Paradigm Shift or Annoying Distraction

Emerging Implications of Web 2.0 for Clinical Practice

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Summary

Web 2.0 technologies, known as social media, social technologies or Web 2.0, have emerged into the mainstream. As they grow, these new technologies have the opportunity to influence the methods and procedures of many fields. This paper focuses on the clinical implications of the growing Web 2.0 technologies. Five developing trends are explored: information channels, augmented reality, location-based mobile social computing, virtual worlds and serious gaming, and collaborative research networks. Each trend is discussed based on their utilization and pattern of use by healthcare providers or healthcare organizations. In addition to explorative research for each trend, a vignette is presented which provides a future example of adoption. Lastly each trend lists several research challenge questions for applied clinical informatics.

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1. Introduction

Kim and Lehmann describe in their first editorial for this Journal that applied clinical informatics "is a vehicle by which data and knowledge are translated and transformed into results and practice" and correctly point out that this research field deals with human activity that "creates and develops relationships and interactions" [1]. Describing five trends in Web 2.0 technologies, also known as social media, social technologies or simply Web 2.0 which facilitates interactive information sharing, interoperability, user-centered design, we will expand Kim and Lehmann's notion of human activity and relationship development by exploring how this new technology can facilitate such desired translation and transformation of knowledge into results and practice. The goal of this paper is to (1) explore the status of Web 2.0 and provide examples of current usage in society as well as in healthcare, (2) extrapolate that into the near-term future to see how Web 2.0 can reshape healthcare delivery, and (3) commence a discussion among applied clinical informaticians by proposing relevant research challenges. The generally accepted need for improved quality, efficiency, and safety of healthcare delivery, along with controlling costs, is understood throughout these discussions. We are looking forward to a stimulating discussion among the readers of this Journal about the emerging implications of Web 2.0.

We believe that part of adopting and exploiting new technology for healthcare is learning about it and vetting it for its value to improve healthcare outcomes. Because learning and vetting is largely done through trial and error, we do not propose to convert medicine's approach to technology adoption from a laggard to an early adopter model; however we see part of the role of applied clinical informatics as leading the way in this learning and vetting process. Over time, healthcare providers have adopted the use of peer-reviewed sources [2, 3], accessed evidence-based information databases such as The Cochrane Collaboration (http://www.cochrane.org/) [last accessed <March 31, 2010>], and implemented clinical guidelines as developed by professional organizations. Will Web 2.0 result in a paradigm shift for clinical practice or is it just another distraction from our clinical work and research and simply another tool clinicians adopt as they have so many others?

Web 2.0 is a term describing Web applications which facilitate interactive information sharing, interoperability, user-centered design [4] and collaboration on the Web. Examples of Web 2.0 include web-based communities, hosted services, social-networking sites, video-sharing sites, wikis, blogs, mashups, and folksonomies [5]. Web 2.0 is often used interchangeably with "social media" or "user-generated content." Kaplan and Haenlein define social media as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of user-generated content" [6]. In the context of medicine, Anderson et al. [7] describe social media as "tools to support distance collaborations inexpensively while offering benefits of placing selected information in online spaces that facilitate discovery and discussion thus supporting the fundamental research processes at the same time as promoting bench-to-bedside information transfer." Benefits from Web 2.0 derive from socially embedded information and exist in the context of interpersonal and group interaction rather than the depersonalized or authoritative information found in traditional databases and documents [8]. However, at this point no stabile and widely accepted conceptual model of Web 2.0 technologies exists in the literature.

We have structured our paper into five trend discussions, each exploring how individual healthcare providers or healthcare organizations exploit Web 2.0, which has recently shifted increasingly toward mobile devices and away from the traditional desktop environment. We have selected these trends based on our combined knowledge and expertise in the social media sphere. While we, as authors, believe these are the most important trends, only the future will show if we were correct in our prediction. In each trend discussion we will begin by analyzing adoption patterns by consumers as well as among healthcare providers. Based on early explorative research, we will then develop vignettes which provide a scenario of how we envision future adoption patterns among healthcare providers. Finally, each trend discussion will conclude with outlining potential research challenges for applied clinical informatics. Currently, definitive answers to these questions are sparse.

2. Trend 1: New Information Channels

Access to information and social influence have always been interplaying components when it comes to modifying the behavior of people and to advancing the sciences. Medical knowledge, for instance, was handed down from one practitioner to the next in an apprenticeship model for a long time. Then, medical schools employed eminent physicians to teach larger numbers of students in a shift toward improved access to information. With the advent of modern times, the medical profession increasingly relied on access to scientific evidence delivered in the form of text books and peer-reviewed journal articles in a broadcast, or "push," model. However, "broadcasting" more information to providers did not satisfy their individual needs. Peer communication discussing individual cases in training and practice has always augmented the broadcast model of information delivery. While the more recent creation of online bibliographical databases further improved access to information, alone it has not resulted in a change of practice behavior – even in the presence of strong evidence [9, 10]. While today the majority of professional information is being pulled online by physicians using various sources, such as literature searches (65%), searches for medical information (53%) and accessing online journals (45%) [11], ubiquitous information access often only results in information overload. This information overflow lowers the attention span per unit of information [12, 13] since the amount of reading does not increase [14].

While access to information has improved continuously, social influence has always been constrained by geographic limitations and pure chance of acquaintance. New Web 2.0-based information channels address the inherent constraints of social influence. Americans spent 17% of their internet time (68 hours per month [15]) using social networking sites in 2009 – nearly triple the time spent in 2008 [16]. Web 2.0 technologies are not increasing our access to information, but modulating how we access it. For instance, pulling information from Websites like CNN (http://www.cnn.com/) [last accessed <March 31, 2010>], or aggregator Websites like Google News (http://news.google.com/) [last accessed <March 31, 2010>], means users retrieve information which was filtered and selected by editors who were not chosen by these users. In contrast, Web 2.0 users first check out the stories recommended by their social-networking friends whom they follow via Twitter (http://twitter.com/) [last accessed <March 31, 2010>] or Facebook (http://www.facebook.com/) [last accessed <March 31, 2010>], or access the bookmarks found through their delicious network (http://delicious.com/) [last accessed <March 31, 2010>]. In other words, access to information is changed based on social contacts. The recently unveiled experimental Google Social Search [17] is a first attempt to surface the content relevant to users based on their broader social network, assuming that users interact with people who have similar interest. These search results are based on users' public Google profiles, which are built from people they follow on Twitter, blogs they read and their Gmail contacts. Why do we look at the information pointed out by our "friends" instead of looking at the headlines? As Edelman's 2008 Trust Barometer finds, for North Americans the most trusted source of information is consistently "a person like myself." Social influence theory emphasizes the role of respected peers in decision making, including other professionals and opinion leaders [18], making it the source of behavior change. Several studies have found that, when seeking professional advice or information, physicians prefer consulting with colleagues [19-22].

While Web 1.0 improved access to information, Web 2.0 has the potential to change people's attitudes and beliefs. For instance, the power of peer influence was demonstrated in the 2008 primary campaign by the Obama team, in which electoral success was mainly attributed to the use of Web 2.0 technologies [23]. Increased engagement with peers using social media technologies might influence providers' behavior more than exposure to messages distributed by authoritative professional organizations [24]. However, it is hard to foresee in which direction such influence might go, since social media are for the most part not peer-reviewed and verified [25].

There are many attempts to exploit the power of Web 2.0 for medical education [26-41]. Information dissemination can be unidirectional. Medical journals use podcasts to engage readers with content, as demonstrated by leading journals such as the New England Journal of Medicine (http://content.nejm.org/misc/podcast.dtl) [last accessed <March 31, 2010>], the Lancet (http://www.thelancet.com/audio) [last accessed <March 31, 2010>], the British Medical Journal

(http://feeds.bmj.com/bmj/podcasts) [last accessed <March 31, 2010>], the JAMA (http://jama.ama-assn.org/misc/audiocommentary.dtl) [last accessed <March 31, 2010>].

However, Web 2.0 is "social" and the benefits are mainly derived from interactions between users, not from watching a podcast or video. Medical journal blogs, such as those of the British Medical Journal (http://blogs.bmj.com/) [last accessed <March 31, 2010>], Health Affairs (http://healthaffairs.org/blog/) [last accessed <March 31, 2010>], the Public Library of Science (http://www.plos.org/) [last accessed <March 31, 2010>], and The Lancet (http://www.thelancetglobalhealthnetwork.com/) [last accessed <March 31, 2010>] encourage interaction between authors and readers.

