Sensor-Enabled Elder Social Support Platform
NIH / National Institute on Aging STTR
Grant Number: 1R41AG035452-01
Kinnexxus, Inc. & Carnegie Mellon University
Final Report

1. State the beginning and ending dates for the period covered by the STTR Phase I grant.

Beginning date: July 1, 2010
Ending date: March 31, 2011

2. List all key personnel who have worked on the project during that period, their titles, dates of service, and number of hours devoted to the project.

All key personnel were actively involved from July 1, 2010 to March 31, 2011.

A. From Kinnexxus, Inc.

i) Benay Dara-Abrams, Ph.D.
CEO and Chief Gerontechnology Officer
0.6 months = 110.4 hours budgeted. However, many more hours were devoted to the project in order to achieve the results described in the final report.

ii) Alec Dara-Abrams
Senior Scientist
2.75 months = 506 hours budgeted. However, many more hours were devoted to the project in order to achieve the results described in the final report.

iii) Drew Dara-Abrams, Ph.D.
Research Scientist
While Drew Dara-Abrams was not originally budgeted on this project, he contributed 12 hours to technology development and support on the platform side

B. From Carnegie Mellon University

i) Martin Griss, Ph.D.
Principal Investigator and Professor
0.6 months = 110.4 hours budgeted. However, many more hours were devoted to the project in order to achieve the results described in the final report.

ii) Michael Smith
Senior Researcher
2.75 months = 506 hours budgeted. However, many more hours were devoted to the project in order to achieve the results described in the final report.

iii) Patricia Collins
Assistant Professor of the Practice
While Patricia Collins was not originally budgeted on this project, she has contributed an average of 5 hours/week to the project (total: 1.25 months).

3. Summarize the specific aims of the Phase I grant.

This project demonstrated the feasibility of utilizing integrated information and measurement technology to help extend the period of an older adult's independence in their residential setting, with improved quality of life and reduced total cost of care. In particular, the project examined how the (semi-) automated in-home collection, analysis, and appropriate distribution of physical, behavioral, and psychosocial data enables older adults to maintain this independence, with support from members of their social support network. Ongoing manual collection of patient health-related behavioral data (e.g., weight, blood pressure) is error-prone and often incomplete due to poor patient compliance, even with customized, context-aware reminders. By augmenting the Kinnexxus Elder Social Support Platform [Kinnexxus 2009-2011] with a selection of sensor-enabled home health devices, it is possible to automate some of the information acquisition. Phase I focused on the feasibility of technology integration, while further work will focus on the commercialization and adoption of the enhanced sensor-enabled system.

The specific objectives of the Phase I project were to develop a systematic approach to selecting, evaluating, adapting, integrating and configuring combinations of sensors to demonstrate the feasibility of a flexible yet robust extension to the Kinnexxus platform, supporting elders' everyday activities. In this context, the term sensor is used to refer to a home health device, which delivers a calibrated measurement result. The project examined issues regarding (remote) maintenance, installation and configuration, architected integration, usability, reliability, precision, and battery life, and tested a Kinnexxus system outfitted with several of the most promising sensor combinations (for specific situations), in order to validate the model and assess the effectiveness and usability.

The Phase I project adopted two primary methods:

1) development of a descriptive framework of selected attributes of home health devices and weights according to multi-attribute utility theory, specifying different sensor features such as measurement attributes, interfacing requirements, precision and interoperability, and

2) experimental validation of the attributes and calibration of the weights by integrating and evaluating a representative set of sensors into the Kinnexxus platform via a flexible architecture.

4. Provide a succinct account of published and unpublished results, indicating progress toward their achievement. Summarize the importance of the findings. Discuss any changes in the specific aims since the project was initiated.

The specific aims of the project focused on the development of a descriptive framework of attributes and weights to select particular sensors and the integration of these sensors into the Kinnexxus Elder Social Support Platform. We conducted a formative evaluation of the initial implementation of the Sensor-Enabled Elder Social Support Platform to determine how to improve the initial prototype. Both the descriptive framework and the integration and formative evaluation were accomplished and the results are discussed in sections 7 and 8 of this report.

The Phase I project accomplished the desired aims of developing an approach to select appropriate sensors and of designing and implementing an initial integration of these sensors into a platform to support older adults and to allow information on the older adult to be shared with their family caregivers and professional care providers. With the development of a descriptive framework to select appropriate sensors and the integration of sensor-enabled home health devices into the Elder Social Support Platform, we have established the technical feasibility of a Sensor-Enabled Elder Social Support Platform. With the development and evaluation of the use of the prototype in specific scenarios, we have accomplished the first step toward the development of a commercial product to help older adults age in place and to receive the support they need by arming their family caregivers and professional care providers with up-to-date measurement data and observations of daily living through both self-report and observations by caregivers.

5. List titles and complete references to publications, and manuscripts accepted for publication, if any, that resulted from the project's effort. Submit five copies of such items, except patent and invention reports, as an Appendix.

Internal Publications:

- *Development of a Descriptive Framework of Attributes and Weights according to Multi-Attribute Utility Theory*, Technical Report #1, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, September, 2010.

- *Collecting Measurements from Multiple Devices*, Technical Report #2, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, December, 2010.

2011 Aging in America Conference presentation:

- *Embedding Personal Health in a Social Context,* April 30, 2011, San Francisco, CA.

6. List patents, copyrights, trademarks, invention reports and other printed materials, if any, that resulted from the project or describe patent status, trade secrets or other demonstration of IP protection.

Before the grant was initiated, Kinnexxus, Inc. had already applied for a patent for the collaborative gerontechnology apparatus and method that provides the foundation for the Elder Social Support Platform. No new patents, trade secrets or other intellectual property were developed as part of the Phase I feasibility project.

Printed materials include two technical reports:

- *Development of a Descriptive Framework of Attributes and Weights according to Multi-Attribute Utility Theory*, Technical Report #1, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, September, 2010.

- *Collecting Measurements from Multiple Devices*, Technical Report #2, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, December, 2010.

7. Describe the technology developed from this STTR, its intended use and who will use it.

The following sections describe the technology developed from this STTR:

- o Descriptive Framework for Characterizing Home Health Devices
- o Sensor-Enabled Elder Social Support Platform

The intended use of the technology is the first step in the development and commercialization of a Sensor-Enabled Elder Social Support Platform.

The Descriptive Framework for Home Health Devices (HHD's) is intended to be used in the design of home health systems, particularly, in subsequent Kinnexxus platform enhancement with HHD's not addressed in this Phase I feasibility study. This technique may also be of use to other system designers faced with the challenge of selecting from the growing array of commercially available HHD;s. Note, we have restricted our scope here to HHD's that have some form of electronic interface capability. See Section 7A below.

The Sensor-Enabled Elder Social Support Platform is intended to be used by older adults, family caregivers, and professional care providers, who are members of the older adult's circle of care and who would like to stay informed of the older adult's condition so that they can provide appropriate care, avoid emergencies as much as possible, and assist the older adult in maintaining his/her independence so that he/she can "age in place" as long as possible. See Sections 7B, 7C, 7D, and 7E below.

7A: Development of a Descriptive Framework for the Characterization and Selection of Home Health Devices

As mentioned earlier, the project adopted two primary methods:

1) development of a descriptive framework of selected attributes of home health devices and weights according to multi-attribute utility theory, specifying different sensor features such as measurement attributes, interfacing requirements, precision and interoperability, and
2) experimental validation of the attributes and calibration of the weights by integrating and evaluating a representative set of sensors into the Kinnexxus platform via a flexible architecture.

This section describes the process and results of the first method.

Multiple Attribute Utility Theory (MAUT)

A challenge in doing a systematic assessment of the various sensors and sensor combinations in a hybrid software/hardware system is the large variety of attributes that can be incorporated. A formal technique for dealing with such mixed attribute systems is Multiple Attribute Utility Theory (MAUT) [Tockey 2004; Keeney & Raiffa 1993]. MAUT is a label for a family of methods used as a means to analyze situations and create an evaluation process. The objective of MAUT is to attain a combined measure of the attractiveness (utility) of each outcome of a set of alternatives. We bring the MAUT formalism to systematically account for risk and unknown factors in assessing the different sensor devices in the system as a whole. MAUT assigns weights to assess economic factors such as installation cost, and total cost of ownership, as well as more technical factors such as usability and maintainability [Fischer & Fischbeck].

Experimental Design

Description of the MAUT process

For the remainder of this report, we will refer to multi-attribute utility theory as MAUT, as it is often called. MAUT analysis is a well-documented decision-making approach. The technique is most useful when a decision-maker is faced with a myriad of considerations or attributes when comparing the relative utility of various options. In this research, the options included a variety of home health sensors and the attributes are characteristics of those sensors. We needed to determine the appropriateness (utility) of each sensor for our feasibility study. To analyze that utility, all options must be evaluated using the same attributes. These attributes must be assessable using a quantitative scale. Initially, the decision-makers compile a list of all relevant attributes for the analysis. The decision-makers then assign a relative weight to each of those attributes. In our case, we stipulated that the sum of the weights across all the attributes must equal 1.0. To assign the weights to the attributes, we employed a Wideband Delphi process (described below). In a standard MAUT analysis, it is common to exclude any attribute that has a weight less than 10% of the total weight distribution (in our case, the sum of attribute weight is 1.0), because those attributes do not contribute substantially to choosing among alternatives. Once the weights have been assigned, an individual with knowledge of the options (e.g., home health blood pressure monitors) evaluates each of the options against each of the attributes, assigning a value within the scale for that attribute. To ensure a mathematically meaningful result, all attribute value assignments (utility) must use the same range of values (e.g., 0 to 5). As described below, we defined each attribute, including an interpretation of the scale (e.g., daily ease of use: 0 = unusable; 3 = moderately easy to use; 5 = extremely easy to use). Therefore, the individual assigning the values for each attribute could do so consistently and with an interpretation that matched that of the decision-makers. Once all options have been assigned attribute values, each attribute value is multiplied by the attribute weight and the weighted-values are summed to create a utility score.

