ORIGINAL RESEARCH

Combining *i*Google and Personal Health Records to Create a Prototype Personal Health Application for Diabetes Self-Management

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Abstract

Objective: *The aim of this project is to create a prototype for a personal health application (PHA) for patients (i.e., consumers) with diabetes by employing a user-centered design process. This article describes the design process for and resulting architecture, workflow, and functionality of such a PHA.* ***Materials and Methods:*** *For the design process, we conducted focus groups with people who have diabetes (n = 21) to ascertain their needs for a PHA. We then developed a prototype in response to these needs, and through additional focus groups and step-by-step demonstrations for people with diabetes as well as healthcare providers, we obtained feedback about the prototype. The feedback led to changes in the PHA's presentation and function.* ***Results:*** *Focus group participants said they wanted a tool that could give them timely, readily available information on how diabetes-related domains interact, how their behaviors affect them, and what to do next. Thus, the prototype PHA is Internet-based, retrieves data for diabetes self-management from a personal health record, displays those data using gadgets in the consumer's iGoogle page, and makes the data available to a decision-support component that provides lifestyle-oriented advice. Manipulation of the data enables consumers to anticipate the results of future actions and to see interrelationships.* ***Conclusions:*** *A user-centered design process resulted in a PHA that uses technology that is publicly available, employs a personal health record, and is Internet based. This PHA can provide the backbone for a decision support system that can bring together the cornerstones of diabetes self-management and integrate them into the life of the person with diabetes.*

Key words: *e-health, technology, medical records*

Introduction

For optimal diabetes self-management, the person with diabetes needs timely information on their blood glucose levels, nutrition, physical activity, medications, medical examinations, and laboratory test results, among other things. There are numerous technologies available to assist with collecting, summarizing, and responding to the information needed for diabetes management, from both a clinical and lifestyle perspective. Existing technologies include (1) Web-based systems with patient and provider portals to enable patient–provider interaction, patient uploading of home monitoring data, summaries of those data, and diabetes education[1–3]; (2) cell phones for transmitting educational content and reminders to patients, local processing of data, transmission of data to Web-based applications for processing, and/or for storing data for processing at a later time by caregivers[4–6]; (3) monitoring devices leveraging wireless (Bluetooth) technologies to transfer biometric data to the consumer's Internet-connected device for upload and integration into Web-based systems; and (4) limited decision support delivered via the Internet, insulin pumps, cell phones, or personal digital assistants.[7,8]

Research suggests that Web-based tools for diabetes management are effective, leading to improvements in individual-level biomedical outcomes.[9–14] Regarding the clinical efficacy of cell phones, Krishna and Boren[15] observed that 9 of 10 studies involving this technology reported improvement in A1c. A pilot study of a cell phone and Internet system with some decision support found that patients who used this tool experienced improvements in clinical outcomes and adherence to recommended treatment regimens.[8] Other studies of decision support technologies have looked at clinician behavior, finding greater levels of compliance with clinical guidelines and better quality of care,[16–20] although not necessarily finding improvement in patient health outcomes after implementation of the systems.[16,20]

Most mature diabetes management technologies have several limitations. First, as noted by Lockett Brown et al.,[14] lack of or limited reimbursement to providers for using such technologies inhibits deployment and sustainment, and patients are unwilling to pay for such technologies. Thus, emerging technologies must be free to consumers and not require continual input from a clinician or clinic. Second, to our knowledge, existing systems have not included consumers in the design process and during development. Consumers have participated in usability tests or focus groups of complete or nearly complete products.[21,22] Third, few diabetes management technologies make use of personal health records (PHRs), which can integrate and host both self-reported personal data that are not associated with medical visits and data found in electronic medical records (EMRs).[23] The University of Pittsburgh Medical Center's HealthTrak and Georgetown University's MyCareTeam are exceptions. The former merges data from an EMR and has a PHR component for communication with providers and some self-management[24] and the latter is linked to Microsoft HealthVault and Google Health for certain data. However, both HealthTrak and MyCareTeam rely on clinicians to provide the decision and lifestyle support, precluding real-time advice while increasing unreimbursed provider time.

Thus, we sought to design a prototype of a Web-based personal health application (PHA) to address the many aspects of diabetes self-management. The project was done in collaboration with Project Health Design, a program sponsored by the Robert Wood Johnson Foundation, and employed a user-centered design process.[25] Our core project team was composed of behavioral scientists, endocrinologists, a leader in telehealth and teleophthalmology, and a systems architect and developer.

