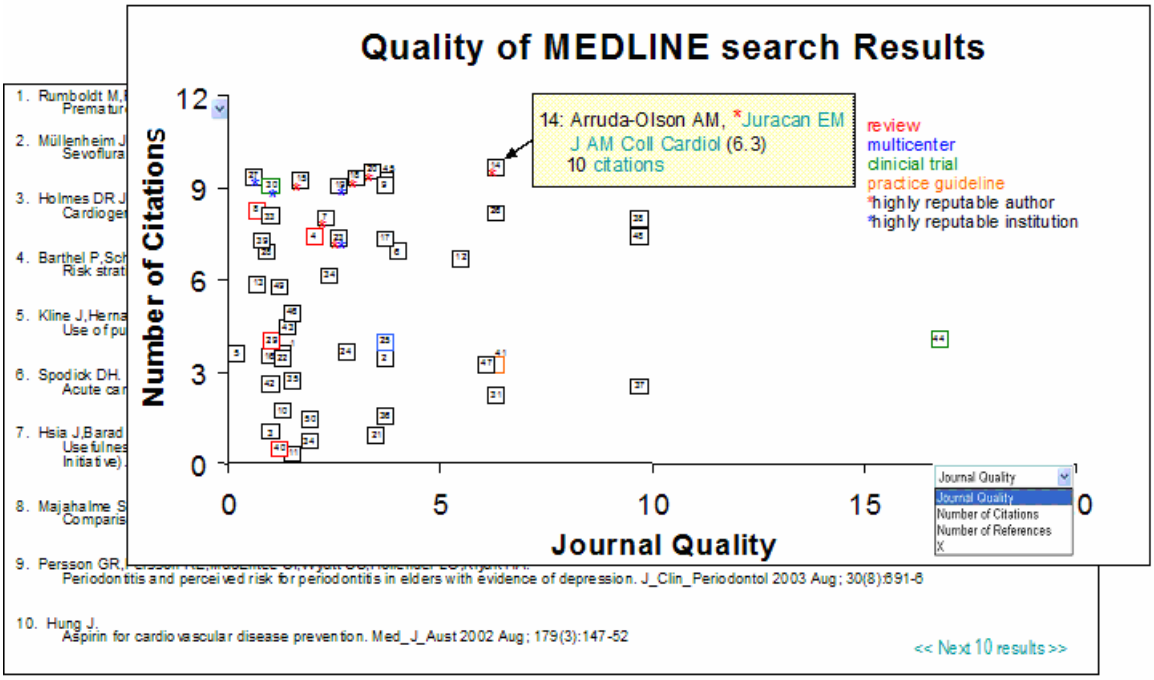

Figure 1. Example of scatter plot design: The scatter plot overlays a date-ranked list of MEDLINE search results. Individual documents are represented by square glyphs that contain their date-ranked position. "High-level of evidence" is represented by colored squares to indicate content quality. Pull down menus allow the user to assign "Journal quality" (i.e., publisher quality), "Number of references" (i.e., content quality), or "Number of citations" (i.e., reference quality) to either axis. Red asterisks represent "Highly reputable authors" (i.e., authorship quality), and blue asterisks represent "Highly reputable institutions" with which authors are affiliated (i.e., authorship quality). The user can click on any square to display document details.

Final Design and Implementation

Throughout our user-driven design iterations, we made incremental improvements to the design that reflected the major points participants provided in their feedback and recommendations. After three design iterations, we arrived at our final design for the prototype tool. Next, we describe the quality indicators and design features we used for the final design, each of which was directly guided by our participants. We end this section with a description of the open source tool we used to implement the final design.

The final scatter plot design represents the quality of documents in a set of MEDLINE search results across a total of five indicators. A single quality indicator represents each of the four dimensions individually. In addition, we represented "Publication Year" (see Table 4) to provide supplemental content quality information on document currency. We used the Centre for Evidence-Based Medicine's levels of evidence grading system [Oxford Centre for Evidence-Based Medicine 2001] to represent content quality. If the MEDLINE publication type of a document was consistent with recommendation grades A or B (i.e., systematic review, randomized controlled trial, or controlled trial), we characterized the document as providing high content quality (i.e., "High-level Evidence," Table 4). We represented content quality as a binary

variable such that all other publication types (e.g., editorial) were not characterized as high content quality. We recognize that our reliance on publication type limits our approach because it could exclude some documents considered grades A or B if the full text were thoroughly analyzed. We used the documents' citation rates (i.e., "Number of Citations," Table 4) provided by the Institute for Scientific Information [Institute for Scientific Information 2007] to represent reference quality as a continuous variable. We represented publisher quality as a continuous variable using the Institute for Scientific Information's "Journal Impact Factor" (i.e., "Journal Quality," Table 4) [Institute for Scientific Information 2007]. We represented authorship quality as a binary variable. If a document's author was present in the Institute for Scientific Information's HighlyCited.com database [Institute for Scientific Information 2007], we considered the document to provide high authorship quality (i.e., "Highly Cited Author," Table 4). A full description for each indicator we used in our final design is provided in Table 4.

The features of our final design included a scatter plot interface to display multivariate data with axes that can be defined for continuous variables and changed by the user, attributes to distinguish documents along binary variables (i.e., glyph shape and color), and interactive features, such as clicking on a glyph to access more document information, filtering the scatter plot according to different quality indicators, and zooming into areas of the scatter plot. These features guided the implementation of our multidimensional framework of health information quality in a prototype tool. We identified an open source tool, the GGobi data visualization system [Symanzik et al. 2002], which provides features consistent with those our participants recommended for our final design. GGobi is a data visualization system for displaying and interacting with multivariate data [Symanzik et al. 2002]. We used GGobi as our prototype tool by creating a number of data sets to demonstrate its use. Data sets included search results from consumer-oriented MEDLINE queries (e.g., <<"heart attack" AND "blood pressure">>, <<"smoking cessation" AND acupuncture>>) and quality indicators corresponding to each document in the search result set. This data was expressed in XML then imported into GGobi. Next, we describe our prototype tool through an example scenario of its use with one of those data sets.