It is very important to test the sensitivity of the results of a MAUT analysis, because the weighting process is somewhat imprecise in most cases. The decision-makers may know that one attribute is the most important, but may be unsure whether the weight should be 0.4 or 0.35. Therefore, one conducts a simple sensitivity analysis that addresses the question of whether small variations in weights cause small variations in the results. If, in fact, a small change in weight values changes which option has the highest utility, then it is important not to over-ascribe meaning to the results.

Description of the Wideband Delphi process

The Wideband Delphi process [Boehm 1981] enables a group of decision-makers to come to agreement in a comparatively quick manner. We applied a variation of this process to the determination of attribute weights. Initially, each member of the group independently assigned weights to each attribute. A facilitator gathered the weight choices from each of the participants. If the weights assigned by each participant for a given attribute varied widely, then participants were given a chance to provide their rationale for the weight they selected. The individuals in the group then reassigned weights and the facilitator again gathered the weight choices. In two to three cycles, the weight values will often stabilize. However, if an attribute weight does not converge, it is the responsibility of the facilitator to assign a weight, typically an average of the weights assigned by the group members. In our case, we used an average of all group members' assigned weights after four cycles.

How attributes were identified and defined

We decided to evaluate the health devices based on both functional and non-functional (quality) attributes. We started with a list of thirteen attributes: commercial availability, integratability, usability (daily ease of use), affordability, maintainability, accuracy, reliability, supportability, usability (ease of installation), efficiency, meaningfulness of results, relevance and timeliness. To ensure that the attributes were interpreted consistently by the team of decision-makers, we provided written definitions for each attribute.

How weights were defined

Four members of the research team met to review the attributes and to assign weights to each attribute. Each member used his or her own experience and expertise to determine a weight. Each decision maker was required to ensure that his or her weights summed to 1.0. The research team agreed that they would assign the weights based on the importance during our phase 1 feasibility study.

This process was repeated for four cycles. Individuals were encouraged to adjust their weights away from the lowest-weighted attributes, so as to focus more on the "most important" attributes. Using this approach we were able to reduce the list of attributes with a non-zero weight to nine: commercial availability (0.25), integratability (0.1875), usability (daily ease of use) (0.1825), affordability (0.13), maintainability (0.0975), accuracy (0.0725), reliability (0.03), supportability (0.025) and usability (ease of installation) (0.025).

How scales were defined for each attribute

Scales were developed to measure each of the nine attributes for candidate devices. All scales were based on a 0-5 rating, with 0 representing least desirable and 5 being most desirable. The nature of each attribute dictated how each scale was constructed. The following table describes the scale framework used for each of the nine attributes:

Attribute	Scale Values
Commercial availability	5 = available for consumer purchase in the U.S. 0 = not available for consumer purchase in the U.S.
Integratability	5 = published protocol, easy to implement 4 = published protocol 3 = published protocol, difficult to implement 2 = unpublished protocol, presumed easy to implement 1 = unpublished protocol 0 = unpublished protocol, presumed difficult to implement
Usability (ease of daily use)	5 = easy for older adult to use without assistance, measurement results transmitted over wireless connection 4 = easy for older adult to use without assistance, measurement results transmitted over a wired connection 2 = within the ability of the typical older adult, but measurement results not electronically transmitted 0 = beyond the ability of the typical older adult
Affordability	5 = trivial acquisition cost & no ongoing costs 3 = average cost among devices of its type 0 = highest priced device of its type
Maintainability	5 = no maintenance required 4 = requires periodic maintenance within ability of typical older adult 2 = requires periodic maintenance that can be completed by the older adult's support network 0 = requires periodic maintenance by a trained person
Accuracy	5 = device's published degree of measurement variance is less than 1% 0 = device's published degree of measurement variance is greater than 5%
Reliability	the number of (rating) stars for the product on amazon.com
Supportability	5 = manufacturer provides the requested information in a timely manner 3 = manufacturer provides some information but it may either be untimely or inadequate 0 = manufacturer is totally unresponsive to requests for information
Usability (ease of installation)	5 = installation by team was (perceived as) trivial 3 = installation by team was (perceived as) possible, with effort 0 = installation by team was (perceived as) not possible

Table 1 MAUT Attributes and Scale Values

How devices were identified

We decided to restrict our evaluation of health devices to four device classes: blood glucose meters, blood oxygen meters, blood pressure monitors and weight scales. Within each of these device classes a great many products exist. However, we also constrained our search to those devices that have some sort of electronic interface for transmitting measurement results to a computational platform.

The list of candidate devices was compiled by searching the Internet. Searches were conducted using terms relating to the device class (e.g. "blood glucose meter", "weight scale", etc.) in conjunction with terms relating to the attributes. Candidate devices were chosen from among the search results that indicated that the device might be worth further investigation.

How cell values were determined

Once a list of candidate devices was compiled, we performed additional research was performed to evaluate how the device measured against the attributes. The amount of available information available for each device varied significantly. A spreadsheet was compiled with the results.

Results of Experiment

Cells for which no data could be found

As mentioned above, there was significant variability in the amount of information available for the devices. In the case where an attribute score could not be supported by published information, a score of 0 was assigned. We chose to use this value, rather than a middle-of-the-road score, because we found that for some attributes, particularly accuracy, the scale chosen was rather "strict" and we felt that the absence of data should not favorably bias the device's score.

Attribute values based on proxies (e.g., reliability)

Reliability proved particularly difficult to evaluate. Metrics such as mean time between failures (MTBF) were nowhere to be found. We chose to substitute an alternative metric in this case. We felt that the customer rating listed on amazon.com would be a suitable, though not perfect, proxy for the reliability metric. We do understand that other factors, such as ease of use and value, may be considered by customers who provided ratings.

Discussion

Difficulties in reaching consensus in list of attributes, definitions, and weighting

The process of defining the attributes and their meaning and weighting was, by design, a group exercise. We wanted to ensure that all team members had input to the way in which candidate devices would be evaluated and scored. This process took a fair amount of discussion until the team agreed that we had reached a point of consensus.

Role of subjectivity (wisdom of the group)

The goal of this MAUT analysis was to identify those devices which would most probably make a good choice for integrating with the Kinnexxus platform. We needed a way to guide us in selecting the best devices from among the many candidates. This process also relied heavily on the general and technical experiences of the team members. Each member uses his/her expertise to subjectively assess the importance of the various aspects of the devices.

Heavyweight process (with respect to attribute characterization through reading device documentation)

The amount of effort to perform the MAUT analysis is proportional to the number of attributes being evaluated. We chose to keep nine attributes with non-zero weights, even though some weights were quite small. Had we elected to prune the list of attributes to four or five, the amount of effort needed to complete the analysis would have been significantly reduced. We found the MAUT approach took a disproportionate amount of time to carry out, given the imprecise nature of the comparisons. It is possible that the simpler wideband Delphi approach would have provided comparable results in much less time. Nevertheless, the MAUT approach seems more “defensible,” which could be important in publishing the results.

Investigating attribute values is difficult

Investigating attribute values proved to be difficult for three reasons: 1) information is not centralized, 2) information is not published, and 3) some ideas about attribute scoring had to be changed, based on what information was available.

Some of the difficulty in performing the MAUT analysis results from the fact that there is no central repository for this sort of information. A variety of data sources must be integrated. Even if only a single device were being researched, it’s likely that the manufacturer’s web pages would contain some information, user manuals would provide a different subset of information, and a phone call to the manufacturer would be required to find “published but not posted” information (such as communication protocols). The lack of MTBF data for reliability analysis caused us to refocus that attribute on customer satisfaction, which in turn required consulting with another data source (amazon.com).

Fewer attributes would make process lighter weight

The MAUT process demonstrated that it would be better to have fewer attributes to make the process lighter weight. We found that it would be better to use four or five attributes rather than nine attributes in the MAUT process. However, the results of the analysis depended on the consideration of the lower-weight attributes. Therefore, we valued accuracy over expediency in our analysis.

Some devices were integrated before the MAUT process was run

While we were careful not to prejudice the evaluations by what we already knew, it helped to have someone with experience in using various classes of devices.

In order to build momentum for the project, we had developed some proof-of-concept interfaces for four devices that we had obtained prior to applying for the grant: two blood pressure monitors and two weight scales. The experience gained from working with these devices proved to be quite valuable in guiding the early stages of the MAUT analysis. However, we were careful to avoid having this experience bias the results of the analysis.

Value of Framework

In conclusion, it is important that results of the MAUT process should be reproducible. In the future, we also feel that it would be helpful to reduce the number of attributes to streamline the process.

The result of the analysis was that we produced a list of devices we determined most likely to result in a successful feasibility study. The number of high-scoring candidates varied by device class, and ranged from one to three. The variance was driven by the number of devices available in the device class. Blood glucose meters have the greatest amount of choice, while blood oxygen meters have the least.

Need for experience on the team

Anyone looking to perform an analysis similar to this would ideally have someone on the team who has some technical experience with device communications and/or home healthcare devices, in general. Using the process without adequate prior experience with the devices will result in a more complicated, and, therefore, an even heavier-weight process.