This article describes the design process and resulting architecture, workflow, and functionality of the prototype PHA. By prototype, we mean a partially functioning version of a system.[26] The design and functionality of the prototype were initially shaped by the needs and preferences of people with diabetes, or our "consumers." For this work we take the view that patients with diabetes are consumers of health information technology, so we refer to them hereafter as "consumers." The prototype was then iteratively modified by additional consumer and healthcare provider responses to versions of it during development.

Materials and Methods

To ascertain the design and functionality of the prototype, we conducted a series of 90-min focus groups with people with diabetes, recruited from the Joslin Diabetes Center (Boston, MA). We used a theoretical sampling model for recruitment.[27] Specifically, we divided the full patient list of the Joslin Diabetes Center into four smaller lists defined by age ($\leq$60 years vs. $>$60 years) and type of diabetes (1 vs. 2), assigned random numbers to each name on the lists, sorted the random numbers, and mailed solicitations to the first two hundred people on each list. We then recruited the first people who responded to the solicitation until we had recruited 6 to 12 participants for each of three focus groups. Six to 12 participants per group is generally thought to be an optimum number because groups of this size are small enough so that people will talk and self-disclose, yet large enough to get a diversity of experiences and perceptions.[28]

Prior to the focus groups sessions, we drafted a facilitator's guide with input from a person with diabetes. The focus group questions asked about what diabetes self-care tasks the participants were performing and in what social and physical environments, the biggest problems they experienced, the things that helped them manage their diabetes, and what features they would need and want in a tool for diabetes self-care. The discussions were open ended, led by two members of the core project team, and taped. The focus groups were intended to elicit the range of thoughts on our topic(s) and not for testing hypotheses, so we did not poll the participants on particular viewpoints for purposes of quantification. We deconstructed the transcripts with systematic and sequential grouping of utterances, drawing together and comparing discussions of similar themes.[29] We held focus groups until we were no longer hearing new information.

To verify the needs articulated in the first focus groups and to present the initial idea for the prototype PHA, we held a second series of focus groups with the same people who participated in the first series. These focus groups used the same data collection and analysis methods as the first. We presented draft scenarios that we developed to guide us with the prototype development and the PHA concept itself. In brief, the PHA concept included several early "gadgets," which are reusable, small Web applications designed to be used within a portal-based Website—*i*Google.

Later in development, core project team members did step-by-step demonstrations of the prototype so that consumers could review it and respond to more mature versions of the gadgets. We asked them about usability at this time, although a full usability assessment was not possible.

To obtain feedback from healthcare providers, we held a group meeting in which we showed them the prototype and the questionnaires we designed for consumers to use when they set-up the PHA. We recruited participants for this meeting using convenience sampling. Most were aware of the efforts of our project team but had not seen the prototype before reviewing it. A team member took notes during these sessions but no audio recording was made.

Results

FIRST ROUND OF FOCUS GROUPS

Our recruitment approach yielded 21 enrollees. Fifteen of the 21 participants were from the cohort 60 years of age and older (average age for all 21 was 63.8 years) and 11 of the 21 had type 1 diabetes,