Communities of Practice (CoP), online communities where practitioners have access to peers, emerge as a natural result of individuals working and learning collaboratively in multidisciplinary teams where members are rewarded for sharing information and promoting mutual learning [42]. One example of such a CoP is The Cochrane Collaboration, an example of a volunteer network that has made vast contributions to summarizing existing medical knowledge [43]. Another example is Alzforum (http://www.alzforum.org/) [last accessed <March 31, 2010>], a CoP of over 4,600 researchers networking to find a cure for Alzheimer's [44, 45]. A third example is Sermo (http://www.sermo.com/) [last accessed <March 31, 2010>], which is the largest online physician community in the US, with over 115,000 physicians. However, based on strict access control via proof of license, it excludes medical students and physicians from countries other than the US, which limits its outreach dramatically. Various new online physician communities provide an opportunity for support and information on a real-time basis. In addition, the anonymity afforded online, coupled with the trust that comes from sites where all participants are licensed physicians, decreases or eliminates the challenges faced by competition for patients, egocentric agendas, or the circulation of spurious information.

Healthcare consumers are sometimes ahead of providers in participating in social networking [46]. For instance, PatientsLikeMe (http://www.patientslikeme.com/) [last accessed <March 31, 2010>] has created a social network for patients with various diseases. Participants share details of diagnosis and treatment, building the basis for a large longitudinal medical outcome database [47]. In addition, social media use by patients is likely to affect clinical practice [48]. While there is often a tendency for physicians to see patients who received advice about their disease online as an annoyance [49], the Internet has the potential to be a positive factor in affecting patients' beliefs, behaviors, and attitudes. The Internet is slowly changing the physician-patient relationship as patients bring information to the consultation in order to take a more active role in their healthcare [50-52].

2.1 Vignette

Consulting with colleagues is an accepted, expected, and essential component of providing comprehensive healthcare to patients. It becomes increasingly critical as technology allows an unprecedented barrage of new scientific information for the healthcare provider to absorb. This can present challenges for a new physician, who may not have established the contacts or credentials to easily find support, or who feels isolated in the midst of experienced clinicians and academicians; it can just as easily be a challenge for the experienced physician who is physically isolated from his peers:

> A physician in his fourth decade of practice in a rural area has been very successful in attracting and retaining patients. Despite his experience and his familiarity with his patients' medical problems, he is still confronted with diagnostic dilemmas. His stacks of medical journals and his well-worn medical texts are no longer current. He has recently computerized his office to include an EMR and subscribes to a physician-only social networking site to improve his access to medical information.

> A long-time, 83-year-old patient presents to the office with a persistent cough which is affecting his sleep and resulting in fatigue, low-grade fever, loss of appetite and weight loss. The cough was treated three months ago with antibiotics and appeared to briefly improve. A chest x-ray did not reveal pneumonia or evidence of other pulmonary disease. Physical examination and routine testing are negative; the patient refuses hospitalization and although he does not appear sick enough to warrant admission to the nearest metropolitan hospital, he is clearly ill. A long and exhaustive search for clinical guidelines from online journals does not uncover any cases which

match this patient's presentation. The physician turns to the social networking site he recently joined to ask for advice. A colleague responds quickly, describing a similar case seen in his office the previous year and recommends a cardiac assessment; two other physicians agree that this should first be ruled out. An academic physician, however, mentions the possibility of a rare case of an autoimmune disease that he currently studies in a clinical trial. He recommends performing various non-standard tests should the cardiac assessment prove to be negative. Subsequently, a diagnosis of an autoimmune disease is made as a result and, following consent, the patient is enrolled in the clinical trial, increasing the pool of subjects enrolled nationwide. The clinical trial's hematologist/oncologist monitors the patient's progress remotely through the course of treatment as the primary care physician manages the immunosuppressive therapy. All research raw data are shared as they are collected, in de-identified format, to the larger research community based on the policy of the funding agency. The newly enrolled patient joins an online support group where he exchanges his struggles with the disease and his participation in the study with others afflicted with the same rare disease. While he is now taking active part in his disease management, his questions and concerns triggered by peer interactions jeopardize his adherence to the strict protocol of the clinical trial.

2.2 Research Challenges

Research about information retrieval (IR) for healthcare providers has a long history in the biomedical informatics field [53, 54]. With the advent of Web 2.0, we can see a change of focus from pure IR questions to research on information access and triggers for behavior change. Fundamental lessons learned during previous IR research, like relationships between recall and precision, can be applied to this new paradigm:

- Which Web 2.0 technologies can help improve the dissemination of clinical guidelines, resulting in better quality of care? How should these guidelines be used?
- Which Web 2.0 strategies, for instance those that allow synchronous peer interaction or those that allow only asynchronous communication, are best suited for healthcare providers? Why?
- What features of Web 2.0 systems (technical and social) contribute to the formation of trust? How does trust contribute to acceptance of information, conclusions formed based on the information, and/or behavior change?
- In which ways do healthcare providers need to alter their moral behavior when using Web 2.0? What is expected in regard to ethics, trust, privacy and etiquette from a physician when interacting with patients as well as with other physicians in this environment [55]?
- While e-communities are used widely for patient education and support groups, how do we measure their success? How should clinicians react to their increasing use? How can e-communities complement clinical services?
- How do we evaluate Web 2.0 use in clinical practice and medical education [56, 57]?
- How does the use of Web 2.0 affect formation of professional networks (e.g., is new physicians helped in the long run by using a Web 2.0 system or are they harmed because they do not develop networks in their local environment)? How does use of Web 2.0 technologies affect isolated clinicians?
- What incentives are needed to motivate provision of quality information in Web 2.0 settings?
- How can the huge amount of information obtained from Web 2.0 resources by filtered and visualized for physicians?
- How can EHR integrate information from trusted social networks and medical research networks?

3. Trend 2: Augmented Reality

Readers of science fiction know this trend from Vernor Vinge's depiction of wearable computer systems in his 2007 Hugo-awarded novel Rainbows End and associated short stories and novella [58, 59]. Vinge presents humans who interact with virtual overlays of reality through their smart clothing and contact lenses that can overlay and replace what the eye would normally see with computer graphics. Augmented Reality (AR) started with the first video goggles and so-called Heads-Up Displays or HUDs [60]. While we are only at the beginnings of display-embedded contact lenses

[61], the emerging technology of AR already enables users to see location-specific data superimposed over their surroundings using smart mobile phones.

Applications such as Layar (http://layar.com/) [last accessed <March 31, 2010>] show users what is around them by blending real-time information on top of real footage as seen through the camera of their mobile phones [62]. The application adds another layer of information to what the camera sees about nearby buildings and shops, including travel directions, houses for sale, tourist information pulled from Wikipedia (http://www.wikipedia.org/) [last accessed <March 31, 2010>], and even notes left by other users in that location. These layers of information, also called content layers, are the equivalent of Web pages in normal browsers, but are currently marketed by advertisement companies in order to highlight, for instance, the next coffee shop of their client's chain in the vicinity, or, as in the case of the London Tube [63], enable users to see the nearest subway stations and other points of interest. Newer applications, like Wikitude World Browser (http://www.wikitude.org/) [last accessed <March 31, 2010>] separate different layers of information, such as that from Wikipedia, local reviews from partner companies, and crowd-sourced information from its social network.

ABR Research predicts a rapid growth of AR in smart phones that will transform the AR ecosystem [64], a trend driven by increasingly powerful phones with cameras and access to considerable bandwidth [65]. While these AR applications rely on the built-in GPS and compass, the question remains: how can AR be used in medicine by, for instance, overlaying a patient's real life body with various diagnostic imaging modalities? In one of the first applications of this technology, researchers collaborated with industry partners to image overlays using a robust and inexpensive augmented reality apparatus. These overlays aid image-guided needle placement on conventional closed high-field magnetic resonance imaging scanners [66, 67].

3.1 Vignette

Location- and direction-based AR using a mobile handheld device has evolved, although it is still in its infancy. Merging this technology with displays which project into the visual field of the user who wears a special kind of glasses is not much of a leap [68]. Augmenting an EMR with this technology stack would allow physicians to interact with the patient record in a completely new way:

> The attending physician rounds on his patient in the ICU (intensive-care unit). While greeting the patient, he activates his glasses, which are equipped with an augmented reality system, using the touch-sensitive area on the left temple. Now he can pull basic patient information such as name, birth date, date of admission, and reason for hospitalization into his viewing field. Another touch to the glasses, while looking at the monitor of her vital signs, projects an overlay of a graph of her vital signs during the past 24 hours. Looking at the IV (intravenous) bag and touching the temple of the glasses again, he can see the medication history since her arrival. A box below indicates that the nurse is concerned about the IV site and wants him to evaluate it. Another touch, while looking at the heart monitor, shows an overlay of her rhythm during the same time period. Following his assessment of the patient, he looks at the EHR and activates the glasses again, starting the voice recorder whose backend uses a natural-language processing engine to capture his narrative into the proper fields of the EHR (electronic health record) as part of the self-documenting encounter (Schleyer T, Feasibility of Self-documenting PatiEnt Encounters in Dentistry (SPEED), unfunded grant proposal 1RC1LM010514-01, 2009). A note from the hospital psychiatrist in the left upper field of vision flashes, alerting the attending physician that she is on her way up to talk to the patient and update the physician on the patient's mental health status.