It is also important to have someone on the team, who understands the use cases in which these devices would be applied. Without these participants, a team would run the risk of missing the context in which the participants must evaluate the devices.

Standardization of interfaces

The need for this MAUT analysis is driven by the current state of the art with connectable health devices. Many manufacturers implement proprietary communication protocols, sometimes varying significantly even among devices in the same class. The Continua Health Alliance is working to establish a common communication protocol across manufacturers and device classes that, when fully implemented, will reduce the necessity for selecting devices based on the ability to integrate them into a larger system and potentially having to re-implement communication protocols. However, their results to date have been quite limited and the guidance they are providing still allows for considerable inconsistency between device interfaces. Corner cases may still exist for devices not covered by the emerging standards, for devices that are developed by manufacturers who choose not to implement the standard, or for legacy devices that predate the standard.

Follow-on work

We agreed that the follow-on work to the MAUT analysis was to obtain a number of these devices and implement prototype interfaces. This would serve to confirm the results of the MAUT analysis. The next steps in our study were to integrate these devices with the Kinnexxus Elder Social Support Platform and to test the feasibility of connecting and using these devices.

Phase II Plans

During phase II, we plan to revisit the MAUT analysis and consider changes in scores based on progress in standardization as well as different needs as we move toward commercialization. In particular, the ease of installation will become a more important consideration.

7B. Overall System Design

Figure 1 depicts the final overall design of the sensor-enabled system. The shaded components (Home Health Device, HHD, and its Physical Interface) are the types of physical components which have been added to the existing Kinnexxus Elder Social Support Platform. Additional enhancements have been made in the existing Support Platform software to:

- Control the HHD, capture its measurement and present that measurement to the Elder (Elder UI, Touch Screen Kiosk and HHD Gateway - section 7C below).
- Present the time history of HHD measurements to the Elder (Elder UI).
- Store the time history of HHD measurements in the central data repository (System Server: Persistent Data Store). This required an extension of the existing Platform database schema.
- Present the time history of HHD measurements to members of the Elder Support Network (Caregiver (CG) UI and Professional (Prof) UI).

The locations of these software enhancements are marked with small filled triangles (▲).

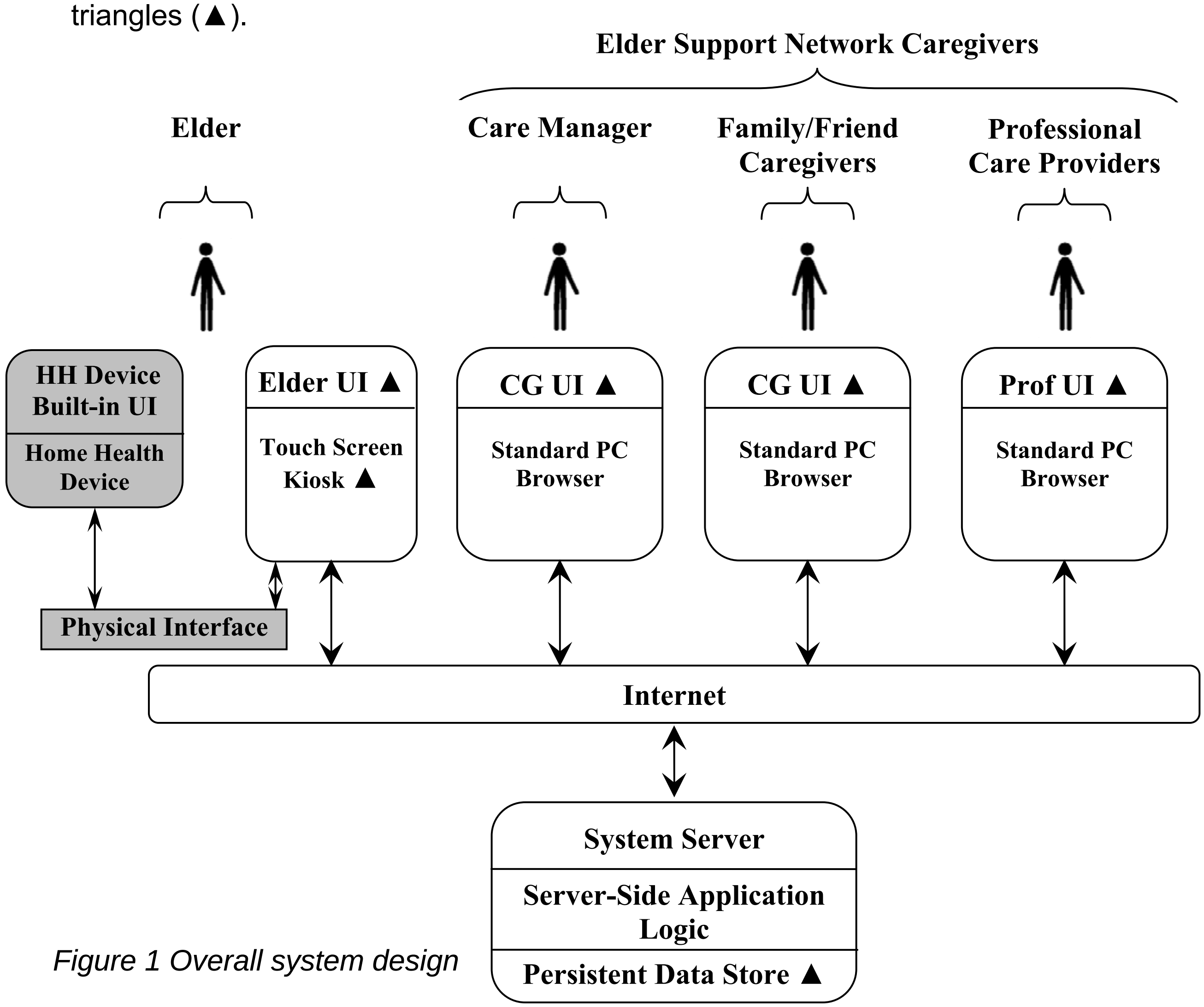

Figure 1 Overall system design

7C. Measurement Capture Sub-System

We developed a software program, the "HHD gateway", to interface with the home health care devices for the purpose of capturing measurements taken by the devices and passing them to the kiosk software system. The gateway executes in a process of its own and includes a collection of "device managers" that are specific to each of the eight models of health care device supported by the system. The gateway reads a configuration file that defines which devices are used in each use case. The configuration data also includes information necessary to establish communication with each device (e.g., serial port identifier, Bluetooth address, etc.) and any device-specific preferences (e.g., on-device display options, alarm sound levels, etc.).

Figure 2 illustrates the relationship between the various software and hardware components involved in measurement capture and local kiosk control and display. For historical reasons and ease of development, the HHD gateway was implemented using a programming system (Java) different from the kiosk software system (Adobe Flex). Each system runs in a separate host operating system process. Therefore, for simplicity of demonstrating feasibility, a file system-based interface was used between the two systems (Kiosk/Gateway Interface Files). The two systems, each running in its own process, continuously poll for changes in the interface files. A productized system would likely replace this with a faster form of interprocess communication or directly incorporate gateway functionality within the kiosk software system. The existing kiosk Manual Measurement Entry UI was retained as a separate interface. A productized system would integrate the Manual and Automatic Entry UIs.