Table 1A and B. Excerpts from the Focus Groups, with Interpretation

1A. FIRST ROUND OF FOCUS GROUPS		
QUESTION DOMAIN	**REPRESENTATIVE EXCERPTS FROM TRANSCRIPTS**	**INTERPRETATION**
Diabetes self-care tasks the participants were performing; problems they experienced	The actual time to test and stuff like that probably isn't that long, an hour or two a day, but we're always thinking about it. What I need to take better care of my diabetes in a day is about 6 or 8 more hours. Because I find when I'm doing everything I need to do to take good care of my diabetes and to get my blood sugar truly in tight control, I'd have to spend at least 6 hours a day just on record keeping and that's blood sugar monitoring, that's writing down everything I eat, and that's recording everything in terms of the dosage of the insulin to carbohydrate ratios.	Recording and collating the data they need for diabetes management is burdensome.
	I came here and took the nutrition course when I first started. They said, "Oh! You can have a sandwich and you can do this and you can do that." But I respectfully disagree with that because if I do that—if I go have a slice of pizza—my glucose blood sugar will spike and why spike it. I can eat very well and very nutritiously without spiking it. There's no need for it. It's just how I do it that's what works for me. I need more understanding of food labels and how to compare the insulin dose with my carbs. And I go to the nutritionists and I've gone over the carb to insulin ratio, but they do it in a session and sometimes when you're home, you don't get it.	Participants reported receiving guidance from providers, but then became confused between visits, or they disagreed. Confusion was especially acute at critical moments, such as when experiencing high or low blood sugar, or when making food selections. Intervisit guidance needed to allay concerns and reinforce recommendations.
Things that helped them manage	By trial and error, I figure out how much insulin I have to take. It's still pretty much guesswork, which I don't think it should be. You always eat the same things; that's what has worked. And I run my same track because I know the level of strenuous activity. I try to eat at home mostly because eating out is always a crapshoot. You've got to be real careful about what you eat when you eat out, so I try to do it at home.	Some had adopted a strict routine to cope, which resulted in a repetitive lifestyle. There is safety is constant behavior but it makes life dull.
Social and physical environments	I also have to say that I do it anywhere. I check my blood sugar when I'm driving in a car, at a light. Or if I'm driving and somebody else is there I might have them do the blood sugar—I just give them the finger to stick. I do it in the airplane. I give myself my shots in the restaurant. I check my blood sugar in the restaurant. I don't think there is anywhere that I wouldn't do it.	Participants reported managing their condition at any time and place.

continued →

Table 1A and B. Excerpts from the Focus Groups, with Interpretation *continued*

QUESTION DOMAIN	REPRESENTATIVE EXCERPTS FROM TRANSCRIPTS	INTERPRETATION
Features they wanted in a tool for diabetes self-care	It'd be nice if through the day—if one wanted—to check and see where you were at a particular time. Total interaction. In other words, not only would it give you a history, but it would then might even tell you, "Okay, as a result you need to do . . . or . . . something that you should be considering or following as a result of what your sugars are . . . ." You need to bring that interaction with putting information into a Web site and getting feedback from the information. Maybe even an alarm on the information that you'd plug into your computer, going over your carb limit. Something to help me understand about exercising and blood testing. It's not something you would have to write down and do it would just be the result of your testing.	Participants wanted actionable, understandable, and timely information about what they needed to do for themselves. They wanted information on how glucose, medication, and lifestyle factors interrelate.
	I want reports of everything because I want to read my report. I just keep track of it myself. I don't depend on my doctor for all of that because they can tell you, "Oh! Everything is fine," but when you look at it you might see just small changes. It may mean nothing to them but I like to look at all that. Almost instant access to my diabetes care team.	Participants wanted an independent yet integrate-able tool that could be part of an overall diabetes health program.
1B. SECOND ROUND OF FOCUS GROUPS		
QUESTION DOMAIN	**REPRESENTATIVE EXCERPTS FROM TRANSCRIPTS**	**INTERPRETATION**
Initial impressions to the PHA concept	I think this program has to be tailored to an individual. What I'm thinking is that those people who are concerned would look. You know, the difference between what my type 2 and your type 1 is . . . . That's great information if you are somebody who is motivated enough to look for it. Not everybody has a computer or uses computers, so there should be another piece of equipment, small maybe, but large enough for somebody to read.	Unsolicited, participants verified the previous observation about group and individual differences and the challenge of making a flexible PHA. That is, it may help those who are ready. Also, they need a choice of viewing platforms.
Initial concerns	Will Google be able to see my data? This seems like "big brother" to me.	They had concerns about security and privacy. These concerns appeared to be outweighed by the potential value of the tool.
	Basically what he's talking about is just having it somewhere where you can see it all. That's why this is good. You can see it. It's all right there and it all goes in. Sometimes you get stuck in a routine. When somebody throws you a bone, yeah maybe you should try it.	
Response to early gadgets, some of which used icons	Personally, I don't want my computer to yell at me. I don't really care about the feedback because I'm just looking at the graph. I don't need a display to tell me, "You've had a good day." I'd much rather have a piece of sugarless candy then a smiling face. A can of beer, something. A smiling face gets you nowhere. Smiley faces are very benign. Let's say you had a really bad day—you need an icon that says you've got to straighten up. A punishment–reward system in the icons would really help make the point.	Participants had different preferences regarding the tone of the feedback and recommendations that they wanted to receive in the gadgets.