3.2 Research Challenges

While there are still many technical, usability and social challenges before AR will find widespread use in the healthcare domain, some research challenges have already emerged:
- How substantial is the learning curve associated with using AR for information access? What are the best ways to train practitioners in its use?
- What are the implications of an AR system which uses face recognition for medical emergency personnel, such as instantly pulling up medical records of unconscious patients?
- Where are the limits of the healthcare provider's cognitive load when using an AR system?

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- Does the presence of information directly within a provider's field of vision alter how they interact with a patient, and does it alter the patient's perceptions, trust, willingness to provide information, or compliance? Should patients be made aware of the presence of such systems?
- How can AR be used for medical education, in particular in conjunction with standardized patients?
- How can the computer-generated imagery from head-mounted devices be calibrated to the same optical focal plane as in the real world, allowing these devices to support high-precision work, such as in a surgical environment?
- What safety mechanisms are needed to avoid accidents when healthcare workers wear HUDs limiting or altering their vision of the real world?
- How could AR technologies be used by patients? Is AR a useful technology to allow individuals to access/review their own EHR (electronic health record)? Is there value to allowing patients to "see" what their physician is seeing?

4. Trend 3: Location-based Mobile Social Computing

Thanks to 3G phones, like the Apple's iPhone and phones that use Google's Android, 490 million people globally are carrying a device that not only knows where they are, but also connects to the Internet to share that information and merge it in real time with online databases for location-based services. This input – who is where and when – has the potential to change many outputs, influencing where we shop, whom we talk to, what we read, what we search for and where we go [69]. The trend toward mobility becomes obvious, for instance, from AT&T's mobile data traffic increase by 4,932% over the last three years, or the estimate that there will be one billion "heavy mobile data users" by 2013 [70].

Google maps (http://maps.google.com/) [last accessed <March 31, 2010>] can not only find the Italian restaurant nearest to your current location, but, by clicking on its map marker, you will bring up the restaurant's Website including the menu, the address and how to get there, the phone number to make a reservation, etc. This information can be combined with the "power of the crowd," allowing you to read reviews about the restaurant and see average ratings. Perhaps someone has taken a picture of the restaurant with embedded geographical identifying metadata and posted it on Panoramio (http://www.panoramio.com/) [last accessed <March 31, 2010>], which automatically places it on Google maps at the correct spot, a widespread practice called geotagging [71].

Taking this a step further, real-time location-based user data aggregation allows services like Trendsmap (http://trendsmap.com/) [last accessed <March 31, 2010>] to draw a live map of what users post on Twitter, a micro-blogging service mainly used on mobile devices, providing coverage of how events unfold over time and far exceeding any news coverage. Twitter can also be used to report news of disasters and to coordinate emergency response. Instedd (http://www.instedd.org/) [last accessed <March 31, 2010>], which stands for Innovative Support to Emergencies, Diseases, and Disasters, uses collective intelligence techniques to mine various publicly available information sources for signals of emerging diseases [47]. Mashups, websites that combine data or functionality from several external sources, such as Harvard University School of Public Health's HealthMap (http://www.healthmap.org/) [last accessed <March 31, 2010>], use a similar approach by providing updates about outbreaks based on the user's location and projecting them onto a map [72, 73]. An explosion of applications allows health consumers to monitor and manage their health problems by combining the power of mobile computing with social interaction to alter behavior [74-77].

4.1. Vignette

Monitoring devices for people interested in tracking food intake, exercise, or even disease progress are available (http://www.sugarstats.com) [last accessed <March 31, 2010>] (http://www.minimed.com/products/software/carelink) [last accessed <March 31, 2010>], but ease of data collection and real-time sharing of this information is not yet realized. Studies which show

that the combination of home monitoring devices and personal feedback from healthcare providers may reduce disease effects more readily than either intervention alone point to the potential for real-time sharing of information from mobile computing devices [78] which can be combined with location-based features:

> An obese 56-year-old patient has been told to lose weight over the years without much success. He is treated for hypertension and diabetes, neither of which is well-controlled. He has tried different diet plans in the past, but gained back all he lost plus additional weight each time he quit a plan. He joined a weight-loss support group but stopped going to the meetings, in part due to the distance he had to drive and the difficulty getting there on time because of his irregular work hours. He also tried a food diary but found entering of data too laborious.
>
> His PCP (primary care physician) wants to try a different approach. She provides him with a small waterproof sensor (http://www.bodymedia.com/) [last accessed <March 31, 2010>] to be worn around-the-clock which communicates with his mobile phone. The sensor monitors his vital signs and uploads the data to an electronic database whenever his vital signs go above or below the target goal. The sensor also monitors and records the time, distance based on GPS data, and calories burned for his walking and related activities; weight and BMI are recorded weekly. This information is combined with data from his glucose monitor, which alerts a nurse when his results fall or rise precipitously or when a trend of poor control occurs. With the patient's consent, his collected data along with his health history and medication use are de-identified and sent to a data repository as part of a large-scale clinical trial to mine data for possible predictors of significant events, such as myocardial infarction.
>
> In addition, the patient uses his phone for various aspects of dietary management. He takes pictures of his meals, which are uploaded and converted into caloric values, and shopping for diabetic-friendly food is recommended to him based on his current location. The data is shared with the dietitian in the PCP's office, who uses the information to time her calls to the patient so she can offer encouragement or congratulate him when small progress is seen. The office has access to the patient's location-tracking data and recommends an exercise scheme for him that takes advantage of his existing habits and locations. The same tracking system automatically determines when the patient is at home and recommends snacks and recipes for healthy eating. Similarly, it recommends healthy-food restaurants when he is away on a business trip. The patient can remain anonymous on a local healthy-lifestyle support group Website, where he shares his successes and frustrations with other participants at any time of day or night. The site plots the combined de-identified data of all its members onto a map depicting how diabetes impacts the local community. Social interaction with his support group peers creates an environment of reflective thinking regarding the density of diabetics in their neighborhood. At the patient's next visit to his physician, a summary report of the past month's data is viewable on the exam room monitor for the PCP to review with him.

4.2 Research Challenges

There are many technological and regulatory challenges in the area of mobile IP devices. For instance, how will we cope with the exponential increase of bandwidth demand by 3G users, or regulate Voice-over-IP services which compete with the regular cellular traffic? However, we believe that there are many additional research challenges specific to the applied clinical informatics researcher:

- What real-time data that can be measured with sensors would be of interest to the healthcare provider?
- How can location-based, remote sensors be used to provide emergency and support services for high-risk patients?
- How do we harvest Web 2.0 "crowd" data to measure health outcomes [79]? Can rich personal log data combined with location-based information be used for disease outbreak surveillance without violating patients' privacy [80, 81]?
- How do we incentivize healthcare consumers to update their health status on mobile devices in order to track disease outbreaks in real time, while at the same time protecting their privacy? What system designs can help build the trust that will be necessary to encourage meaningful participation?
- How can (and should) these data be used in the context of insurance and health cost management? What controls (technical, legal, professional) are needed to ensure that individual access to care is not compromised?

- While Web 2.0 is all about sharing, where do we and how do we draw the line to prevent breach of confidentiality and exposure of PHI (protected health information)? Are user-set access controls sufficient to accomplish this? What tools and education are needed to enable individuals to make informed decisions about the privacy implications of sharing PHI?

5. Trend 4: Public Virtual Worlds and Serious Gaming

The use of virtual worlds and games has increased significantly in all age groups. Sixty-eight percent of Americans play games [82], with 25% of video gamers above the age of 50 [82]. Video games are being used from entertainment to fitness to education. It is not uncommon for physicians to 'prescribe' games to disabled patients as a means of relief [83]. Approximately one in five casual gamers self-identifies as having some form of disability [83]. Games that are used for more than just entertainment are often classified as 'Serious Games' (http://www.seriousgames.org/) [last accessed <March 31, 2010>].