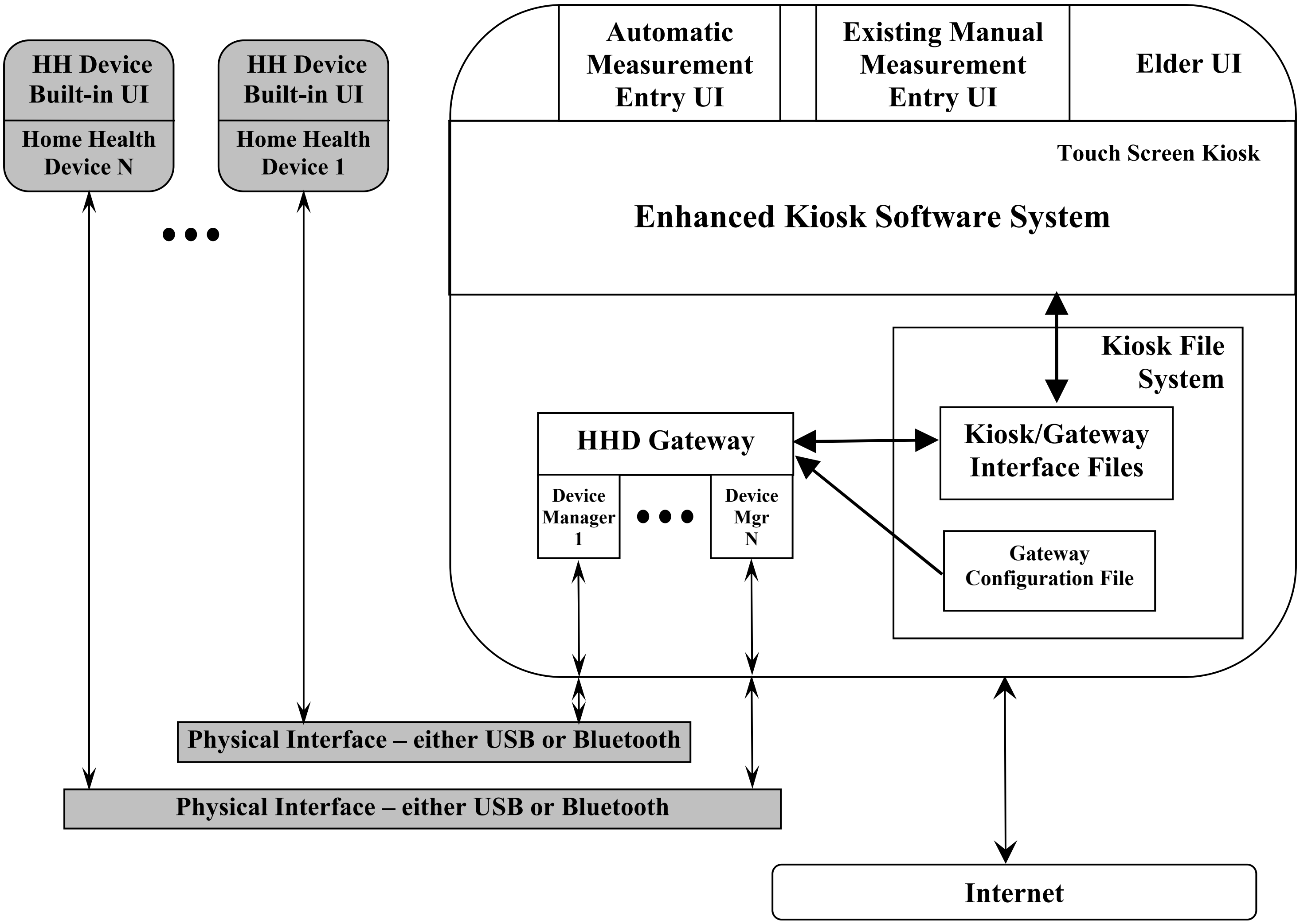

Figure 2 Measurement capture sub-system design

The gateway interacts with the home health devices in a manner appropriate for each device. Regardless of whether a device communicates with the kiosk via a wired or wireless connection, all of the devices operate using a client/server communication model. The communication roles are specific to each device; some devices act as clients, others as servers, and some devices alternate between the two roles. (This inconsistency demonstrates the lack of adequate device interface standards.)

The devices that communicate as clients are used by the older adult to take a measurement. After the measurement is taken by the device, it is transmitted to the kiosk hosting the gateway. The gateway must be running so that the device managers will be listening for any incoming measurements. The device manager inspects the incoming measurements for transmission errors and completes the device-specific communication protocol. Finally, the measurement is passed to the kiosk system software via the kiosk/gateway interface files for further processing.

The devices that communicate as servers are interrogated as requested by the kiosk. Upon receiving a measurement request from the kiosk via the kiosk/gateway interface files, the appropriate device manager initiates a communication session with the health care device and requests a measurement. Depending on the device involved, this may result in a new measurement being taken or a request to transmit one or more previously collected measurements stored in the device's internal electronic memory. The gateway checks measurements for transmission errors before passing them along to the kiosk for further processing.

The kiosk software will display measurements via the Automatic Measurement Entry UI to allow the user to validate and either accept or reject the measurement. Accepted measurements will be passed to the Kinnexxus system server for long term storage and management and, most importantly, for access by other members of the elder support network.

7D. Intermediate Prototypes: Collecting Measurements from Multiple Devices

After developing the descriptive framework of attributes and weights according to multi-attribute utility theory [Sensor-Enabled Technical Report #1], we began work on the experimental validation of the attributes and calibration of the weights by integrating and evaluating a representative set of sensors into the Kinnexxus platform using the measurement capture subsystem architecture outlined in Figure 2. This section describes the work that was done to collect measurements from multiple devices.

Selection of Sensors

The first home health devices to be integrated were selected based on a number of factors. Primary among those factors are consumer availability, integratibility, ease of use and affordability. The initial devices are:

- A&D Medical's UA-767PC blood pressure monitor, which transmits measurements over a wired RS-232C connection. The blood pressure measurement includes systolic and diastolic pressures along with the pulse rate. [A&D]
- Tanita's HD-351BT weight scale, which transmits measurements wirelessly over a Bluetooth connection. The measurement consists of the older adult's weight. [Tanita]
- Bayer's Breeze2 blood glucose meter, which transmits measurements over a wired RS-232C connection. The blood glucose measurement includes blood glucose concentration. [Bayer]
- Nonin's Onyx II 9560BT fingertip pulse oximeter, which transmits measurements wirelessly over a Bluetooth connection. The device is capable of performing spot check measurements of the older adult's blood oxygen. The measurement includes the percent saturation peripheral oxygen (%SpO_2) and the pulse rate. [Nonin]

For all measurements, we capture the date and time when the measurement was taken. The date and time are recorded by the device, in those cases where the device supports such a capability. When that is not feasible, as in the case of the weight scale, the HHD gateway appends the date and time to the sensor data when the measurement is transmitted from the device to the kiosk software system.

Sensors

We successfully brought up each of the four sensors (blood pressure monitor, weight scale, blood glucose meter, and pulse oximeter) that were selected through the multi-attribute utility theory process. All four types of these sensors are operational at this time.

Each image below shows one of devices with one of our initial older adult test subjects using the device. In addition, there are photos of how measurements are displayed on the Elder Kiosk and through the Caregiver Interface. In the initial Kinnexxus Platform, measurement values were acquired by the older adult manually “touching” in the digits of the measurement using the touch screen of the Elder Kiosk. We developed new software to capture these measurements via sensor interfaces. In preparation for this further integration we defined a text file-based protocol for measurement instrument driver software to communicate with the Elder Kiosk [JSON] via the Kiosk/Gateway Interface Files in Figure 2 above.

The Elder Kiosk is a lightweight, easy-to-use touch screen display that enables older adults to communicate with their family and informal caregivers and their professional care providers, including home care aides and home care agency management.

The Caregiver Interface (browser-based) allows remote family and informal caregivers to monitor the results from their older adults’ health care measurements, to track trends in the data and to organize the results in a way that facilitates logical interpretation.

Blood Pressure Monitor

Figure 3 shows the Elder Kiosk with a touch screen reminder alerting the older adult to take his blood pressure at a certain time of day. Also shown in Figure 3 is the family caregiver interface on a laptop in the center background, through which a caregiver can see the results of the blood pressure measurement soon after the older adult’s measurement is taken (assuming that the older adult has given permission to share his measurements).

Figure 3 A&D Medical wired blood pressure monitor, Caregiver interface, & Elder Kiosk

Figure 4 shows the Caregiver Interface with a graph displaying the older adult's blood pressure readings over the last few days. These measurements are automatically shared with the caregiver through the Kinnexxus server.

Figure 4 Caregiver Interface with graph of historical blood pressure data

Weight Scale

Figure 5 shows an older adult weighing himself with the wireless Tanita HD-351BT weight scale

Figure 5 Weight scale with wireless Bluetooth communication

Blood Glucose Meter

Figure 6 shows an older adult getting a reminder and taking her blood glucose measurement with the Bayer instrument. The Caregiver Interface is shown in the background as well

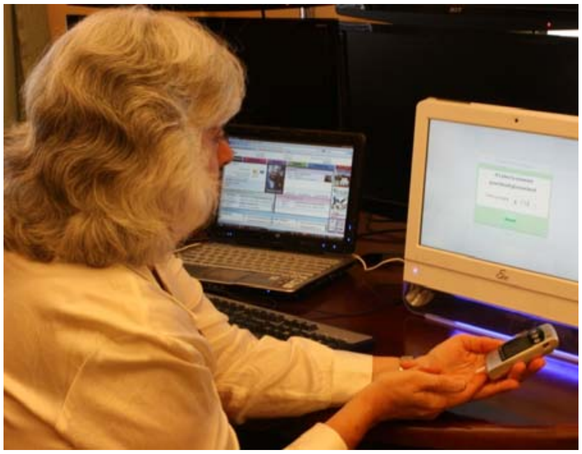

Figure 6 Bayer wired blood glucose meter

Pulse Oximeter

Figure 7 shows an older adult using the wireless Bluetooth Nonin pulse oximeter. In this situation, the reading is transmitted to the kiosk, where it is formatted for storage and display. One important finding of this study is the unreliability of transmission of data via Bluetooth. In many situations, the device failed to connect successfully to the kiosk and data were lost. Also, with this particular device, it is essential to “pair” the kiosk with the particular device. In experiments in which we moved the pulse oximeter between kiosks, the pairing process had to be manually executed. This is a system administration task that we could not expect older adults (or their caregivers) to undertake reliably.

Figure 7 Wireless Nonin pulse oximeter

Integration with Kinnexxus Platform to form final prototype

The next steps we followed to further integrate the home health devices with the Kinnexxus platform included the following:

1) We controlled data acquisition of the measurements directly through the Kinnexxus Elder Kiosk user interface.
2) We extended the Kinnexxus data schema to be able to store the measurement values from these particular devices on the Kinnexxus server.
3) We then extended the user interfaces for the older adult and caregiver in the Kinnexxus platform to display the measurement values stored in the server database.

7E. Final Prototype Development

As the first step in developing the final Phase I prototype, we selected a variety of Bluetooth (wireless) and USB (wired) home health devices (blood pressure monitor, blood glucose meter, pulse oximeter, and weight scale) to verify feasibility. We then developed an interface for each type of device, to demonstrate that the devices can be used with the platform. These distinct interfaces are essential. For example, each Bluetooth device may implement a different protocol. We observed that all devices connect appropriately with a Linux-based system. However, we also discovered that devices which operate as Bluetooth clients do not reliably connect with a Windows XP system. (We are currently discussing the possibility of moving to an Android tablet platform for Phase II, as this might be a more commercially viable option for our target market.)

On the platform side, the kiosk (the older adult's user interface) was outfitted with a temporary debugging tool in order to aid the programmer's efforts (Figure 8).