PHA, personal health application.

15 were male, and 13 used e-mail. The average hemoglobin A1c of the 21 enrollees was 8.1%, ranging from 5.6% to 12.6%.

We conducted three focus groups for the first series. *Table 1A* displays representative excerpts from the focus group transcripts. One point the consumers expressed is that diabetes is burdensome. Recording and collating the data they need to make decisions for their diabetes care is time consuming, and even when they are not doing what they "should," they were thinking about their condition. To cope, they had adopted various strategies, such as strictly limiting their diets (e.g., by not eating out or eating the same foods) and their exercise regimens (e.g., by running the same course always). This resulted in repetitive lifestyles lacking in spontaneity. When they tracked their diabetes data, they did not always understand what the data meant or how things interrelated (such as the relationships among physical activity, medications, and blood glucose). Also, consumers reported receiving guidance during appointments with providers, but then becoming confused between visits. Confusion was especially acute at critical moments, such as when they were experiencing a high/low blood sugar, or when making food selections. They wanted a tool that could be part of an overall diabetes health program but was not necessarily reliant on their provider for input. It was clear from the issues raised that the technology needs of people with type 1 diabetes differed from those with type 2 diabetes. For example, diabetes knowledge tended to be greater among those with type 1 than among those with type 2.

SECOND ROUND OF FOCUS GROUPS AND DEMONSTRATIONS

We conducted two focus groups for the second series. Participants first responded to the scenarios that we created to steer prototype development. The results of that review are not shown here, but the final scenarios have been published at www.projecthealthdesign.org. Next, in their response to the initial PHA concept, participants underscored the salience of consumer differences and the requirement that the PHA be flexible (*Table 1B*). They also expressed concern over the security and potential intrusiveness of their personal health information being displayed in an *i*Google page, although most in the group thought that this concern was outweighed by the value of the PHA, especially if we follow industry standard best practices. Participants had different preferences regarding the tone of the feedback and recommendations that they wanted to receive in the gadgets. Some preferred supportive, positive feedback and recommendations while others preferred to be admonished when they did not meet diabetes self-care targets. Some said they did not want text-based feedback or icons; they instead wanted the information displayed graphically.

The consumers who participated in the guided demonstrations were naive to *i*Google. They required brief training on how to obtain an *i*Google account and load and manipulate gadgets. One suggested that instructions on how to use the PHA should include a video or article on the use of *i*Google. Once through the training and an explanation of the relationship between the PHA and *i*Google, consumers focused on the gadgets. Gadgets can be used independently of each other or together, and consumers said the choice of which gadgets to use was confusing. The consumers recommended that the PHA include an overview or "tracking" gadget that would list events and point to other gadgets the consumers might need to look at. This recommendation led to the creation of a data tracker gadget noted

Table 2. Design Objectives for the Prototype Personal Health Application for Diabetes Self-Management

DESIGN OBJECTIVE	SOURCE
Display and summarize current and past information on the cornerstones of diabetes self-management and how they interrelate, including diet, glucose, physical activity/exercise, medications, and clinical care of the person using the application.	A
Update automatically as new information related to diabetes care enters the personal health record, particularly self-monitoring data on glucose, diet, physical activity, and medications.	A, B, C
Allow the consumer to control which aspects of self-management they focus on. By giving the consumer more control, the application can be relevant to a wider range of people in terms of diabetes knowledge and goals.	A
Provide decision support in the form of targeted feedback and education on lifestyle—not medical advice—on demand. The decision support needed to cover the current circumstances of the consumer as well as future actions she/he might take, such as going for a long run or eating a certain meal.	A, B
Use a system that is free, potentially familiar, and available wherever there is Web access.	A, B, C
Take a "best-of-breed approach," meaning the consumer can choose how/where to capture the data for their diabetes self-management.	C
Anticipate the latest sensing technologies.	C

Note: A, focus groups; B, review of previous applications and/or the literature; C, Project HealthDesign.