Two developments have altered the potential of games for healthcare. First, new gaming systems, such as Wii (by Nintendo, Inc.), use a type of motion sensor that allow players to physically interact with the games they play. Thus, instead of "exercising" just the hands/fingers as with previous joystick-driven game consoles, these new systems combine game playing with physical motions, as in WiiFit. Performance trackers and other features entice users to participate repeatedly, promoting entire exercise programs. Systems like the Wii are being used in retirement and nursing homes to stimulate physical activities among their inhabitants [84-86].

The second development is the emergence of three-dimensional online digital worlds, like Second Life (SL) (http://secondlife.com/) [last accessed <March 31, 2010>]. These public virtual worlds are imagined, created and owned by their residents, and are also known as a Metaverses, a term coined by a Neal Stephenson [87]. In contrast to CoPs which focus tightly on one domain in order to advance knowledge in that area, virtual words provide a video game-like infrastructure running in a special browser, with no goals in and of themselves. Thus, they can be used for leisure activities as well as for "serious" purposes, or for experiencing activities not possible in real life, such as flying through the inside of a capillary. As the most successful Multi User Virtual World (MUVW) to date, SL has 16 million subscribers and often over 50,000 users online at the same time. SL's serious uses can be categorized into 1. **immersive learning**, 2. **collaboration** and 3. **simulation**. All of them have their strength in synchronous interactions.

1. **Immersive learning**. Learning through engagement in immersive worlds has been well documented [88] and is mainly achieved by promoting learner control and a shift from pure knowledge acquisition to practical engagement and social interactions within realistic contexts [88]. A healthcare example of immersive learning might be the focus groups with people with disabilities on the topic of our issues with the healthcare system that Virtual Ability, Inc. (www.VirtualAbility.org/) [last accessed <March 31, 2010>] holds every semester for a BSN (Bachelor of Science of Nursing) program. Another health education example is Virtual Hallucination (http://slurl.com/secondlife/Sedig/26/45/22/) [last accessed <March 31, 2010>], an immersive build by doctors from the University of California, Davis, where visitors experience being schizophrenic. Virtual Ability has also hosted graduate student interns from library science (who collected resources on set topics and created dissemination tools), social work (who analyzed the social resources available to peer support groups) and digital art (who created websites and other media for peer support groups). The University of Texas System is starting a year-long project to explore the use of virtual worlds for learning, and they are bringing their entire 16-campus system into SL [89]. The strongest community of educators in SL is the International Society of Technology in Education (ISTE) with almost 6,000 SL members, weekly meetings and invited speaker presentations. The Virtual World Best Practices in Education (VWBPE) Conference is held entirely online in SL and is preparing for their second biannual meeting.

2. **Collaboration.** Collaboration in SL is mainly facilitated by its location-independent character and its use of personal avatars; virtual meetings are much closer to real life than an email exchange or a text-based chat. Disability-based support groups for the autism spectrum disorder (ASD), depression, substance abuse and brain injury, for example, meet regularly in SL. Mem-

bers use their avatars for an exchange relatively free of stigma and social constraints. The most comprehensive compilation of consumer health locations and groups in SL, along with general health education resources, can be found at SLHealthy (http://slhealthy.wetpaint.com/) [last accessed <March 31, 2010>]. Researchers and professionals from areas around the world reduce travel costs and enhance their personal productivity by replacing real-world meetings that require travel with virtual meetings in SL. The first international Virtual Conference on Counseling, sponsored by the Counselor Education in Second Life (CESL) group, was held in September 2009 (http://sl.counseloreducation.org/) [last accessed <March 31, 2010>]. These meetings resemble many aspects of a real conference: they take place at a fixed time (SL time is Pacific Time) and location (virtual location in SL); meeting organizers and meeting staff take care of the technical setup; presenters speak while showing their slides; the audience (avatars) sits in chairs and can chat with their nearby neighbors; and an open discussion can be moderated after each talk. Services like Treet.tv (http://treet.tv/) [last accessed <March 31, 2010>] can film the event using a virtual camera, stream it live to a website and combine it with Chatbridge [90], blending the communication between SL audience and real-time web observers. While location-independent meetings are, for some SL users, simply a great convenience, they make meetings possible for some for whom they are next to impossible in real life. Virtual Ability, Inc. attempts to provide people with a wide range of disabilities-physical, mental, emotional, and sensory-with a supportive environment in the online virtual world Second Life. This is done by helping new users interface their assistive technology with a prize-winning SL environment (http://slurl.com/secondlife/Virtual%20Ability/171/97/23/) [last accessed <March 31, 2010>] that is based on the principles of Universal Design (Zielke et al, 2009; Krueger et al, 2009). Another Virtual Ability, Inc. project, the Amputee Virtual Environment Support Space (AVESS), supported by the US Army Medical Research and Materiel Command, establishes best practices and protocols for providing online peer-to-peer support services for military amputees and their families.

3. **Simulation.** Because of its rich 3D environment and the video game-like controls for personal avatars and objects in the virtual world, SL has emerged as a leading platform for simulations. While web-based simulations were often flat and frequently had only single-user capabilities, SL simulations allow collaborative wiki-type functionality in visual 3D spaces. This environment lends itself to, for instance, interactive anatomical and cellular models and nanotechnology demonstrations. Examples for nanotechnology can be found at (http://nanoisland.wordpress.com/) [last accessed <March 31, 2010>] and (http://slurl.com/secondlife/Nanotechnology/128/128/0/) [last accessed <March 31, 2010>]. The most well-known medical simulation in SL may be the Tour of the Testis (http://www.youtube.com/watch?v=O1YuRSyzBAE/) [last accessed <March 31, 2010>] in which the student becomes the size of a sperm while traveling through a giant testis while observing the process of spermatogenesis (http://slurl.com/secondlife/OSU%20Medicine/74/92/302/) [last accessed <March 31, 2010>], and the Folliculogensis Tour through a virtual ovary (http://slurl.com/secondlife/OSU%20Medicine/116/128/1002/) [last accessed <March 31, 2010>]. Team simulations, such as disaster response simulations where ambulance drivers interact with fire department personnel and health officials in the scene, allow for team building and behavior forming at low costs compared to real world simulations of disasters (Bolero Group: http://slurl.com/secondlife/Motorcycle/146/79/87/ [last accessed <March 31, 2010>]; and York University: http://slurl.com/secondlife/York%20University%20DEM/65/209/28/ [last accessed <March 31, 2010>] are two examples). Other types of simulations provide for training in communication skills in a safe environment. Patient history-taking, cultural competencies and ethical role-playing are taught in a virtual clinical space resembling the real world. At the Ann Myers Medical Center (AMMC http://ammc.wordpress.com/) [last accessed <March 31, 2010>], real-world medical professionals, patients and students collaborate and interact to learn together (http://slurl.com/secondlife/Hospital/89/208/24/) [last accessed <March 31, 2010>]. Run by volunteer physicians, nurses, midwives and psychologists, AMMC's goal is to assist students to become more proficient in initial history-taking and physical examination, as well as in analyzing diagnostic imaging and laboratory results. Simulation of activities not easily or safely done in real life is an SL theme which is well explained using an example related to medical training. Medical

students need to learn how to interact with autistic children – something which would be ethically questionable for pure training purposes with real patients. In SL, parents of autistic children could act like an autistic child based on their personal experiences with their own children, allowing medical students to have a virtual experience with autistic patients, enriching their education. It warrants noting that SL is not yet a very reliable platform. In addition, it demands high bandwidth and high-end hardware and requires frequent software updates.

5.1 Vignette

Virtual worlds create opportunities for participation in experiences which would otherwise prove to be difficult, if not impossible, for some individuals. Until now, patients with limited mobility who could not leave their real world to visit alternative housing, for example, could only explore reality through crude proxies. In the virtual world, these same individuals can peek into their next stage of life without needing to leave their real world:

> A 43-year-old male patient undergoes several major operations in a hospital in a major city far from his rural home after a farm accident left him paralyzed from the waist down. Two weeks before leaving the hospital to enter a rehabilitation facility, the hospital social worker discusses various options for rehabilitation, as well as several rehabilitation centers located both nearby and in other states. The patient, overwhelmed by the choices and not yet accustomed to his new life, agrees to have virtual tours of three facilities set up over the next few days. From his hospital bed, he uses the attached high-definition screen and the provided headset to log in to SL.
>
> He then teleports to a simulation of the BetterLiving Rehabilitation Facility, 800 miles away from the hospital, and is immediately greeted by the avatar of his host, the facility administrator. The host explains some basic facts about the facility and makes the patient aware that the session will be recorded and stored in his inventory for his later review. Then the host introduces him to a current resident in the facility who has almost completed his stay and is ready to return home. The resident, also paralyzed from the waist down, acts as a guide for the patient and provides a first-hand account of life in the rehabilitation facility. Both navigate their avatars, in wheelchairs, through the facility, including the pool, recreational areas, the physical therapy area and the visitor lounge.
>
> However, the patient is much more interested in meeting the other residents of the center, finding out how they are supported and how they interact with each other. Using a mixed reality 2-way audio/video system, the patient uses the computer's webcam to attend one of the daily peer support meetings held at the facility, where he is considered an invited guest. Current residents talk about their anxieties and expectations for their new lives. The patient engages in an intense conversation with several group members and gets the impression that many of the topics discussed are matching his personal fears related to his life, ranging from how to make a living and how to modify his house to accommodate his handicap, to where to get financial aid to pay for everything.
>
> By the time he leaves, he has already established a friendship with several of the residents and has a feeling of belonging to this group. Near the end of the tour of the facilities, the patient meets the physician responsible for spinal-injury patients and asks questions which enable him to begin to form a relationship with the doctor. After completion of the virtual tour, the patient thanks his host and guide, exchanging contact information for follow-up questions. The patient believes that he wants to go to BetterLiving, but withholds judgment until he completes the two other virtual tours on his schedule and reviews the recordings with his wife and daughter, who also have accounts on Second Life. Members of his extended family have used their Second Life avatars to keep in touch with him when they were not able to visit him in the hospital, and will be able to stay in contact wherever he decides to go for rehabilitation.