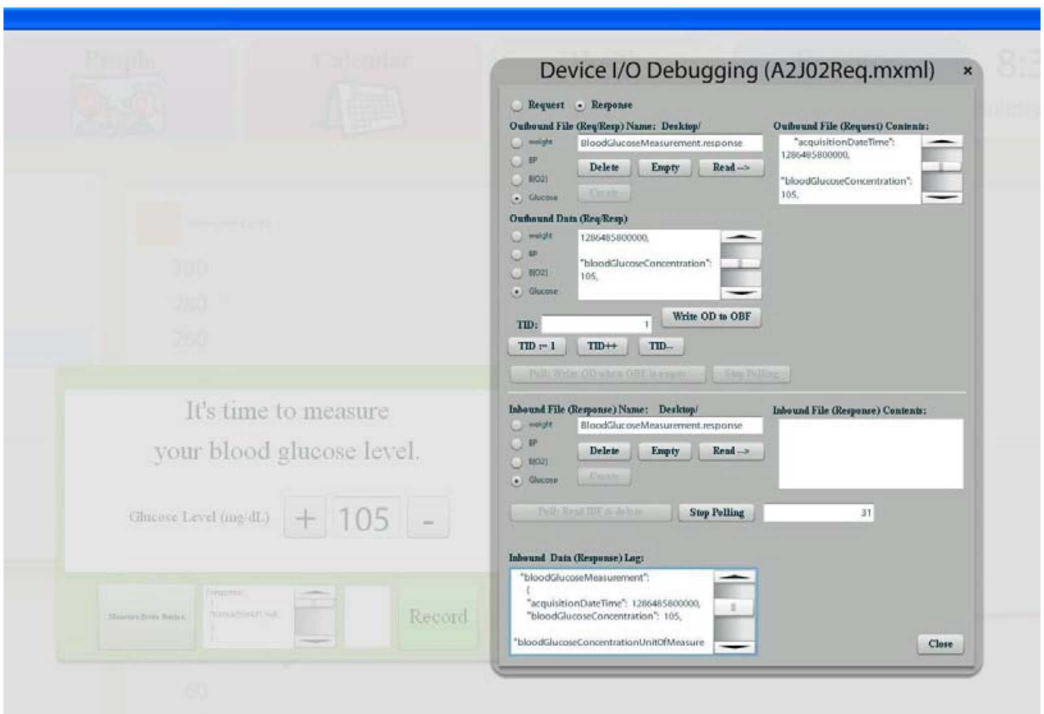

Figure 8 Kiosk temporary Device I/O debugging panel

The kiosk displays historical measurement data in a graphical format (Figure 9).

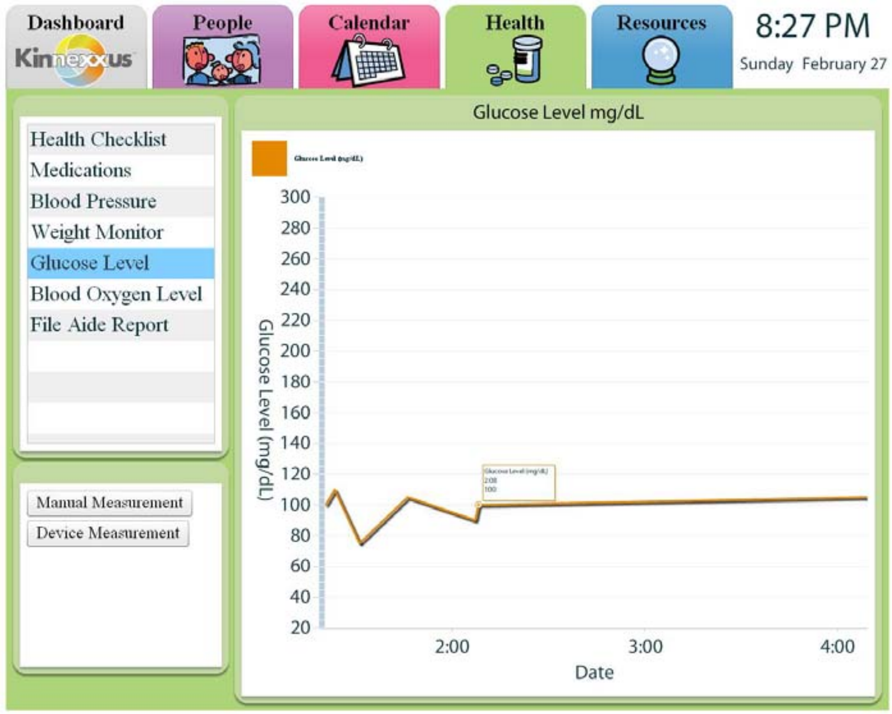

Figure 9 Kiosk blood glucose historical record

Both the family caregiver's web-based interface (Figure 10) as well as the professional care provider's web-based interface (Figure 11) also display this historical measurement data. (Note that the particular blood glucose data displayed is simulated test data constructed to show variation.) These interfaces are essential to evaluating the utility of the Sensor-Enabled Elder Social Support Platform with the target users (informal caregivers and professional care providers).

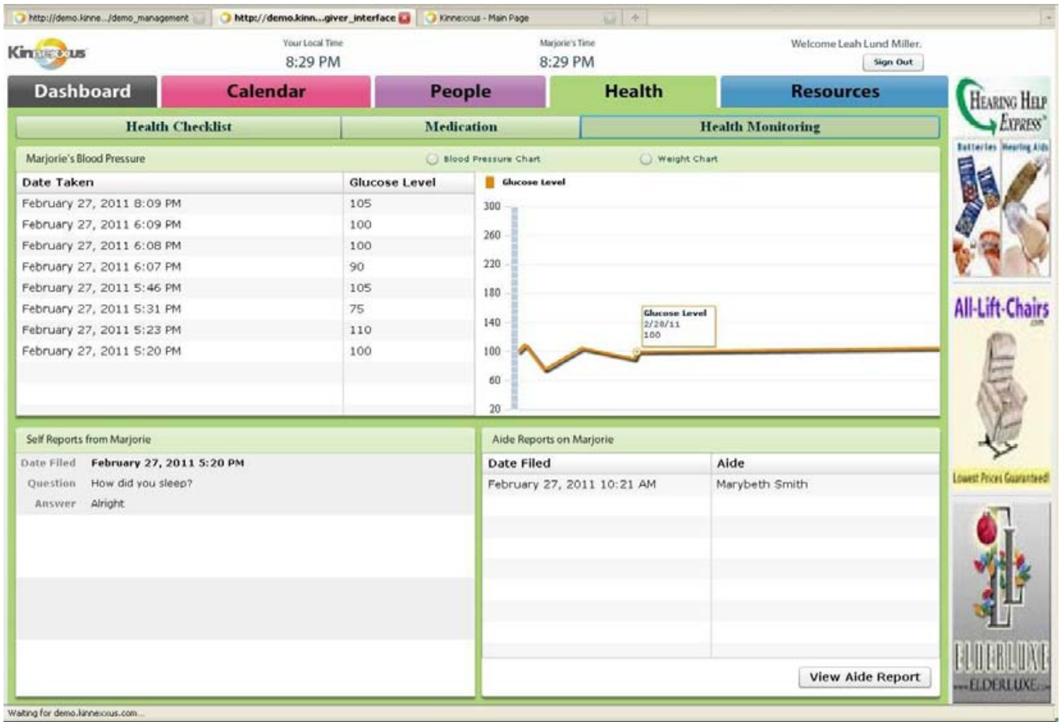

Figure 10 Family Caregiver browser blood glucose historical record

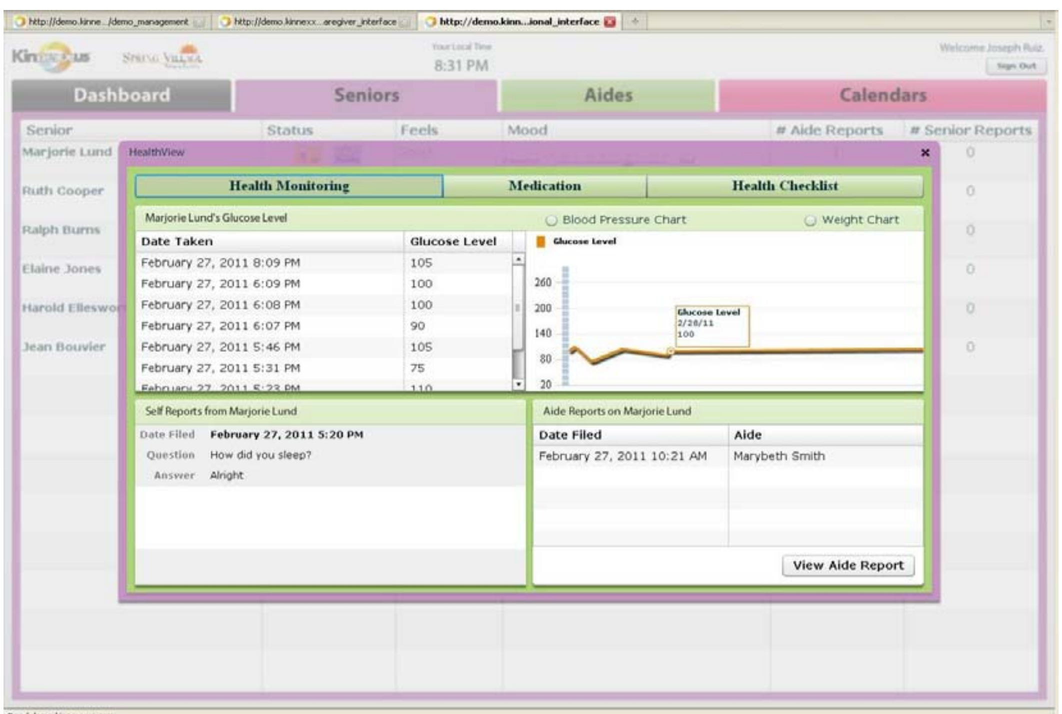

Figure 11 Professional Caregiver browser blood glucose historical record

During the process of implementing an on-demand manual data entry feature, Kinnexxus discovered techniques for improving the user interface for this feature. The existing Kinnexxus platform (before it was sensor-enabled) was then improved for usability.