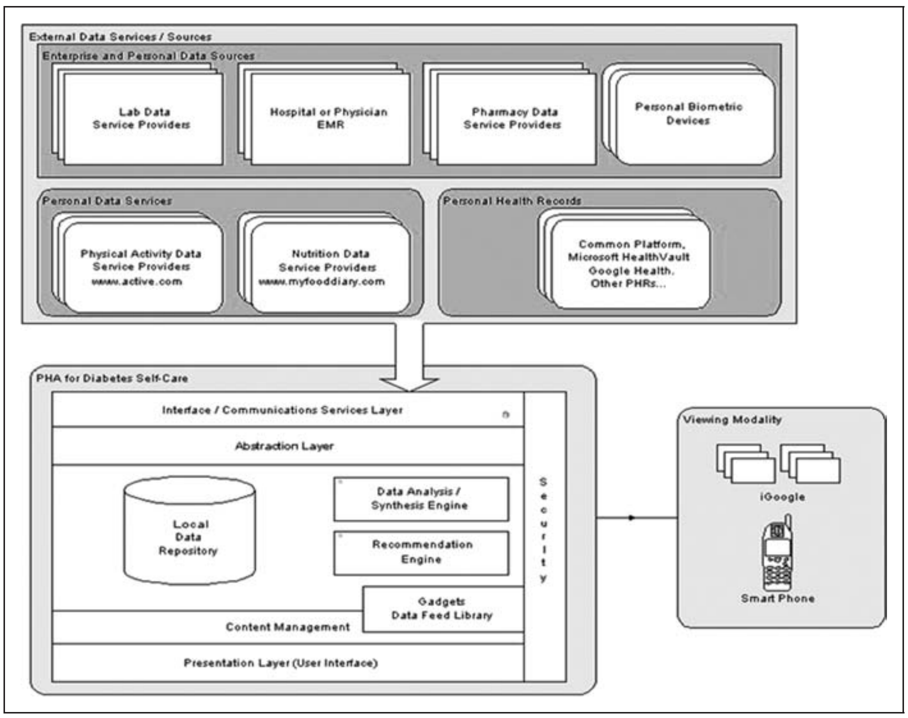

Fig. 1. System architecture of the prototype PHA for diabetes self-management. Much of the data that the prototype PHA uses originate from the consumer's providers, laboratories, or pharmacy and are stored in a PHR requiring login to access content. When data are not available electronically, the consumer can data enter them using setup questionnaires. Other data will come from biomonitoring devices, such as glucose and physical activity monitors. Consumers determine which devices to use, but the brand must be integrated with a PHR. Other diabetes-related data may come from journaling services for the recording of physical activity and nutrition/diet. Viewing the PHA with a smart phone is possible with the smart phone's Internet browser, but the main option for viewing the prototype is with a computer. PHA, personal health application; PHR, personal health record.

below. Overall, consumers reported that the gadgets themselves were useful and easy to understand.

PROVIDER FEEDBACK

Ten providers attended our meeting about the PHA prototype: seven nurse practitioners specializing in diabetes care, one nutritionist, and two physicians. One observation they made in reviewing the gadgets is that the data from the latest biomonitoring technologies contained measurement errors, such as a heart rate of zero. This is important because the prototype draws from external data sources and PHRs and envisions future technologies for monitoring observations of daily living, namely physical activity and continuous glucose monitors. The latest physical activity monitors record readings every minute and the latest continuous glucose monitors record readings every 5 min,[30] so errors are soon corrected within those devices with follow-up measurements and displayed correctly within the gadgets. These errors were not specific to the prototype, but nonetheless should be recognized because the PHA gives actionable recommendations based on the information it retrieves. This issue can be mitigated by writing algorithms that search for impossible values and outliers. Another observation by the providers is that the prototype PHA can be another way for their patients to share personal health data with them, which the patients bring to appointments in handwritten logbooks or in their glucometers. The PHA as currently conceived can be accessed by providers if consumers access their *i*Google accounts during their clinic appointments.

PROTOTYPE PHA DESCRIPTION

Table 2 lists the design objectives for the prototype PHA. The design objectives were mainly informed by the focus groups, but were also influenced by the goals of Project HealthDesign 7and our review of the literature and/or previous applications. A goal of Project HealthDesign was to envision the future of PHRs and other technologies at 5–10 years from the date of the program announcement in 2006.

The prototype PHA is a collection of flexible, reusable, small Web applications called "gadgets" designed to be used within a portal-based Website. The initial implementation uses *i*Google as the portal.