5.2 Research Challenges

Virtual worlds and serious games pose various computer science and software engineering challenges, such as usability, software stability and data traffic handling. However in addition, the following research challenges present themselves for the applied clinical informatician:
- How do we measure and compare the effects of patient education in the immersive world, serious game environments, and the real world?
- What types of people are most receptive to games as a way of learning? What are the features and contexts of games that work well for educational purposes?

- Which capture technologies support the recording of teachable moments in real life in a format that allows them to be used in virtual worlds and vice versa? Can you use teachable moments recorded in one environment repeatedly as teachable moments in the other environment?
- How should virtual environments be adapted to allow them to be accessible to a diverse audience?
- Can a MUVW such as SL enhance learning by immersing its participants in standardized simulation and role-playing technology used for primary and continuing medical education [64]?
- How can life-like patient avatars be made realistic enough to maximize instructional effectiveness without divulging personally identifying data?
- Can motion capture be used to match sensitive motions at a level usable for simulation of activities, like surgery? How do we determine the necessary fidelity of the haptic feedback to promote dexterity skill development?
- How can different types of games be used to support clinician and patient education, for instance, first-person simulation games vs. second-person strategy games?

6. Trend 5: Collaborative Research Networks

Social networks, such as Facebook and MySpace (http://www.myspace.com/) [last accessed <March 31, 2010>], attract large numbers of users who are older than teenagers [91]. Corporations have begun to employ social networks for, among other things, locating experts and hiring new employees. LinkedIn (http://www.linkedin.com/) [last accessed <March 31, 2010>], which surpassed 50 million users in October 2009 [90], claims that 80% of US companies use its services as a primary tool to find employees [92]. Features like "friend request" in Facebook try to connect users socially, but are still far from resembling relationships in real life. The use of online dating services resulted, according to McKinsey, in the fact that one out of eight couples married in the US last year met online (http://socialnomics.net/2009/08/11/statistics-show-social-media-is-bigger-than-you-think/) [last accessed <March 31, 2010>]. While we don't have data about the divorce rate of these couples, we know since Malcolm Gladwell's book Blink that humans can use thin-slicing [93] to determine personality quite accurately by viewing even a short video [94], thus letting us believe that computer-mediated evaluation of personality and style can be achieved with more accuracy than previously thought.

Most collaborations among researchers are not episodic transactions, but long-term engagements built on evolving relationships (Schleyer T, Feasibility of Self-documenting PatiEnt Encounters in Dentistry (SPEED), unfunded grant proposal 1RC1LM010514-01, 2009). Locating experts and collaborators in biomedical science is an increasingly important obstacle to enhancing the capacity, efficacy and effectiveness of the nation's biomedical research enterprise [95, 96]. The need to transform science into a multi- and interdisciplinary activity has been supported by funding agencies, such as the NIH Common Fund (http://nihroadmap.nih.gov/) [last accessed <March 31, 2010>] and Clinical and Translational Science Award (http://www.ncrr.nih.gov/clinical_research_resources/clinical_and_translational_science_awards/) [last accessed <March 31, 2010>] programs.

However, while modern communication technologies have significantly expanded the pool of potential collaborators, existing research network systems, like Digital Vita (http://www.dental.pitt.edu/informatics/orc/) [last accessed <March 31, 2010>], BiomedExperts (http://www.biomedexperts.com/) [last accessed <March 31, 2010>] or Epernicus (http://www.epernicus.com/) [last accessed <March 31, 2010>], have so far reduced the multifaceted and complex process of collaborator location to displaying curriculum vita-style profiles of researchers including their list of peer-reviewed publications. The Nature Publishing Group, publisher of Nature, has gone a slightly different route by creating nature networks, a science community that attempts to bring scientists together to discuss, share and explore each others' research using various Web 2.0 applications inside one infrastructure (http://network.nature.com/) [last accessed <March 31, 2010>] with less emphasis on profiles and vitae.

Researchers evaluate potential candidates for collaboration using various criteria, such as publication record and funding support, but also decide whether to approach a prospective collaboration

partner based on work style, personality [97], friendliness, character, trustworthiness and sense of humor [98,99]. These "soft" aspects of the search and selection process are researched through existing social connections, "hub" people (such as deans and former mentors), common activities (such as serving on PhD committees), informal social interactions and low-cost personal contacts mostly activities which require proximity [97].

Constructing successful social networks will be a key feature of any effective research network system. Initially such networks could be based on co-author relationships in an attempt to overcome "critical mass" constraints. However, these co-author relationships do not completely describe collaborative networks [100] and only cover the past, omitting due to publication lag time the present, and oblivious to future plans.

Collaboration among biomedical researchers and clinicians is often dominated by the use of "old" technology. Teenagers are sharing their favorite music and pop-art resources using social bookmarking websites like delicious, while researchers still work with Endnote (http://www.endnote.com/) [last accessed <March 31, 2010>], preventing them from easily accessing the same papers when several distant co-authors work on the same manuscript. Newer bibliographical tools, like Why RefWorks (http://www.refworks.com/) [last accessed <March 31, 2010>] or Zotero (http://www.zotero.org/) [last accessed <March 31, 2010>], allow such online collaboration.

New collaborative environments, such as Google Wave (http://wave.google.com/) [last accessed <March 31, 2010>], will change the way researchers and clinicians are working together. Google Wave, an infrastructure for interaction and collaboration, can bring people together for a certain time, allowing them to work on a project simultaneously. While previous group efforts were characterized by using a variety of tools for asynchronous communication (email), synchronous communication (Instant Messaging), document exchange (email attachments), screen sharing and Webinars (video conferencing), joint manuscript development (MS-Word revision mode), etc., new environments such as Wave combine all these functions in one browser window. Collaborating in Wave is part conversation and part document sharing. In addition, the process of the collaboration can be examined at any time by using the "play" button which plays back the process of the creation of the space, which had left a viewable history (http://wave.google.com/help/wave/about.html/) [last accessed <March 31, 2010>] which can serve as audit trail complying with regulations. However at this point, Google Wave and "cloud computing" in general raises many safety and security concerns which in the case of Google have been fueled by remarks of its CEO, Eric Schmidt [101]. Existing collaborative research networks have solved the privacy and confidentiality issues, such as the medical research network SIOPEN-R-NET [102] and the BIRN – Biomedical Informatics Research Network [103].

6.1 Vignette

One strategy to bridge the bench-to-bedside gap is to gradually blur the boundary between information search and information gathering. If information gathering is a natural extension of seeking information, information flow between these activities increases:

> A family practitioner, while personally not involved in any research activities, frequently reads the blog of a research-oriented academic clinician friend who is interested in diabetes research. Several of the family practitioner's diabetic patients have recently raised concerns regarding potential risks of a new flu vaccine. Thus the physician is now searching for vaccination risks for patients with diabetes mellitus. One of his social search results includes a link to his friend's blog entry discussing several papers exploring some of these risks. The family practitioner now contacts this friend directly to follow up with some specific questions regarding his own patients. The research-oriented clinician is working in a large academic center where he is currently preparing a longitudinal study involving a nationwide sample of diabetic patients. He is interested in getting in touch with practitioners across the country who can help him with his study – particularly recruiting subjects. He invites the family practitioner to a Google Wave in which several practitioners and academic clinicians discuss the research protocol, including recruitment procedures and incentives. Here, the family practitioner receives answers to his immediate questions from fellow clinicians and provides feedback on the draft protocol. Toward the end of their protocol development, an IRB (Institutional review board) expert from the academic center is temporarily invited to their

> Wave, helping them with their preparation for IRB submission. Several interactive sessions result in major revisions of the protocol prior to submission. Upon approval, the family practitioner pilot tests the recruitment scripts he helped to develop with his own patients. He continues to participate in the study, using the same collaborative environment to report his study progress and upload video recordings of his focus group meetings for analysis. All interactions are captured in Google Wave including the development of the manuscript, which gets published in an open access journal and immediately distributed.