In the final stage in the development of the Sensor-Enabled Elder Social Support Platform prototype, we implemented the following:

1) We replaced the debugging interface on the kiosk with the usual elder kiosk user interface,
2) We extended the server-side database schema to include data from the pulse oximeter, which was a new instrument for the Kinnexxus platform, and
3) We correspondingly extended the kiosk and the caregiver interface to be able to display a graph of the pulse oximeter readings in a manner similar to the other devices. Figure 12 illustrates the time history of pulse oximeter blood oxygen and pulse rate readings on the Elder Kiosk UI. (Note that the particular pulse oximeter data displayed has been manipulated to show variation.)

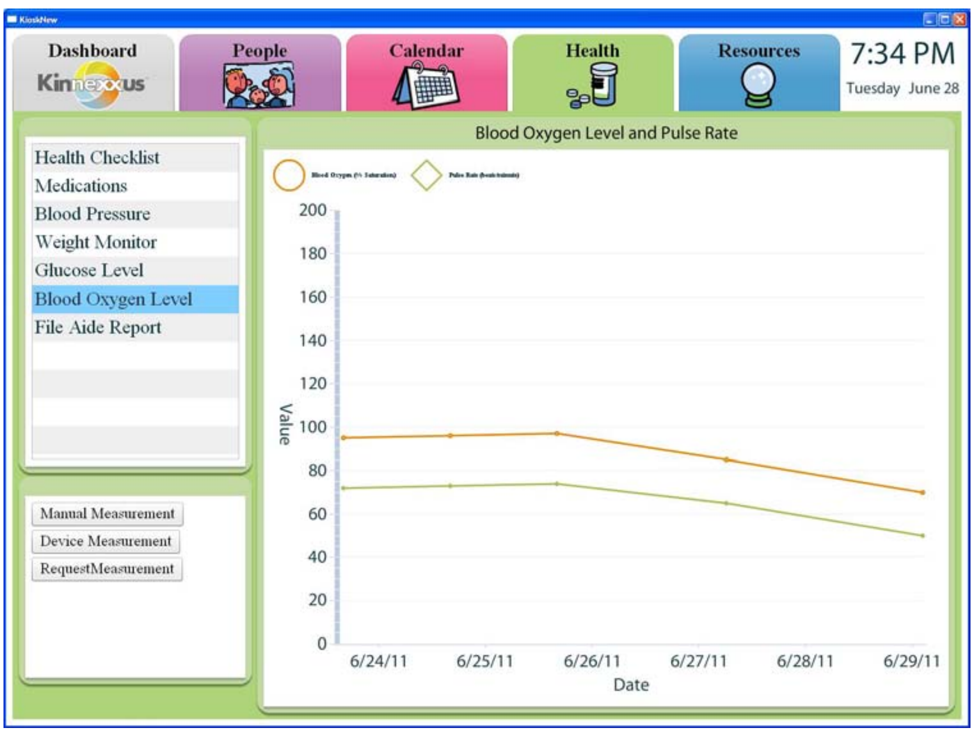

Figure 12 Elder Kiosk pulse oximeter time history

Figure 13 depicts the time history of pulse oximeter blood oxygen and pulse rate readings for the older adult as seen by the caregiver through their browser-based user interface.

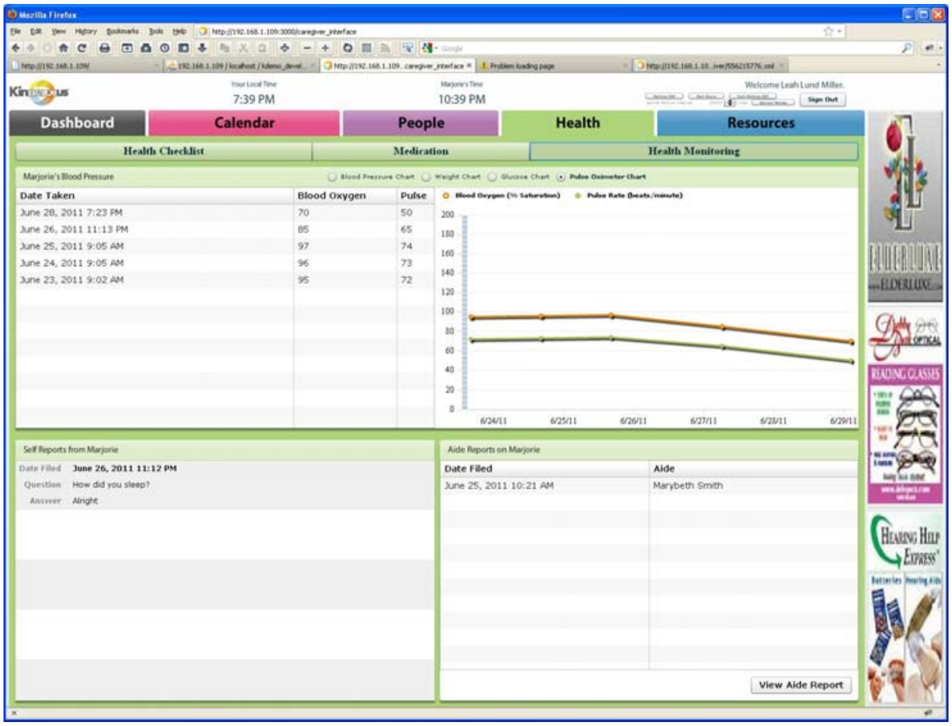

Figure 13 Caregiver UI showing time pulse oximeter time history for older adult

8. Describe the current status of the product (e.g., under development, commercialized, in use, discontinued).

The current status of the Sensor-Enabled Elder Social Support Platform is that Phase I feasibility has been demonstrated through:

1) the completion of the development and analysis of the MAUT for the characterization and selection of sensor-enabled home health devices,
2) the development and integration of an initial prototype of the Sensor-Enabled Elder Social Support Platform, integrating the capture of data from the sensor-enabled home health devices into the Kinnexxus Elder Social Support Platform so that data can be recorded, charted, and shared with family caregivers and professional care providers, and
3) conducting a formative evaluation of the initial prototype of the Sensor-Enabled Elder Social Support Platform, using personas and scenarios we had created at the start of the project, as part of the human-centered design process.

Formative evaluation is the evaluation of a working prototype or, in some cases, a rough draft of a system [Tessmer 1996]. The objective of the formative evaluation stage is for participants to use the prototype system and provide feedback in order to improve the usability of the system [Tessmer 1996]. Figure 14 illustrates the iterative process of feedback and revisions to the prototype during each step of the formative evaluation and improvement process [Tessmer 1993].

Feedback questionnaires pose a number of questions about the participant's user experience as part of the formative evaluation process. The questions raised during the formative evaluation stage are designed to improve the system by identifying problems and weaknesses as well as features that positively contribute to the user's experience. Tessmer [Tessmer 1993] states that there are four classically recognized types of formative evaluation: expert review, one-to-one, small group, and field test, and these steps are conducted through an iterative process. Figure 15 illustrates the general sequence of steps in the formative evaluation process, with iterative loops of evaluation and improvement after receiving feedback from the evaluators.

Before we undertook the formative evaluation process, we designed a feedback questionnaire, which we have included at the end of this section. We used this questionnaire to obtain direct user feedback on how to improve the initial prototype.