The prototype's architecture is built using open source tools and technologies and is designed to be extensible via a service-oriented architecture. Although the architecture was designed to work with any PHR, we developed this prototype using a Common Platform PHR created by Sujansky and Associates, LLC (San Carlos, CA; www.sujansky.com), developed specifically for Project HealthDesign.

The PHA captures data from external data services or sources, covering recent laboratory and test values, medications, nutrition/diet, physical activity, and blood glucose (*Fig. 1*). Using information that the application receives from external data services and sources, it analyzes, interprets, provides feedback, and makes recommendations.

Because the application is displayed within the *i*Google Website as a set of gadgets, consumers must have a password-protected, free *i*Google account, which requires secure login to access content. *i*Google is the visual framework used by the consumer to display gadgets from our PHA or other Websites, and as such, *i*Google never accesses data that reside in the gadgets, but only coordinates the presentation.

When the consumer is logged into their *i*Google account, their computer sends simultaneous requests to access content at separate Websites (*Fig. 2*, lines 3a, 3b, and 3c) and displays the content within the consumer's *i*Google page. When a consumer's computer requests to view a gadget, our PHA makes calls to various Web services, repositories, and PHRs to gather information used in the gadgets (*Fig. 2*, lines 4a, 4b, and 4c). Once the information is gathered, analyzed, and the recommendations are generated, the information is returned to the consumer's interface and presented within the *i*Google gadgets.

Figure 3 shows a sampling of available gadgets, from the perspective of a theoretical consumer interested in losing weight: she/he is using the glucose gadget, the diabetes tip of the day gadget, a "what if" gadget regarding physical activity, and a caloric expenditure gadget. Gadgets not shown are (1) a nutrition gadget, which captures meal data from external sources and displays nutrition facts, summary statistics, and the amount that a certain meal or series of meals falls short of or exceeds the consumer's goals; (2) a physical activity gadget, which collects activity data from external monitors that upload to a PHR, or allows consumers to specify their physical activity within the gadget, and then provides an estimate of calories burned; (3) a medications gadget, which tracks adherence and links to outside resources for information; (4) an insulin calculator for calculating the amount of insulin needed given the grams of carbohydrates in the consumer's upcoming meal and their current blood glucose; (5) interactive relational graphs, which allow the consumer to see trending information for multiple diabetes-related domains; and (6) a data tracker that provides a consolidated list of key events as information comes into the application from the common, shared repository (such as a meal event or a low glucose reading). Depending on the type of event, the tracker guides consumers to certain gadgets, to tailored feedback, or links to educational information. Gadgets share data through a common repository, and input in one gadget can be reflected in another.

Feedback and recommendations in all gadgets reflect consumer's responses to questions about their history, exercise preferences, and goals in the setup questionnaires designed for the application. The clinical aspects of the feedback and recommendations were guided by clinical guidelines of the American Diabetes Association and the American Association of Diabetes Educators, but because this is a consumer-driven application, certain guidelines can be overridden by the consumer based on their specific needs and preferences.

Discussion

The overarching vision of this project is to help people with diabetes better manage their condition by providing them with