III. USAGE CASE EXAMPLE OF PROTOTYPE TOOL

Our prototype tool uses an interactive scatter plot interface [Symanzik et al. 2002] to characterize the quality of MEDLINE documents by highlighting the four dimensions of quality from our Multidimensional Quality Framework. This interface allows the user to visualize and interact with MEDLINE search results (Figure 2). The interactive scatter plot allows the user to learn about the characteristics of the overall set of results, identify documents rating high on one or more dimensions of quality, and appraise quality according to their own preferred indicators.

The scatterplot is well suited to represent multivariate data types underlying our multiple indicators. Interactive features allow users to define axes variables, zoom, pan, brush, identify data points, and exclude data points from the scatter plot.

Users can set the axes of the scatter plot to reflect reference quality (i.e., "Number of Citations"), publisher quality (i.e., "Journal Impact Factor"), or content quality in terms of currency (i.e., "Publication Year"). Open grey disks act as glyphs to represent individual documents. Glyphs that represent documents deemed to have high quality content are highlighted in red. The glyphs representing documents with high authorship quality are converted from disks to plus signs (i.e., "+"), and the glyphs representing documents for which data is not available to determine reference or publisher quality are converted to x signs (i.e., "x"), rather than being excluded from the plot.

We describe the use of our prototype tool through a usage case example based on Jean, a fictional thirty-five-year-old smoker who has unsuccessfully attempted to quit numerous times. Jean wonders if acupuncture might help her quit permanently. Jean has heard that MEDLINE offers extensive scientific medical literature and wishes to find information about the efficacy of

acupuncture for smoking cessation. Jean queries MEDLINE using the search terms *smoking cessation* and *acupuncture*. Jean uses our prototype tool to explore the fifty-six results that MEDLINE returns.

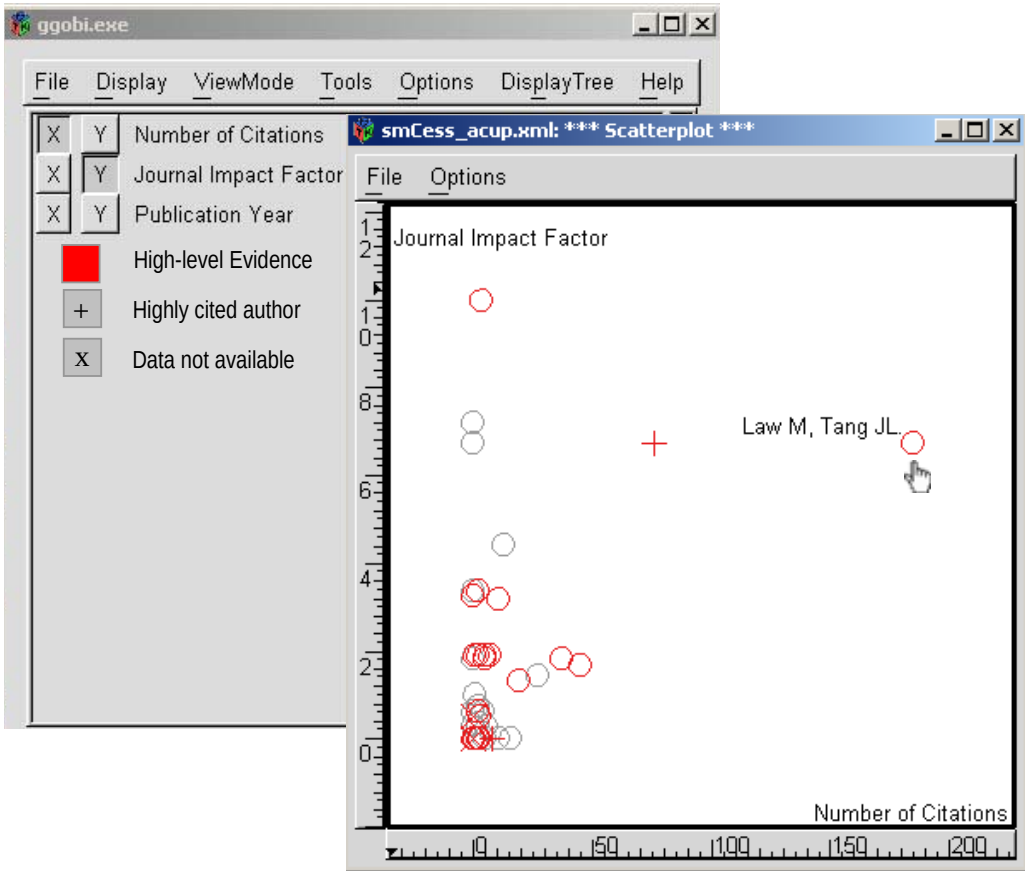

Figure 2. Interactive scatter plot visualization: The visualization represents MEDLINE search results for query <"smoking cessation" AND acupuncture>. The user identifies an article by "M. Law" and "J.L. Tang" having high-level evidence (i.e., document represented by a red glyph), a high citation rate, and published in a journal with a high journal impact factor.

Jean begins to explore these results by interacting with the scatter plot. She places "Number of Citations" on the x-axis, and "Journal Impact Factor" on the y-axis (see Figure 2). When Jean clicks on the document with the most citations (i.e., farthest right red disk in Figure 2), the document's author names appear. Jean notices that the document just to the left of the "Law & Tang" article also indicates high content quality (i.e., document glyph also colored red) as well as high authorship quality (i.e., glyph is a plus sign).