6.2 Research Challenges

We agree with Schleyer et al. about potential research questions regarding the use of social networks to facilitate expertise location and collaboration decisions (Schleyer T, Feasibility of Self-documenting PatiEnt Encounters in Dentistry (SPEED), unfunded grant proposal 1RC1LM010514-01, 2009) and have derived our research challenges from their initial compilation:

- What are the special challenges faced by a practitioner who intends to participate in academic research? Can social networking extend the boundaries of these practitioner-researcher collaborations?
- What collaborator traits, other than expertise and interests, are useful in making collaboration decisions? How could these traits be assessed, modeled and presented? Which traits should be highlighted in interfaces designed to support evaluation of potential collaborators?
- How could a measurement of personality and other psychological preferences, such as the Myers-Briggs Type Indicator (MBTI), be used to find compatibility between researchers while avoiding the use of lengthy assessment instruments?
- Can a short video clip which augments a researcher's profile increase prospective research partners' confidence about collaboration decisions?
- How can healthcare providers and public health officials exploit the information embedded in the social network of an individual, as for instance expressed in his/her email account without violating privacy and confidentiality?

7. Delicious Channel for Further Reading

Since there are more pointers to resources than this publication can incorporate, we have compiled a collection of references using a social bookmarking tool (http://delicious.com/dioc/ACIWeb20/) [last accessed <March 31, 2010>] which allows us to share our research process with the readers.

8. Conclusions

The advent of Web 2.0 changed the information delivery and retrieval paradigm for large portions of the population. It has not yet noticeably done so for healthcare providers. The question is not so much if providers shall embrace this development – they will have to sooner or later – but how can they most benefit from it, and how can they avoid the many pitfalls of adopting a new paradigm. The need to practice medicine based on best evidence makes it imperative that information is accurate, timely, and easily accessible. Information which is widely available and rapidly disseminated to the public does not necessarily reflect evidence-based medicine and poses additional challenges to physicians, who must address fears and beliefs related to perceived withholding of care due to cultural, gender, or age bias. This was well demonstrated by the public backlash against the new prescribing practices for mammograms [104], which are in sharp contrast to what the public has come to expect, fueling fears of rationing care. Applied clinical informaticians have a formidable task ahead in guiding healthcare providers through this new world. Starting a dialog and sharing best practices should be seen as an important contribution of this field to the challenges ahead.

Let's conclude with remarks from Tim O'Reilly, who coined the term Web 2.0 during a conference in 2004: "The Web is no longer a collection of static pages of HTML that describe something in the world [5]. Increasingly, the Web is the world – everything and everyone in the world casts an

'information shadow,' an aura of data which, when captured and processed intelligently, offers extraordinary opportunity and mind bending implications."

Clinical Relevance Statement

Technology has always influenced how we practice medicine and information technology has played a particular role. Exploiting new technological discoveries and trends to improve healthcare outcomes is our obligation as clinical informaticians and providers. Social media has the potential to change the way we interact with each other as clinicians as well as how we interact with our patients.

Conflict of Interest

The authors do not declare any conflicts of interest.

Human Subject Research

No human subjects were used during this study.

Acknowledgements

References

1. Kim GR, Lehmann CU. In search of dialogue and discourse in applied clinical informatics. Applied Clinical Informatics 2009; 0: 1-7. doi: 10.4338/ACI09-10-0002

2. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud PA, et al. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA 1999; 282(15): 1458-1465.

3. Carlsen B, Glenton C, Pope C. Thou shalt versus thou shalt not: a meta-synthesis of GPs' attitudes to clinical practice guidelines. Br J Gen Pract 2007; 57(545): 971-978.

4. Sharma P. Core characteristics of web 2.0 services [Online]. 2008 November 28 [cited 2009 Nov 24]; URL: http://www.techpluto.com/web-20-services/ Archived at: http://www.webcitation.org/5mZSTfYr8

5. Web 2.0. 2009 November 14 [cited 2009 Nov 24]; URL: http://en.wikipedia.org/wiki/Web_2.0 Archived at: http://www.webcitation.org/5mZSmGwpo

6. Kaplan AM, Haenlein M. Users of the world, unite! The challenges and opportunities of social media. Business Horizons 2010; 53(1): 59-68.

7. Anderson PF, Blumenthal J, Bruell D, Rosenzweig M, Conte M, Song J. An online and social media training curricula to facilitate bench-to-bedside information transfer. Positioning the Profession: the Tenth International Congress on Medical Librarianship; 2009 Aug 31; Brisbane Australia. 2009 p. 1-11.

8. Cummings JN, Sproull L, Kiesler SB. Beyond hearing: where real-world and online support meet. Group Dyn-Theor Res 2002; 6(1): 78-88.

9. Committee on Quality of Health Care in America, Institute of Medicine. Crossing the quality chasm: a new health system for the 21st century. Washington, D.C.: National Academy Press; 2001.

10. Rindal DB, Rush WA, Boyle RG. Clinical inertia in dentistry: a review of the phenomenon. J Contemp Dent Pract 2008; 9(1): 113-121.

11. Casebeer L, Bennett N, Kristofco R, Carillo A, Centor R. Physician Internet medical information seeking and on-line continuing education use patterns. J Contin Educ Health Prof 2002; 22(1): 33-42.

12. King DW, Tenopir C, Montgomery CH. Patterns of journal use by faculty at three universities. D-Lib Magazine 2003; 9(10).

13. Tenopir C, King DW, Bush A. Medical faculty's use of print and electronic journals: changes over time and in comparison with scientists. Journal of the Medical Library Association 2004; 92: 233-241.

14. Tenopir C, King DW. Reading behaviour and electronic journals. Learn Publ 2002; 15: 259-265.

15. Warren C. Average internet user now spends 68 hours per month online [Online]. 2009 October 14 [cited 2009 Nov 24]; URL: http://mashable.com/2009/10/14/net-usage-nielsen/ Archived at: http://www.webcitation.org/5mZSoIfnC

16. Nelson Wire. Social networking and blog sites capture more Internet time and advertising [Online]. 2009 September 24 [cited 2009 Sep 29]; URL: http://blog.nielsen.com/nielsenwire/online_mobile/social-networking-and-blog-sites-capture-more-internet-time-and-advertisinga Archived at: http://www.webcitation.org/5k9SKkT3P

17. Heymans M. Introducing Google Social Search: I finally found my friend's New York blog! [Online]. 2009 October 26 [cited 2009 Nov 24]; URL: http://googleblog.blogspot.com/2009/10/introducing-google-social-search-i.html Archived at: http://www.webcitation.org/5mZSrGkkj

18. Moulding NT, Silagy CA, Weller DP. A framework for effective management of change in clinical practice: dissemination and implementation of clinical practice guidelines. Qual Health Care 1999; 8(3): 177-183.

19. Coumou HC, Meijman FJ. How do primary care physicians seek answers to clinical questions? A literature review. J Med Libr Assoc 2006; 94(1): 55-60.

20. Murray BP. Dentists' preferred sources of new drug information and their attitudes toward the use of drugs by patients. Soc Sci Med A 1981; 15(6): 781-788.

21. Selvi F, Ozerkan AG. Information-seeking patterns of dentists in Istanbul, Turkey. J Dent Educ 2002; 66: 977-980.

22. Landry CF. Work roles, tasks, and the information behavior of dentists. J Am Soc Inf Sci Tec 2006; 57(14): 1896-908.

23. Lutz M. The social pulpit: Barack Obama's social media toolkit [Online]. 2009 [cited 2009 Nov 24]; URL: http://www.edelman.com/image/insights/content/Social%20Pulpit%20-%20Barack%20Obamas%20Social%20Media%20Toolkit%201.09.pdf Archived at: http://www.webcitation.org/5mZStZQ43

24. Owyang J. Who do people trust? (It ain't bloggers) [Online]. 2009 April 29 [cited 2009 Nov 24]; URL: http://www.web-strategist.com/blog/2008/04/29/who-do-people-trust-it-aint-bloggers/ Archived at: http://www.webcitation.org/5mZSuZ8Z8

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H. Spallek et al.: Paradigm shift or annoying distraction – emerging implications of Web 2.0 for clinical practice.