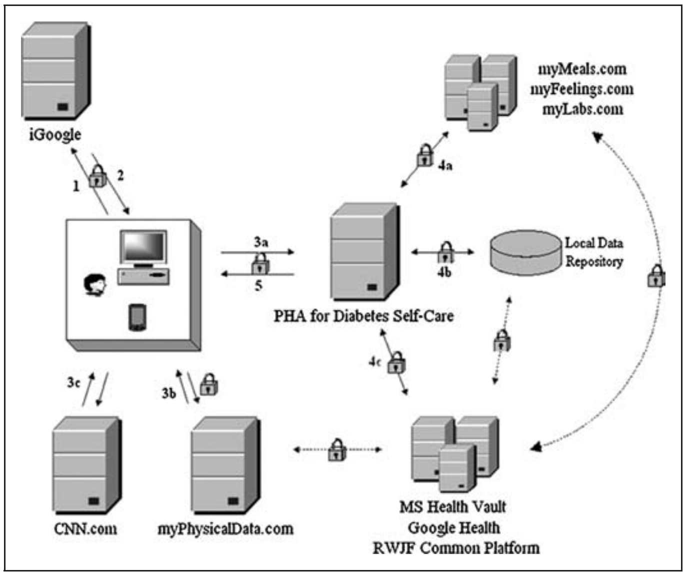

Fig. 2. System workflow of the prototype PHA for diabetes self-management. Line 1 is a request to access the consumer's iGoogle page. Lines 2 and 5 represent the requested data being sent to the consumer's computer. Line 3a is a request to access our PHA for diabetes self-management. The padlock indicates that this exchange is secure and private as defined by industry standard best practices. Lines 3b and 3c are examples of the many other public gadgets now available and that might be viewed concurrently with the PHA, including weather gadgets, news feeds, and recipe-of-the-day gadgets, among others. Line 4a represents the use of Web services to access data at third-party sites that the consumer may be using to collect data. Line 4b illustrates how the PHA gathers data from the local data repository, such as information pertaining to consumer preferences for the content of the PHA as they indicate during set-up, past recommendations, and educational materials. Line 4c indicates that the PHA can access data from multiple PHRs. Dotted lines represent potential links between PHAs and the actual data repository.

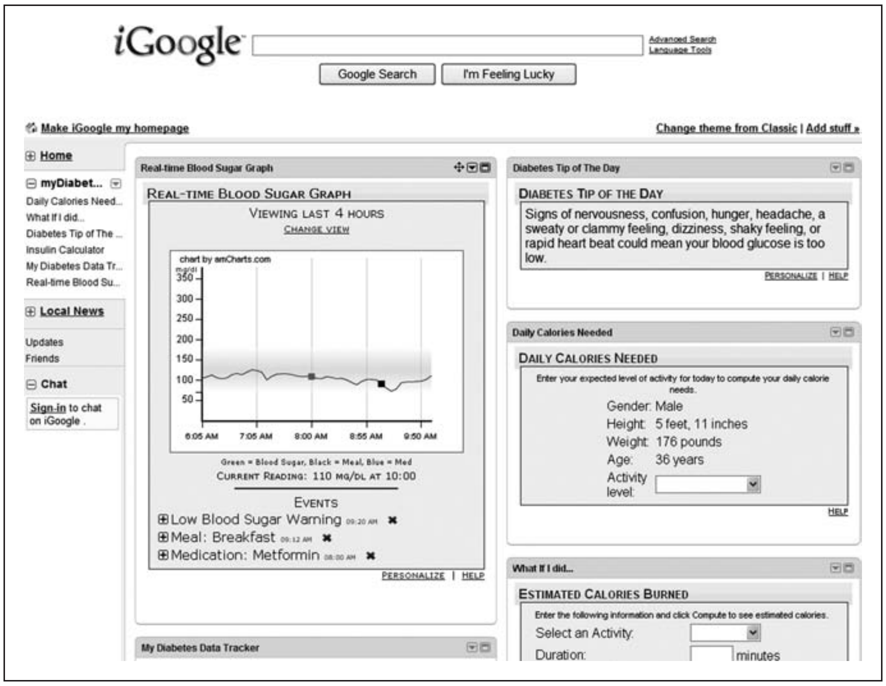

Fig. 3. Demonstration of potential gadgets of the prototype PHA, for a theoretical consumer. The gadgets shown include the glucose gadget, which collects data from monitors (point or continuous) or allows consumers to enter a blood glucose value. The graph shows blood glucose values in relation to specific events. The glucose gadget can notify the consumer when his/her glucose is trending too high or low, via email, text message, telephone, or a message within the application itself. These gadgets also include a diabetes tip of the day, which is a text- or video-based diabetes-related tip or a reminder for recommended care. To make reminders, it uses data input by the consumer at set-up and/or their PHR data for dates of previous examinations and tests. One of two "what if" gadgets is shown here. These allow the consumer to enter information about planned activities related to nutrition and physical activity and receive feedback on how to better control their glucose levels given their plans in these domains. The last gadget is for estimating caloric expenditure given a certain physical activity.

appropriate tools. Thus, we employed a user-centered design process to develop a prototype PHA to assist with major domains of diabetes self-management: (1) nutrition/diet, (2) physical activity, (3) blood glucose levels, (4) medications, and (5) how these domains interrelate. Using information that the prototype PHA receives on these major self-management domains from a PHR of the consumer's choice and which is managed by the consumer, the PHA analyzes, interprets, provides feedback, and makes recommendations based on clinically vetted educational content on diabetes self-management. The analyses tell the consumer what their status is and where they have been, the interpretation tells them how well they are doing with respect to goals and/or guidelines, the feedback points to problem areas and successes, and the recommendations can be individualized according to consumer preferences specified when they set up the application. The consumer is able to enter data on an upcoming activity and learn what the outcome of that activity may be. This information is presented within a series of gadgets on their *i*Google page(s). Details of the project are available at www.projecthealthdesign.org.