Next, Jean decides to compare these two articles to the other articles contained in the set of search results. Jean uses the pointer to draw a box around these two articles (Figure 3), which become highlighted in green to indicate selection. Jean then creates a scatter plot matrix, which provides nine views of the search results among the various combinations of the three available axes variables (Figure 4). In the scatter plot matrix, the two articles that Jean selected maintain their green highlight. From this view, Jean is able to simultaneously compare the selected articles to other articles contained in the search results along the four dimensions of quality.

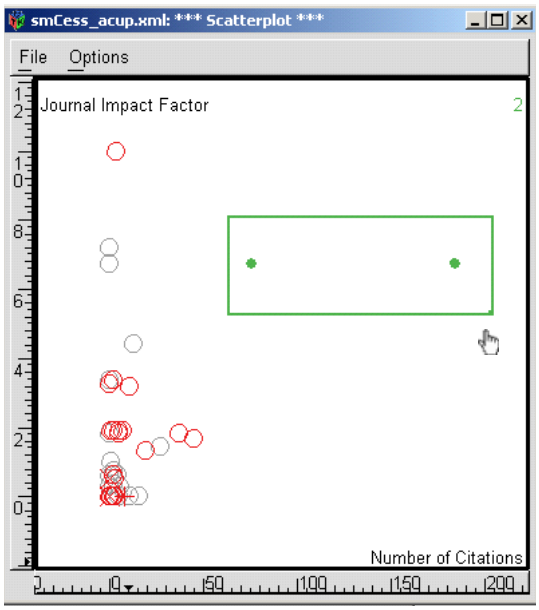

Figure 3. User selects two articles: The two selected articles boxed in green highlight have the highest citation rates and higher journal impact factors than other articles in the search result set.

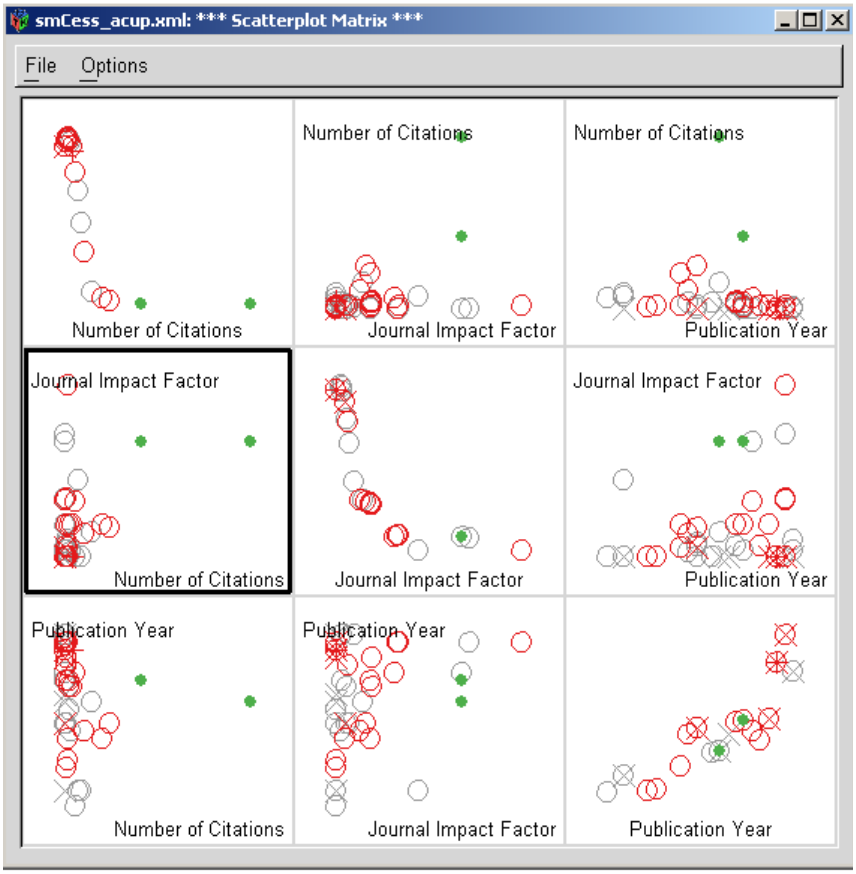

Figure 4. Scatter plot matrix: The selected articles in green highlight are compared to other articles in the search results set among various combinations of the three available axes variables.

Jean then goes back to the original scatter plot and changes the x-axis to "Publication Year." Jean finds that both selected articles were published within the last few years. Based on this flexible and interactive evaluation of search results, Jean decides that the two selected articles provide a good starting point for learning about the relationship between acupuncture and smoking cessation.

IV. CHALLENGES TO QUALITY APPRAISAL WORK

Determination of an appropriate definition of quality poses a significant challenge to researchers who focus on health information quality appraisal. Accurately assessing quality and validating quality appraisal methods is problematic because we lack an operational definition, and thus a gold standard, for health information quality [Eysenbach et al. 2002; Gagliardi and Jadad 2002]. Variation in consumers' individually situated needs increases the complexity of quality appraisal. These challenges are shared by researchers in more general contexts of information quality, who have found utility in both theoretical [Wand and Wang 1996] and empirical approaches [Wang and Strong 1996] to inquiry.

We took a theoretical approach by drawing upon a broad sample of quality appraisal methods and identifying quality indicators representative of the dimensions making up this breadth. Although usability and design aesthetics are components of some health information quality-appraisal methods [Eysenbach et al. 2002; Kim et al. 1999], we considered these factors to relate more directly to the quality of the Web site technology than to the quality of the content those Web sites provide. Our explicit focus on intrinsic quality characteristics reflected in existing tools leaves open the possibility that our framework does not capture additional characteristics not broadly emphasized or captured among existing tools, but that are important to health consumers.