25. The structure of scientific revolutions. 2009 December 9 [cited 2009 Dec 17]; URL: http://en.wikipedia.org/wiki/The_Structure_of_Scientific_Revolutions Archived at: http://www.webcitation.org/5mZSwOzVD

26. Casebeer L, Allison J, Spettell CM. Designing tailored web-based instruction to improve practicing physicians' chlamydial screening rates. Acad Med 2002; 77(9): 929.

27. Curran VR, Fleet L. A review of evaluation outcomes of web-based continuing medical education. Med Educ 2005; 39(6): 561-567.

28. Wiecha J, Barrie N. Collaborative online learning: a new approach to distance CME. Acad Med 2002; 77(9): 928-929.

29. Wantland DJ, Portillo CJ, Holzemer WL, Slaughter R, McGhee EM. The effectiveness of web-based vs. non-web-based interventions: a meta-analysis of behavioral change outcomes. J Med Internet Res 2004; 6(4): e40.

30. Grassley JS, Bartoletti R. Wikis and blogs: tools for online interaction. Nurse Educ 2009; 34(5): 209-213.

31. Nordqvist C, Hanberger L, Timpka T, Nordfeldt S. Health professionals' attitudes towards using a web 2.0 portal for child and adolescent diabetes care: qualitative study. J Med Internet Res 2009; 11(2): e12.

32. Cobus L. Using blogs and wikis in a graduate public health course. Med Ref Serv Q 2009; 28(1): 22-32.

33. Roach PB, Roggin KK, Selkov E Jr, Posner MC, Silverstein JC. Use of a novel, web-based educational platform facilitates intraoperative training in a surgical oncology fellowship program. Ann Surg Oncol 2009; 16(5): 1100-1107.

34. Lemley T, Burnham JF. Web 2.0 tools in medical and nursing school curricula. J Med Libr Assoc 2009; 97(1): 50-52.

35. Mattheos N, Stefanovic N, Apse P, Attstrom R, Buchanan J, Brown P, et al. Potential of information technology in dental education. Eur J Dent Educ 2008; 12 (Suppl. 1): 85-92.

36. King S, Greidanus E, Carbonaro M, Drummond J, Patterson S. Merging social networking environments and formal learning environments to support and facilitate interprofessional instruction. Med Educ Online 2009; 14(5).

37. Hughes B, Joshi I, Lemonde H, Wareham J. Junior physician's use of web 2.0 for information seeking and medical education: a qualitative study. Int J Med Inform 2009; 78(10): 645-655.

38. Sandars J, Homer M, Pell G, Croker T. Web 2.0 and social software: the medical student way of e-learning. Med Teach 2008; 1-5.

39. Feeney L, Reynolds PA, Eaton KA, Harper J. A description of the new technologies used in transforming dental education. Br Dent J 2008; 204(1): 19-28.

40. Bouldin AS, Holmes ER, Fortenberry ML. "Blogging" about course concepts: using technology for reflective journaling in a communications class. Am J Pharm Educ 2006; 70(4): 84.

41. Kamel Boulos MN, Wheeler S. The emerging web 2.0 social software: an enabling suite of sociable technologies in health and health care education. Health Info Libr J 2007; 24(1): 2-23.

42. Parboosingh J. Continuing education and professional development for hospital doctors and dentists. Med Educ 2000; 34(6): 421-423.

43. Margolis P, Halfon N. Innovation networks: a strategy to transform primary health care. JAMA 2009; 302(13): 1461-1462.

44. Clark T, Kinoshita J. Alzforum and SWAN: the present and future of scientific web communitites. Brief Bioinform 2007;8(3):163-71. http://bib.oxfordjournals.org/cgi/content/full/8/3/163 Archived at: http://www.webcitation.org/5mZSy1htd

45. Kinoshita J, Clark T. Alzoforum. Methods Mol Biol 2007; 401: 365-381.

46. Frost JH, Massagli MP. Social uses of personal health information within PatientsLikeMe, an online patient community: what can happen when patients have access to one another's data. Journal of Medical Internet Research 2008;10(3):e15. http://www.jmir.org/2008/3/e15/ Archived at: http://www.webcitation.org/5mZSzwbbA

47. O'Reilly T, Battelle J. Web squared: web 2.0 five years on [Online]. 2009 [cited 2009 Dec 17]; URL: http://www.web2summit.com/web2009/public/schedule/detail/10194 Archived at: http://www.webcitation.org/5mZT1e3WW

48. Lau A, Coiera EW. Impact of web searching and social feedback on consumer decision making: a prospective online experiment. Journal of Medical Internet Research 2008;10(1):e2. http://www.jmir.org/2008/1/e2/ Archived at: http://www.webcitation.org/5mZT35NWd

49. Broom A. Virtually he@lthy: the impact of internet use on disease experience and the doctor-patient relationship. Qual Health Res 2005; 15(3): 325-345.

50. Giveon S, Yaphe J, Hekselman I, Mahamid S, Hermoni D. The e-patient: a survey of israeli primary care physicians' responses to patients' use of online information during the consultation. Isr Med Assoc J 2009; 11(9): 537-541.

51. Hart A, Henwood F, Wyatt S. The role of the Internet in patient-practitioner relationships: findings from a qualitative research study. J Med Internet Res 2004; 6(3): e36.

52. Stevenson F, Kerr C, Murray E, Nazareth I. Information from the Internet and the doctor-patient relationship: the patient perspective – a qualitative study. BMC Fam Pract 2007; 8: 47.

53. Hersh WR, Greenes RA. SAPHIRE: an information retrieval system featuring concept matching, automatic indexing, probabilistic retrieval, and hierarchical relationships. Computers and Biomedical Research 1990; 23: 410-425.

54. Hersh WR, Greenes RA. Information retrieval in medicine: state of the art. M D Computing 1990; 7: 302-307.

55. Karahasanovic A, Brandtzaeg PB, Vanattenhoven J, Lievens B, Nielsen KT, Pierson J. Ensuring trust, privacy, and etiquette in web 2.0 applications. Computer 2009; 42(6): 42-49.

56. McLean R, Richards BH, Wardman JI. The effect of web 2.0 on the future of medical practice and education: Darwikinian evolution or folksonomic revolution? Med J Aust 2007; 187(3): 174-177.

57. Boulos MN, Maramba I, Wheeler S. Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education. BMC Med Educ 2006; 6: 41.

58. Vinge V. Rainbows end. New York, New York: Tor Science Fiction; 2006.

59. Vinge V. Synthetic serendipity. IEEE Spectrum 2004; 41(7): 35-44.

60. Birkfellner W, Figl M, Huber K, Watzinger F, Wanschitz F, Hummel J, et al. A head-mounted operating binocular for augmented reality visualization in medicine = design and initial evaluation. IEEE Transactions on Medical Imaging 2002 Aug;21(8):991-7.
http://ieeexplore.ieee.org/search/wrapper.jsp?arnumber=1076043 Archived at:
http://www.webcitation.org/5mZT4XroE

61. Greene K. How to build a bionic eye [Online]. 2008 January 25 [cited 2009 Nov 24]; URL:
http://www.technologyreview.com/computing/20113/?a=f Archived at:
http://www.webcitation.org/5mZT5kyys

62. Cascio J. How an emerging technology could threaten civility [Online]. 2009 [cited 2009 Nov 24]; URL:
http://www.theatlantic.com/doc/200911/augmented-reality Archived at:
http://www.webcitation.org/5mZT7rSVb

63. Underground: London Tube iPhone and iPod touch application: your new eye. 2009 [cited 2009 Nov 24];
URL: http://www.presselite.com/iphone/londontube/ Archived at:
http://www.webcitation.org/5mZT93zXF

64. Phillips J, Berge ZL. Second Life for dental education. Journal of Dental Education 2009; 73(11): 1260-1264. http://www.jdentaled.org/cgi/content/abstract/73/11/1260 Archived at:
http://www.webcitation.org/5mZTC0tBG

65. Vaughan-Nichols SJ. Augmented reality: no longer a novelty? IEEE Computer 2009; 42(12): 19-22.
http://doi.ieeecomputersociety.org/10.1109/MC.2009.380 Archived at:
http://www.webcitation.org/5mZTCzmSq

66. Khamene A, Wacker F, Vogt S, Azar F, Wendt M, Sauer F, et al. An augmented reality system for MRI-guided needle biopsies. Stud Health Technol Inform 2003; 94: 151-157.