The experience of creating and reviewing this prototype PHA suggested issues to be addressed and avenues for further development in a fully functioning production version. One is that publicly available, free PHRs (Microsoft HealthVault and Google Health) have emerged only in the last few years. They have quickly gained popularity. Microsoft HealthVault recently started collaborating with Aetna, and as of November 2008, 6 million Aetna members can transfer their personal health information from Aetna's own PHR to Microsoft's HealthVault. Also, Google Health and Blue Cross Blue Shield of Massachusetts (BCBCMA) contracted to make Google Health available to BCBSMA's members. As the PHRs gain popularity, numerous device manufacturers are "integrating" with them so that consumers can upload and store their biometric data or results there and make them available for analyses by PHAs such as the one described in this article. Future work will involve working with Microsoft HealthVault and Google Health as well as formally adopting interoperability standards to move patient data between patient (PHR) and provider (EMR) domains. As part of this work with other PHRs, we will have to address their security requirements so that the PHA gadgets can access them.

Since the development effort for this prototype PHA was initiated, *i*Google has made changes in functionality and presentation. When we created the gadgets, *i*Google presented pages or tabs within a consumer's account across the top of the browser. The tabs have subsequently been moved to the left side of the page, changing the space available for gadgets to display data. As a result of this change the gadgets became slightly smaller, but Google implemented a new view called the Canvas view. The new Canvas view allows the consumer to expand a gadget to encompass the available screen real-estate within the tab. The larger display allows our PHA to show more content and allows the user more control over what is presented. Future work on gadget development might take advantage of this large display by creating more detailed, interactive graphs. But it is noteworthy that such changes are an unavoidable hazard of any system that relies on free, publicly available tools. Fortunately, such changes in layout, design, and policy are not frequent and are published in advance, leaving time for developers to adapt systems.

The range of telemedicine and e-health technologies is broad, and consumer engagement with a technology may depend on the degree of fit between the technology and the needs, abilities, and resources of the consumer.[31] The prototype PHA described here, although it took into account the consumer input, is not for everyone. Appropriate consumer-technology "fit" may be dictated by, among other things, costs, whether the consumer owns a computer, Internet access, and self-motivation. With respect to costs, currently providers are not reimbursed for using Web-based and cell phone technologies and often costly biomonitoring equipment is not covered by insurance, so, for now, costs may be a barrier to use. We have tried to adapt to the high costs of some biomonitoring equipment by building the prototype PHA to work with data sources and services that allow for manual data entry, if that is the consumer's choice. Internet use, while increasing rapidly among all segments of the American population, is still proportionately lower among older adults.[32] As the application is designed to address self-management of diabetes and the feedback and recommendations are about lifestyle, usage is entirely dependent on the consumer's self-motivation, as noted by the focus group participants. We considered some of these barriers in the design and development of the prototype; for example, we recruited older adults for the focus groups and designed the PHA so that consumers can choose which gadgets to use, can specify their own goals and type of feedback, and can use the PHA within *i*Google with their other gadgets (e-mail, stocks, weather, etc.). But future development efforts will need to consider these issues further.

Recently, the project team received a grant from the Telemedicine and Advanced Technology Research Center to develop a production version of the PHA and conduct a prospective, randomized trial of its clinical efficacy among people with diabetes who will use it for 6 months. The 6-month test will also allow us to examine the application's usability and the consumer's patterns of use in a formal way. The prototype PHA is an Internet-based program and is available on computers and Internet-enabled cell phones by typing the prototype URL into a smart phone's Internet browser, whereas the production version will be designed more intentionally for cell phone use. Additionally, the production version of the PHA will allow for users to enter biomonitoring data that are collected through lower-cost, more common types of monitors. We anticipate that these two changes to the application will reduce some of the aforementioned barriers to use. Our overall hypothesis for this project and the future test of clinical efficacy is that "smart," Internet-based, publicly available tools that address the cornerstones of diabetes self-management can improve diabetes outcomes, particularly glycemic control.

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Disclosure Statement

No competing financial interests exist.

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