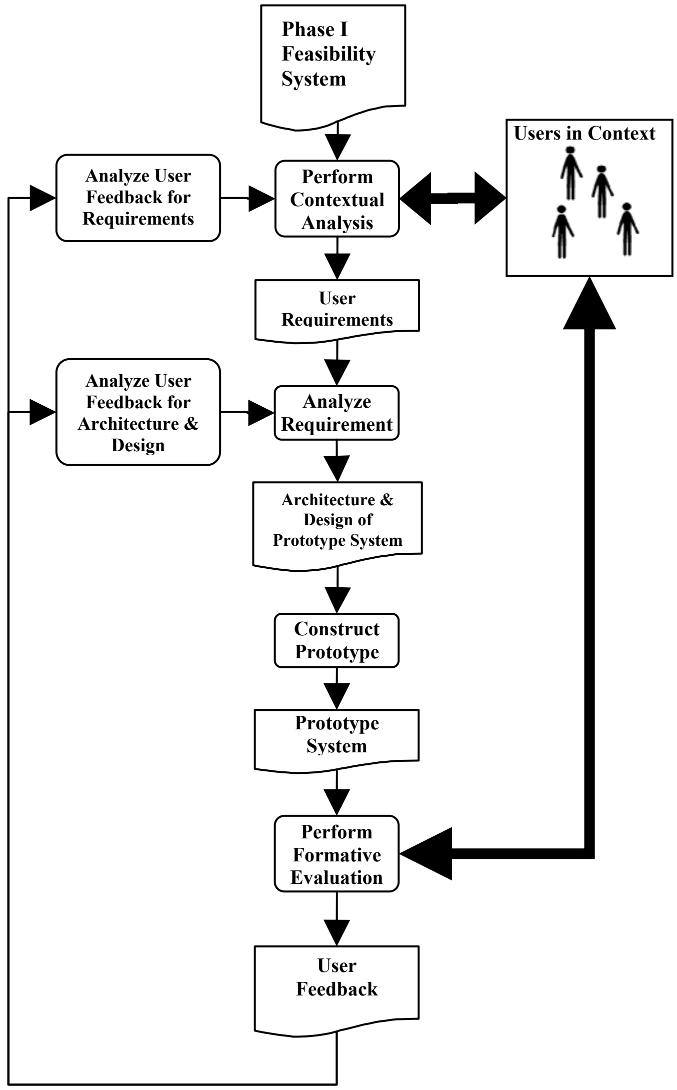

Figure 14 Cyclic prototype evaluation & improvement process

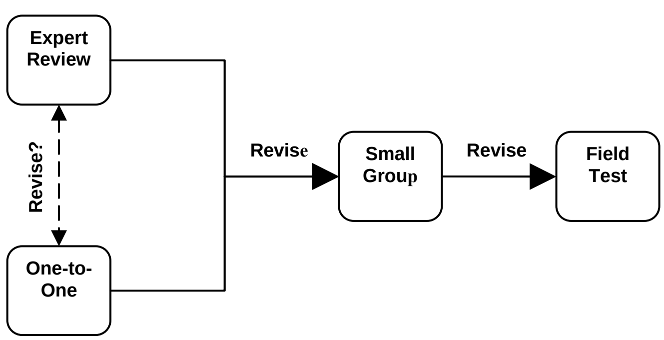

Figure 15 General sequence of formative evaluation types

Another useful tool for evaluation is Kirkpatrick's 4-level assessment model [Kirkpatrick 2009]. This assessment model started as an evaluation tool for educational programs and then was extended to evaluate multimedia and hypermedia systems. The four levels described by Kirkpatrick are as follows:

> Level 1: Reaction - To what degree participants react favorably to the system. This is done during the formative evaluation stage, primarily through feedback questionnaires and also now through "instrumented" prototypes, which capture data on the user's use of the system. A formative evaluation is conducted on level 1 of the assessment model.
>
> Level 2: Learning - To what degree participants acquire the intended knowledge, skills, attitudes, confidence, and commitment based on their use of the system. On this level, evaluation is conducted to see if the user is learning something from his/her use of the system.
>
> Level 3: Behavior - To what degree participants apply what they learned during their use of the system in their daily lives. In this stage, evaluation is done to see if there has been a change in the user's behavior.
>
> Level 4: Results - To what degree targeted outcomes occur as a result of the participant's use of the system and subsequent reinforcement. This is done through a summative evaluation, with a larger group of participants, to see how their use of the system has impacted these individuals and their support networks over time.

This model is an accepted model in evaluation research. Subsequent research in evaluation has led to models which add another level of assessment, or, in some cases, expand the application of each of the levels. Some evaluation researchers have added a 5th level for societal results [Kaufman 1996], viewing the 4th level as results for an individual or a small group, e.g. the older adult's support network. During the Phase I feasibility project, we focused on Level 1: Reaction, the level on which a formative evaluation is conducted. Collecting this feedback is the first step in gaining user feedback to improve the prototype, in ways that lead to successful commercialization and market acceptance.

At the beginning of the Phase I project, we developed personas and scenarios to guide the human-centered design and development of the Sensor-Enabled Elder Social Support Platform. To conduct the formative evaluation, we walked through three of the scenarios we had developed: scenario #3, scenario #4, and scenario #5. We assessed a demonstration of the use of the Sensor-Enabled Elder Social Support Platform, with a kiosk for the older adult and laptops for the family caregiver and the professional care provider. Each scenario provided feedback on ways to improve the prototype. Each scenario is described below and is followed by the observations we made and issues that arose during the formative evaluation process.

Scenario #3

This scenario includes quite a few capabilities that have not been integrated with the sensor-enabled platform. Therefore, we have identified two types of requirements, ones that should be met in Phase I and the others that should be met in Phase II.

Marjorie wakes up at 7 AM and gets out of bed. She receives an automated reminder to take her weight and blood pressure. Marjorie knows that if she does not take her blood pressure, she will get another reminder and a notice will go to her son Fred, so she immediately complies with the reminder because she does not want to upset her son. Once Marjorie heads to the kitchen, she receives another reminder to take her medications. She really doesn't want to take her Amoxicillin because she's feeling much better, but she knows that the system tracks her medication consumption and it has explained to her the importance of completing the course of antibiotics this time so that she doesn't develop a resistant strain of urinary tract infection. So, she takes her Amoxicillin and notes this with the system.

All of Marjorie's data are securely available to Joseph Ruiz, Leah, Fred, and Marybeth. Unfortunately, Marjorie's blood pressure has been trending upward. Fred has happily taken on responsibility for monitoring his mother's vital signs, so he calls his mother to discuss her condition. The Kinnexxus system displays relevant information: Mom has been preparing her own meals, maintaining a low-sodium diet. But she has not been taking her daily 30-minute walk. To be sure that his mother is entering the necessary information accurately, Fred asks her what she ate for lunch. This is confirmed by the Kinnexxus display. Because the Kinnexxus system reports that Marjorie is not taking her walk, Fred reminds her that she could be walking with a group of older adults in the neighborhood. Marjorie still needs this encouragement. She enjoys the group walks when she goes, but it's easier to sit at home. This is a long process of developing new habits with new friends.

Based on the rising blood pressure information that is clearly indicated on the Kinnexxus display, Fred and Marjorie agree that it might be a good time to call Marjorie's cardiologist. Her weight has increased by 5 pounds in the past three days and her blood pressure is at 150/95. Fred decides to ask caregiver Marybeth to take Marjorie to the cardiologist, taking with them a printout of the complete vital signs history so that the cardiologist can determine a prudent course of action. The data clearly show that Marjorie's weight gain is sudden and that her blood pressure has been increasing gradually.

Because she is already at Marjorie's house, Marybeth calls immediately to make the appointment with the cardiologist, to be seen at the end of the day. She puts the appointment in the system and Marjorie will get a reminder 30 minutes before it's time to leave. (Marjorie is going to run errands and come back to pick up Marjorie for the appointment.)

At the cardiologist's office, the physician is delighted to review the vital signs data, because it provides rich, succinct information about the trends in Marjorie's condition. Marjorie is pleased, because she knows that the reminders from her system have really benefited her. She's relieved that her doctor knows her whole condition and can prescribe treatment more effectively. The doctor makes an adjustment to Marjorie's medications, which he enters into the physician's Kinnexxus interface, and asks her to resume daily 30-minute walks. Meanwhile, he verifies her vital signs and makes notes in her electronic medical record.
Based on scenario #3, we identified the following features as satisfying the Phase I requirements of the scenario:

- Automated reminders to take weight, blood pressure, blood glucose, and specific medications prescribed for that older adult. These reminders come up on the older adult's kiosk at scheduled times according to his/her physician's orders.
- Recording of vital sign measurements for each older adult.
- Tracking of medication consumption for each older adult
- There are some features implemented for secure availability to caregivers:
    - Caregivers have UID and password
    - Caregivers are linked to the older adults
- All health data are available or not, based on the access privileges of each individual caregiver.
- In the data history, blood pressure over time is displayed to the older adult

Additional functionality we feel may be useful in Phase II to commercialize the product would include:

- Improved presentation of medication consumption for users
- Explanations and tutorials to guide users
- Relevant information determined by context
- The ability for the older adult to update her calendar and enter her own appointments
- Appropriate user interface for mobile devices
- Support for multiple kiosks
- It would be helpful to enhance access control to allow for fine-grained access to data, depending on the needs and roles of each member of the older adult's circle of care.
- Data needs to be encrypted on the server

We have some questions that need further research in order to determine the best approach for commercialization of the product:

- Looking at the presentation of the blood pressure data over time, we felt that we should further research the choice of line colors and use a larger font for legends
- We also felt that in phase II, there should be data printouts from care-givers' web interface
    - However, we raised a question about whether older adults should have printers to maintain. While we recognize that older adults like to read printed information, we are concerned about the added cost of a printer and the added maintenance issue.
- We also raised the question of how best to get physicians and other health care professionals in the loop. Specifically:
    - Are data displayed as they expect?
    - Do they require a special interface different from that of other professional care providers?

Scenario #4

This scenario focuses on the Kinnexxus platform and what it needs to handle in communications among stakeholders.

It's Friday morning. Marybeth has gone into the office and Joseph has shared the latest data on Marjorie. Joseph reminds Marybeth to take Marjorie for an easy 30-minute walk before lunch. Joseph has verified that Marjorie is entering her data correctly. The various home health devices that Marjorie uses automatically record readings. But, Marjorie provides some manual start/stop control for some of the devices. Joseph asks Marybeth to have Marjorie run the online video instructions, just to be sure that Marjorie takes her measurements correctly (e.g., she sits up with her feet touching the floor and her arm at rest when taking blood pressure measurements).

Marybeth has a few responsibilities that are specific to the use of the Kinnexxus system. When she arrives at Marjorie's home, she uses her own kiosk interface to enter basic information (e.g., time of arrival, observations of Marjorie's well-being). Before leaving Marjorie's home, Marybeth must enter information based on a Homecare Inc. caregiver's form. This interface has a separate login, to ensure the privacy of Marybeth's information.