Although participants in our design process found our framework to provide reasonable coverage of quality characteristics of health information, an empirical approach to framework assessment could further ground and possibly extend our framework by taking into accounting consumers' perspectives explicitly. For example, in the general context of information quality, Wang and Strong [Wang and Strong 1996] identified a broad range of quality characteristics when they directly asked consumers what characteristics they use to assess whether information is fit for use in their tasks. These characteristics, such as extrinsic characteristics associated with an information resource's representation, accessibility, and contextual relevance to their tasks, extended well beyond intrinsic quality of information. Similarly, relevance and usability (e.g., design and usefulness [McCray et al. 2000]), accessibility [Zeng and Parmanto 2004], and readability [Berland et al. 2001; Graber et al. 2002; McCray 2005]) are necessary for consumers to effectively use and understand high-quality health information. Extending our knowledge of health information quality could come from capitalizing upon existing information quality research in general contexts as well as upon our growing understanding of the actual quality assessment strategies health consumers currently use [Adams et al. 2006].

As proxies for quality, quality indicators do not necessarily ensure the quality of an information resource. The single quality indicator we used in our prototype to represent each dimension in our framework could limit the effectiveness of our tool in capturing the essence of those dimensions. Further, these indicators correspond well to MEDLINE documents, but might be limited in capturing quality of health information in other contexts. However, agreement of indicator levels among the different dimensions represented by our tool could increase the health consumer's confidence in a resource's quality. Moreover, our use of multiple quality indicators could provide the flexibility required to meet the variation inherent to consumers' needs. Our visual approach to implementation allows consumers to decide for themselves which quality characteristics fit their own specific needs, then appraise document quality in a transparent and self-directed way.

The flexibility of our multidimensional framework of health information quality leaves open the possibility for many alternative approaches to implementation (e.g., text mining, pattern

recognition, automated ranking across quality dimensions, use of multiple indicators per dimension, selection of indicators for multiple contexts). For example, we explored the implementation of our framework using some of our final design features to represent Google [Google, Inc. 2007] search results for the consumer-oriented query <"quit smoking" acupuncture> (Appendix, Figure 7). Creating this quality mock-up to overview results from a general purpose search engine required the selection of an alternative set of quality indicators to represent each dimension in our framework. These indicators included accreditation by the Health on The Net Foundation for content quality [Price and Hersh 1999], number of inbound links for reference quality [Hernandez-Borges et al. 1999; Griffiths et al. 2006], identification of author credentials in text (e.g., "MD," "RN," "ND") for authorship quality [Price and Hersh 1999], and a noncommercial or governmental site (i.e. URL ending with ".org" or ".gov") for publisher quality [Griffiths and Christensen 2000].

Given the challenge of appropriately defining quality, we envision our multidimensional framework of health information quality to be most useful when used to develop tools that identify and transparently represent quality attributes of documents to users, but that also coordinate with other search tools that can describe additional document attributes that are critical for effective consumer use (e.g., relevance, usability). For example, a search engine could retrieve and rank documents using a relevance algorithm, then use our framework to provide a structure for organizing those relevant documents by quality dimensions. This organization could be coordinated with the original ranked result list to indicate document relevance. Additional tools could indicate usability features associated with documents contained in the result set.

V. FUTURE WORK

Direct collaboration with health consumers to evaluate our multidimensional framework of health information quality as well as the utility and usability of our prototype tool are important areas of future work. Future empirical studies could evaluate the strength and scope of our framework to determine whether the quality dimensions we identified match those consumers deem a priority. We anticipate that our prototype tool could allow consumers the flexibility they need to configure their own quality scheme by highlighting those characteristics of quality they deem most important. We also anticipate that our prototype tool could provide a more efficient method for consumers to find high quality health information than currently exists. However, future research that evaluates both the utility and usability of our prototype tool with health consumers is needed to determine whether the tool provides consumers with a useful and efficient quality appraisal method. Such an evaluation could inform further design improvements to the interface or incorporated indicators. Future work could also explore additional interesting questions. For example, do tradeoffs exist between the flexibility provided by multiple indicators and either the adequacy of the quality measure or the potential for information overload? What tradeoffs exist between a user-controlled versus a fully automated quality appraisal process? How does usability influence quality appraisal? How can we best communicate to users what each quality indicator means?

VI. CONCLUSION

A range of valuable quality appraisal methods for health information are not frequently used by health consumers [Eysenbach and Kohler 2002; Adams et al. 2006]. Our new perspective on health information quality could help health consumers overcome barriers these methods present by acknowledging and supporting health consumers' needs to assess the quality of health information they find in the context of their own, individually-situated needs. We identified four focal characteristics of intrinsic quality underlying existing quality appraisal methods for health information using a theoretical review: content quality, reference quality, authorship quality, and publisher quality. The user-driven design of our prototype tool illustrates one way our framework can be implemented to highlight, rather than hide, these focal characteristics of quality. However, insights from our work provide opportunities to explore a full range of new consumer tools that

characterize information quality in both the health context and more general contexts. In particular, we believe our multidimensional framework of health information quality provides a useful model for the design of new tools that could bring health consumers one step closer to finding high quality health information that is suited their individual needs and empowers them to play active roles in health information quality assessment.

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1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
2. The contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. The author(s) of the Web pages, not AIS, is (are) responsible for the accuracy of their content.
4. The author(s) of this article, not AIS, is (are) responsible for the accuracy of the URL and version information.