67. MRI-guided needle placement with augmented reality guidance. 2007 April 3 [cited 2009 Nov 24]; URL:
http://showcase.erc-assoc.org/accomplishments/bioengineering/jhu-07-10-guidedneedle.htm Archived at:
http://www.webcitation.org/5mZTEjBXp

68. Grimson WEL. Medical applications of image understanding. IEEE Expert-Intelligent Systems & Their Applications 1995; 10(5): 18-28.

69. Honan M. I am here: one man's experiment with the location-aware lifestyle. Wired 17[2]. 1-19-2009. 11-24-0009.

70. Parr B. Mobile web is taking over the world (and other internet trends) [Online]. 2009 October 20 [cited 2009 Nov 24]; URL: http://mashable.com/2009/10/20/mobile-web-presentation/ Archived at:
http://www.webcitation.org/5mZTIQJIE

71. Geotagging. 2009 October 28 [cited 2009 Nov 24]; URL: http://en.wikipedia.org/wiki/Geotagging Archived at: http://www.webcitation.org/5mZTKmvm2

72. Goldstein J. Social media explored as tool for health experts [Online]. 2009 November 8 [cited 2009 Nov 24]; URL:
http://www.philly.com/inquirer/local/20091108_Social_media_explored_as_tool_for_health_experts.html
Archived at: http://www.webcitation.org/5mZTOWFF7

73. Brownstein JS, Freifeld CC, Madoff LC. Influenza A (H1N1) virus, 2009--online monitoring. New England Journal of Medicine 2009; 360(21): 2153-2157.
http://content.nejm.org/cgi/content/full/NEJMp0904012 Archived at:
http://www.webcitation.org/5mZTQ17yk

74. Lee G, Tsai C, Griswold WG, Raab F, Patrick K. PmEB: a mobile phone application for monitoring caloric balance. CHI '06 extended abstracts on Human factors in computing systems; ACM; 2006; 1013-1018.

75. Ali-Hasan N, Gavales D, Peterson A, Raw M. Fitster: social fitness information visualizer. CHI '06 extended abstracts on Human factors in computing systems; ACM; 2006; 1795-1800.

76. Consolvo S, Everitt K, Smith I, Landay JA. Design requirements for technologies that encourage physical activity. Proceedings of the SIGCHI conference on Human Factors in computing systems; ACM; 2006; 457-466.

77. Mamykina L, Mynatt E, Davidson P, Greenblatt D. MAHI: investigation of social scaffolding for reflective thinking in diabetes management. Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems; ACM; 2008; 477-486.

78. Bosworth HB, Olsen MK, Grubber JM, Neary AM, Orr MM, Powers BJ, et al. Two self-management interventions to improve hypertension control: a randomized trial. Annals of Internal Medicine 2009; 151(10): 687-695.

79. Gawande A. Getting there from here: How should Obama reform health care? [Online]. 2009 January 26 [cited 2009 Dec 17]; URL: http://www.newyorker.com/reporting/2009/01/26/090126fa_fact_gawande Archived at: http://www.webcitation.org/5mZTRqyuh

80. Tsui F-C, Espino JU, Dato VM, Gesteland PH, Hutman J, Wagner MM. Technical description of RODS: a real-time public health surveillance system. Journal of the American Medical Informatics Association 2008; 10(5): 399-408.

81. Chapman WW, Dowling JN, Wagner MM. Fever detection from free-text clinical records for biosurveillance. Journal of Biomedical Informatics 2004; 37: 120-127.

82. Essential facts about the computer and video game industry. Washington D.C; 2009.

83. Survey: 'disabled gamers' comprise 20% of casual video games audience. 2008 June 11 [cited 2009 Dec 22]; URL: http://www2.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/06-11-2008/0004830408&EDATE Archived at: http://www.webcitation.org/5mZTTQJl2

84. Lanningham-Foster L, Foster RC, McCrady SK, Jensen TB, Mitre N, Levine JA. Activity-promoting video games and increased energy expenditure. Journal of Pediatrics 2009; 154(6): 819-823.

85. Nitz JC, Kuys S, Isles R, Fu S. Is the Wii Fit a new-generation tool for improving balance, health and well-being? A pilot study. Climacteric 2009; Nov 12.

86. Parker FS. Nursing home technology: Wii video game (video 58 secs.) [Online]. 2007 June 6 [cited 2009 Dec 22]; URL: http://hospiceandnursinghomes.blogspot.com/2007/06/nursing-home-technology-wii-video-games_06.html Archived at: http://www.webcitation.org/5mZTUTcIA

87. Stephenson N. Snow Crash. New York: Bantam Dell; 1992.

88. Freitas Sd. Serious virtual worlds: a scoping study [Online]. 2009 [cited 2009 Nov 24]; URL: http://www.jisc.ac.uk/publications/documents/seriousvirtualworldsreport.aspx Archived at: http://www.webcitation.org/5mZTW3GNS

89. Linden P. The first statewide rollout of a virtual world learning environment: the University of Texas System in Second Life [Online]. 2009 September 15 [cited 2009 Sep 28]; URL: https://blogs.secondlife.com/community/learninginworld/blog/tags/education Archived at: http://www.webcitation.org/5k88ojrph

90. Warren C. LinkedIn surpasses 50 million users [Online]. 2009 October 14 [cited 2009 Nov 24]; URL: http://mashable.com/2009/10/14/linkedin-50-millon/ Archived at: http://www.webcitation.org/5mZTXO0SU

91. Infographic: social networking. 2009 October 8 [cited 2009 Nov 24]; URL: http://www.pewinternet.org/Infographics/Growth-in-Adult-SNS-Use-20052009.aspx Archived at: http://www.webcitation.org/5mZTZKyr3

92. Quek F. Socialnomics: how social media transforms the way we live and do business. Hoboken, New Jersey: John Wiley & Sons, Inc.; 2009

93. Grottman JM, Murray JD, Swanson C, Tyson R, Swanson KR. The mathematics of marriage: dynamic nonlinear models. MIT Press; 2002.

94. Gladwell M. Blink. New York, New York: Black Bay Books; 2005.

95. Schleyer T, Spallek H, Butler BS, Subramanian S, Weiss D, Poythress ML, et al. Facebook for scientists: requirements and services for optimizing how scientific collaborations are established. J Med Internet Res 2008; 10(3): e24.

96. Schleyer T, Spallek H, Butler BS, Subramanian S, Weiss D, Poythress ML, et al. Requirements for expertise location systems in biomedical science and the Semantic Web. Mochol M, Zhdanova AV, Nixon L, Breslin J, Polleres A, editors. Proceedings of the 3rd Expert Finder Workshop on Personal Identification and Collaboration: Knowledge Mediation and Extraction PICKME 2008; 2008 Oct 27; Karlsruhe, Germany. Tilburg University, The Netherlands: CEUR-WS.org; 2008; 31-41.

97. Spallek H, Schleyer T, Butler BS. Good partners are hard to find: the search for and selection of collaborators in the health sciences. Project Management and User Engagement. Fourth IEEE International Conference on eSciene (eScience 2008); 2008 Dec 7-12; Indianapolis, IN. Los Alamitos: IEEE Computer Society; 2008; 462-467.

98. Casciaro T, Lobo MS. Competent jerks lovable fools, and the formation of social networks. Harvard Bus Rev 2005; 83(6): 92-99.

99. Casciaro T, Lobo MS. When competence is irrelevant: the role of interpersonal affect in task-related ties. Admin Sci Quart 2008; 53(4): 655-684.

100. Katz JS, Martin BR. What is research collaboration? Res Policy 1997; 26(1): 1-18.

101. Bosker B. Google CEO on privacy (video): 'If you have something you don't want anyone to know, maybe you shouldn't be doing it' [Online]. 2009 December 7 [cited 2010 Mar 16]; URL: http://www.huffingtonpost.com/2009/12/07/google-ceo-on-privacy-if_n_383105.html Archived at: http://www.webcitation.org/5oHt6dgg0

102. Schreier G, Messmer J, Rauchegger G, Modre-Osprian R, Ladenstein R. A web-based platform for interdisciplinary biomedical research. Front Biosci 2009; 14: 2738-2746.

103. Keator D, Grethe J, Marcus D, Ozyurt B, Gadde S, Murphy S, et al. A national human neuroimaging collaboratory enabled by the biomedical informatics research network (BIRN). IEEE Trans Inf Technol Biomed 2008; 12(2): 162-172.

104. Wang SS, Rockoff JD, Martinez B. Group Issues Clarification on Mammography Advice [Online]. 2009 November 20 [cited 2009 Dec 29]; URL: http://online.wsj.com/article/SB125867464145956577.html Archived at: http://www.webcitation.org/5mZTarXan

H. Spallek et al.: Paradigm shift or annoying distraction – emerging implications of Web 2.0 for clinical practice.