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APPENDIX

DESIGN ALTERNATIVES

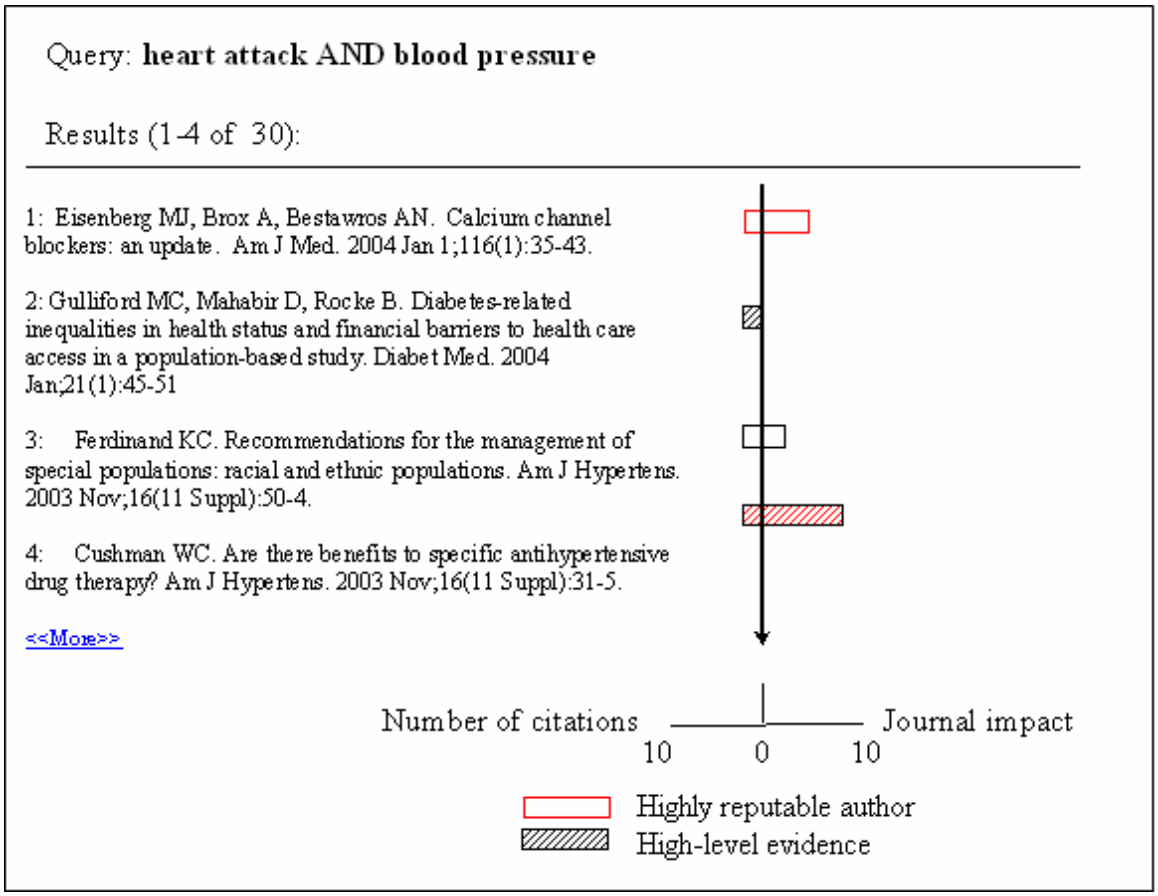

Figure 1. Bi-directional bar chart:

The bi-directional bar chart shows quality indicators for the first four documents in search results for MEDLINE query <"heart attack" AND "blood pressure">. The chart is shown to the right of the date-ranked list of the first four search results. The number of citations (i.e., reference quality) is shown on the left bar and journal impact factor (i.e., publisher quality) on the right bar. Documents with a highly reputable author (i.e., authorship quality) are shown as red bars. Documents with high-level evidence (i.e., content quality) are shown as shaded bars.

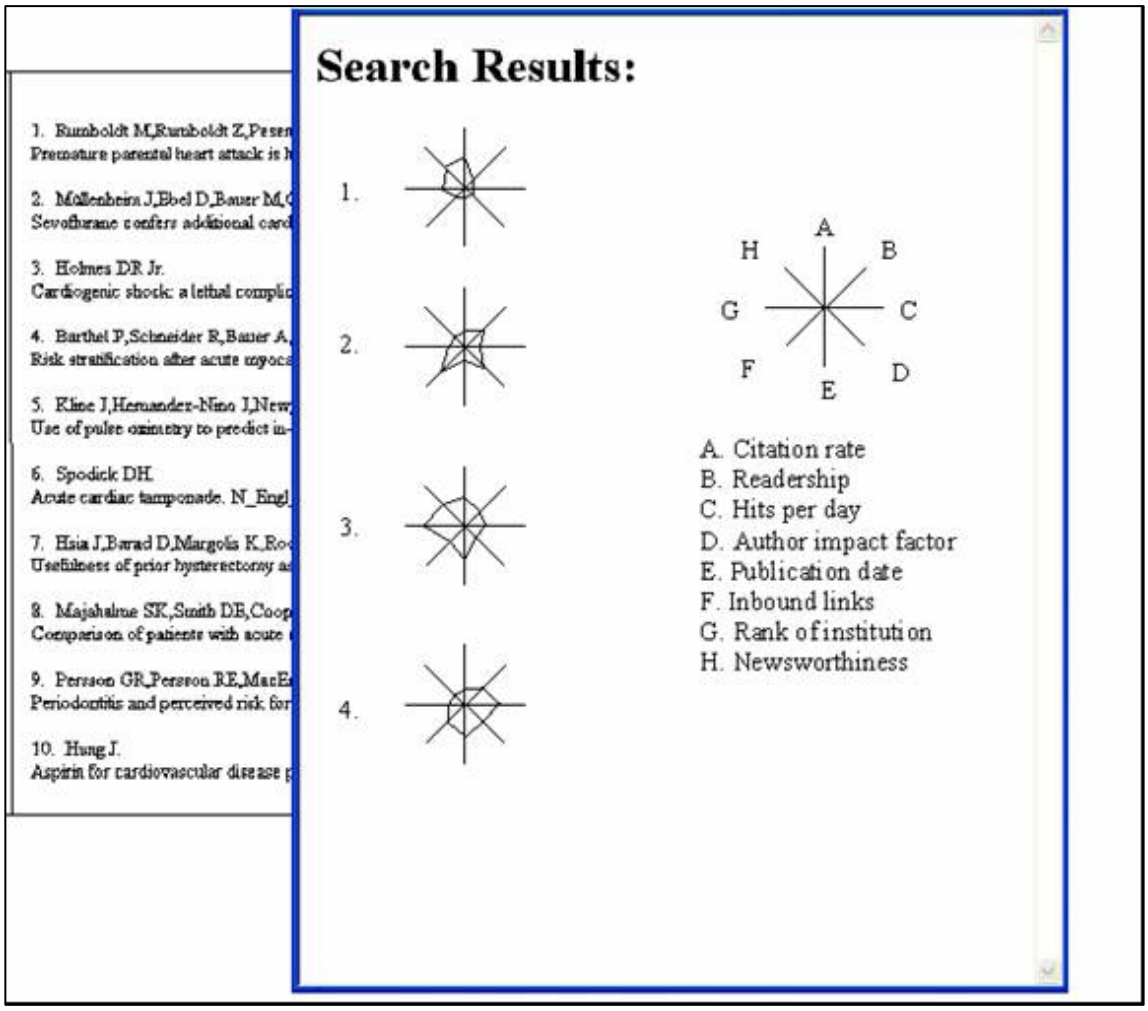

Figure 2. Star plot:

The star plot shows quality indicators for the first four documents in search results for MEDLINE query <"heart attack" AND "blood pressure" AND test>. The star plot overlays the ranked list of the first ten search results. Quality indicators (i.e., "A." through "H.") are fictional and used as exemplars for the purpose of demonstration, rather than precise document quality indicator data.

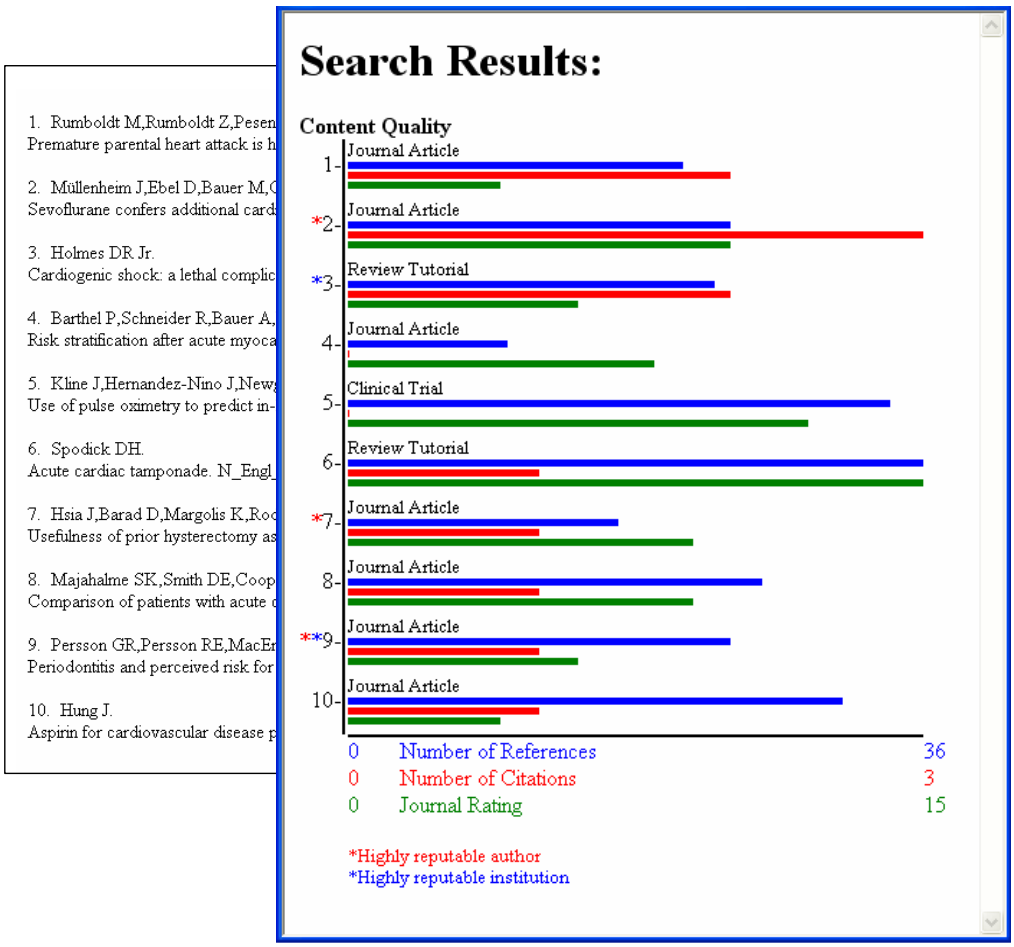

Figure 3. Synthesized bar chart:

The synthesized bar chart shows quality indicators for the first ten documents in search results for MEDLINE query <"heart attack" AND "blood pressure" AND test>. Documents are shown on the chart as a set of numbered bars that correspond to their position number in the underlying date-ranked list of results. For each article, a blue bar represents the number of references (i.e., content quality), a red bar represents the number of citations (i.e., reference quality), and a green bar represents the journal impact factor (i.e., publisher quality). Above each set of bars, is the document's publication type (i.e., content quality). Documents with a highly reputable author are noted by a red asterisk and those having an author affiliated with a highly reputable institution are noted by a blue asterisk (i.e., authorship quality).

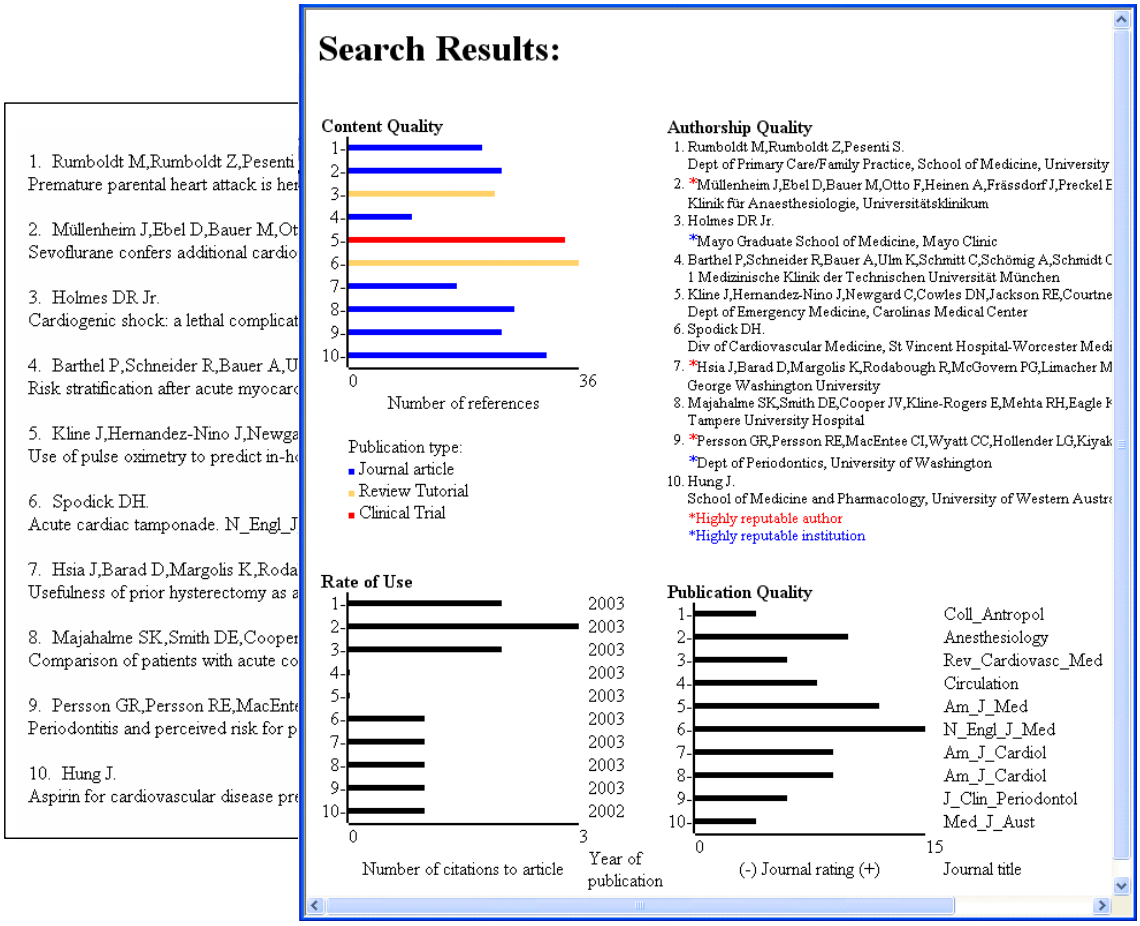

Figure 4. Bar chart with quadrants:

The chart shows quality indicators for the first ten documents in search results for MEDLINE query <"heart attack" AND "blood pressure" AND test>. The chart overlays the date-ranked list of these search results. Quality indicators are shown for documents according to their date-ranked position in each of four quadrants: the top left quadrant shows the number of references in each article (i.e., content quality); the top right quadrant shows authorship quality with red asterisks for highly reputable authors and blue asterisks for authors associated with a highly reputable institution; the bottom left quadrant shows the number of citations for each article (i.e., reference quality); and the bottom right quadrant shows the journal impact factor for each document (i.e., publisher quality).

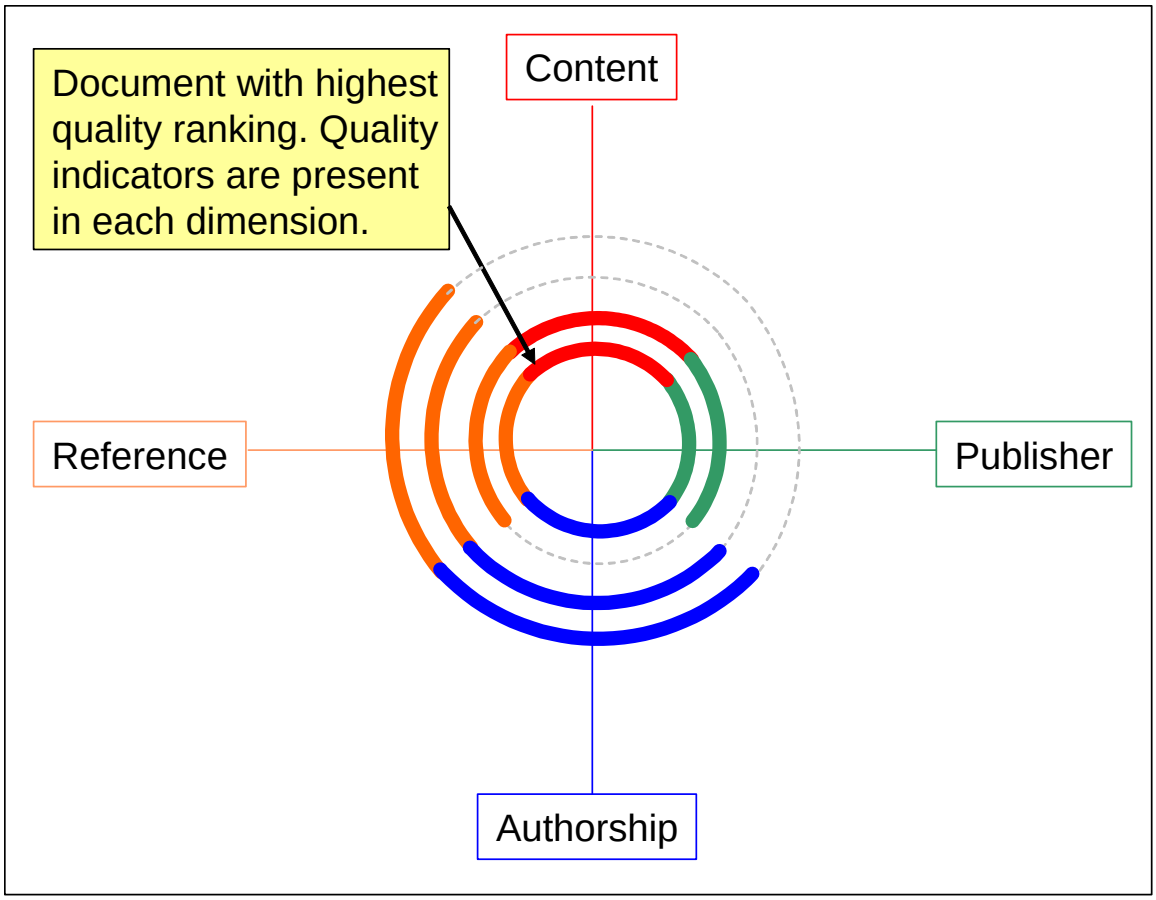

Figure 5. Spatial plot:

The spatial plot shows arbitrary quality indicators for the first four documents in an arbitrary set of search results. The chart overlays the ranked list of these search results. Each document is represented by a circle made up of quality indicators in four quadrants for each of four quality dimensions (i.e. content quality, publisher quality, authorship quality, and reference quality). Each quality dimension is represented by a different color. If a quality indicator for a document is present for any of the four quality dimensions, the corresponding quadrant of the circle for that document is highlighted in the color representing that dimension. The plot orders the documents from presence of the highest number of quality indicators (i.e. inner circle) to the least (i.e. outer two circles).

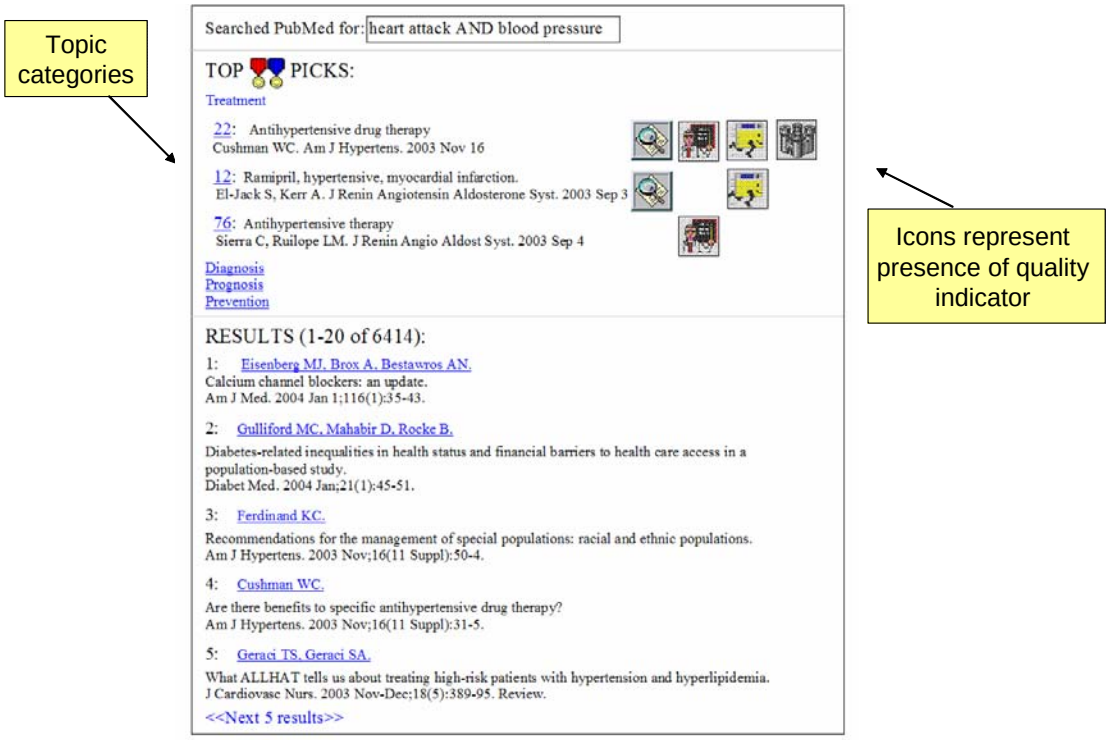

Figure 6. Date-ranked list with forward categorization:

The list shows the search results for MEDLINE query <"heart attack" AND "blood pressure">. The search results are categorized according to topic by PubMed's Clinical Queries [National Library of Medicine 2005b]. These topics include "treatment," "diagnosis," "prognosis," and "prevention." Icons are placed to the right of each document for which a quality indicator is present. Each icon represents a different quality dimension when the indicator is above a predefined threshold. The magnifying glass icon represents content quality, the professor icon represents authorship quality, the running diskette icon represents reference quality, and the castle icon represents publisher quality.

Figure 7. Quality overview for search results from Google:

A scatter plot (top of figure) displays the quality dimensions for the first 20 Google [Google, Inc. 2007] search results for query <"quit smoking" acupuncture>. Individual results are represented by open red disks. If author credentials are found (e.g. "MD," "RN," "ND," etc), the disk is outlined in green (i.e., authorship quality). If the document is published on a noncommercial or governmental site (i.e., ".org" or ".gov"), the disk is filled green (i.e., publisher quality). The x-axis shows the position of the result in the underlying list of ranked search results (i.e. "relevance"). If the site is accredited by the Health on the Net Foundation, a HON code accreditation certificate is placed at the result position number along the x-axis (i.e., content quality). The y-axis shows the number of inbound links to the site (i.e., reference quality).

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