A few days after the visit with the cardiologist, Marjorie's daughter Leah wants to check on her mother's progress. Immediately, she looks over the data and sees that Marjorie has been measuring her weight and blood pressure three times a day. Her weight has already dropped 3 pounds. Her blood pressure is down to

130/80. And her blood oximeter reading is 97%. She has been walking with the neighborhood walking group each morning. (This seems to be reducing the edema in her lower legs.) Leah no longer feels alone and talks with her brother weekly to discuss their mother's well-being.

Using scenario #4, we determined that the following features were useful in satisfying the requirements of the scenario in Phase I:

- Each of the home health devices recorded the data that was captured.
- Each caregiver has a private passcode to protect privacy.
- An older adult can record measurements using each of the home health devices multiple times each day.

Areas of improvement that we noted for Phase II include the following:

- For the graphical display of history, the system only showed the data for the last three days. In the commercial product, it is important to be able to graph the data over a selectable period of time.
- Add instructions for using each of the home health devices.
- Add caregiver data entry upon arrival or departure when visiting an older adult.
- Add customized forms for various organizations (e.g., home health assistants, home management services).

Scenario #5

Philippe has just had lunch. He's prepared one of his favorites: tuna salad on multigrain toast with lettuce and tomato. He has a banana and wonders what's so important about potassium, but he eats a banana every day because his doctor has encouraged him to have fresh fruit. He gets a kick out of preparing something this healthy for himself and looks forward to telling his grandson, Jamal, about the repast. Until recently, Philippe suffered quietly with a mild form of depression. He was mostly just unhappy with his health situation. His various health problems seemed overwhelming and he really didn't understand his uncontrolled diabetes and obesity. He'd always carried his weight well. At 6 ft. tall, no one would guess that he weighed 258 pounds. Still, his doctor made it clear that this was far too much weight to be carrying around; it was hard on Philippe's heart and aggravated his diabetes.

About a month ago, Philippe's doctor had a serious conversation with him about getting his conditions under control since he had another gangrenous toe, which would require surgical removal. After surgery as part of his follow-up care, Philippe was assigned nurse who checks to make sure his foot is healing properly and a caregiver who takes him for a walk. The aide, Marybeth Smith, visits Philippe twice/week. Marybeth also told Philippe and his daughter, Laclare, about a new system from Kinnexxus that would let Philippe's family provide essential support in tracking and managing wellness. Philippe talked it over with Laclare, who was enthusiastic about finding a way to support her father's efforts. That Thursday night, Philippe's grandson Jamal called. By now, Philippe was feeling hopeful about the Kinnexxus system and its ability to facilitate the family's collaborative efforts to ensure Philippe's well-being. Jamal could hear a difference in his grandfather's voice and immediately agreed to participate. That Saturday was the family's monthly gathering. Everyone gathered around the computer at Jamal's house to see the options for the Kinnexxus system. They could all participate in supporting "Gramps" in his efforts to stay healthy and to live independently with the Kinnexxus system. The system would clearly pay for itself in a short amount of time if it prevented a few doctor's visits or extended the time that Philippe could continue to live on his own.

So, for the past two weeks, the family has been learning how to use the intuitive interfaces for the Kinnexxus system. As part of his daily morning routine, Philippe weighs himself and takes his blood pressure first thing in the morning, before breakfast. He tests his blood glucose level three to four times a day. The measurements are automatically recorded on the kiosk and maintained on a remote server. Philippe can see the historical data for his blood glucose and is amazed at how quickly he's been able to get more consistent, healthy readings. Of course, he knows that part of the success is due to the recent heart-to-heart talk that Laclare had with her father about giving up Snicker's bars and Coke. Because Laclare was now tracking her father's caloric intake, especially his simple carbohydrate intake, Philippe felt there was an incentive to improve his diet. Laclare had taken to sending her father special messages, congratulating him when he had eaten a healthy meal or had gone a whole day eating only foods allowed on his diet. Grandson Jamal still preferred to call his grandfather twice a week, but now he called with knowledge of his grandfather's adherence to diet, his vital sign readings, and his overall wellness. With the simple-to-use interface, Philippe now received short messages from his busy great-granddaughters, Sarah and Rebecca, and Jamal and Laclare kept Philippe's online photo gallery filled with the latest snapshots of his beloved granddaughters.

That evening, Jamal calls his Gramps. He goes through the usual updates about his daughters' activities, and then sounds a more serious note. "Gramps," he says, "you know that we're all so pleased that you decided to get the Kinnexxus system so that we could better keep in touch with you. But, I'm amazed. You've already lost five pounds in two weeks! I don't know how much your weight varied before we got the Kinnexxus system, but if you can keep up with this weight loss, you are bound to get better control over your diabetes and that would be a huge relief to the whole family. What can I do to keep supporting your success?"

Philippe is caught off guard. He hadn't realized that he'd lost a total of five pounds already-- in just two weeks. He also wasn't sure why. But as he thinks about it, it becomes clear that he is eating healthier and taking in fewer calories.

He is motivated, in part, because he knows that Laclare and Jamal are cheering him on. And they would know instantly if anything was going wrong-- a high blood glucose reading, increased blood pressure (stress is the enemy of blood pressure and blood glucose), or weight increase. And all he had to do was look at a photo of his great-granddaughters and he began to look forward to healthier years-- watching them graduate from high school and begin college. He hoped that the improved diabetes condition would also give him more time before diabetic retinopathy claimed his vision! Philippe replies, "Just keep sending those snapshots of Sarah and Rebecca. And track those numbers for me. I didn't realize that I'd lost five pounds, but I can believe it. You know what I made myself for lunch today...?"

Using scenario #5, we observed that the following features fulfilled requirements set by the scenario for Phase I:

- Measurements are recorded and stored on the server
- The system includes the capability of sending and receiving messages
- There are self-report questions to assess overall wellness. These are based on querying the older adult. In addition, overall wellness is based on observations of daily living (ODLs) by various caregivers.
- Family photos can be viewed by the older adult on his/her kiosk.

Features that would be useful to add in Phase II include the following:

- In the Phase I system, photos must be entered by a caregiver. It would be useful to enhance this feature with an interface to commonly-used online photo-sharing services.
- The Phase I system supports reminders and monitoring of medication compliance and vital sign measurements. Another useful feature would be the capability to monitor caloric intake and possibly other specific food categories, such as, carbohydrate intake.

The feedback questionnaire we used for our formative evaluation is included below.

Feedback Questionnaire for the
Formative Evaluation of the
Sensor-Enabled Elder Social Support Platform

Participant's Name:

Date of Evaluation:

Age: Gender:

Rate the following with 1 being the least/worst and 5 being the most/best and 3 being a neutral rating.

Current state of health:

Level of activity:

Computer familiarity:

Please check the home health devices that you currently use:

__ Blood pressure monitor
__ Weight scale
__ Pulse oximeter
__ Blood glucose meter

After you use the Sensor-Enabled Elder Social Support Platform, please rate the following with measurements from 1 to 5 with 5 being the best (or easiest), 1 being the worst (or hardest), and 3 being a neutral rating.

1) Please rate your comfort and ease in using each of the home health devices to take your measurement.

__ Blood pressure monitor
__ Weight scale
__ Pulse oximeter
__ Blood glucose meter

2) Please rate how understandable the displayed information is at the time of acquisition for each of the home health devices.

__ Blood pressure monitor
__ Weight scale
__ Pulse oximeter
__ Blood glucose meter

3) Please rate how understandable the displayed graph of your measurement is for each of the home health devices.

__ Blood pressure monitor
    __ Systolic pressure
    __ Diastolic pressure
    __ Pulse rate
__ Weight scale
__ Pulse oximeter
    __ Pulse rate
    __ Oxygen level
__ Blood glucose meter

4) Please rate the length of time it took you to complete the measurements with all four home health devices.

Shorter than expected   About as long as I expected   Longer than expected

5) Overall, please rate your experience with the Sensor-Enabled Elder Social Support Platform, from 1 to 5, with 5 indicating a positive experience and 1 indicating a negative experience.

6) Please add any comments you would like us to know. You can add any comments or additional observations to any of the questions above. Please also add any general feedback you'd like to give us.

Thank you for your feedback, which will help us improve the prototype.

Results from administering the feedback questionnaire to four members of the team are summarized in Table 2A-2B.

Question	1	2	3	4	Average
Age	51	61	62	62	59
Gender	M	F	F	M	
Health	Healthy	4	4	4	4
Activity Level	4	1	4	1	2.5
Computer Familiarity	5	4	5	5	4.75
Current Use: Blood Pressure Monitor	No	Yes	No	No	No
Current Use: Weight Scale	Yes	Yes	Yes	Yes	Yes
Current Use: Pulse Oximeter	No	No	No	No	No
Current Use: Blood Glucose Meter	No	No	No	No	No
Comfort: Blood Pressure Monitor	5	5	3	2.5	3.875
Comfort: Weight Scale	5	5	4	4	4.5
Comfort: Pulse Oximeter	5	5	5	3	4.5
Comfort: Blood Glucose Meter	2	3	2	1	2
Understand Display: Blood Pressure Monitor	4	2	4	4	3.5
Understand Display: Weight Scale	5	2	4	4	3.75
Understand Display: Pulse Oximeter	4	2	4	4	3.5
Understand Display: Blood Glucose Meter	5	2	4	4	3.75
Understand Graph: Blood pressure monitor	4	4	3	2	3.25
Understand Graph: Weight Scale	5	5	4	3	4.25
Understand Graph: Pulse Oximeter	4	3	3	2	3

Table 2A Formative Evaluation Results

Question	1	2	3	4	Average
Understand Graph: Blood Glucose Meter	5	4	4	3	4
Length of time to complete	about as long as expected	longer than expected	longer than expected	longer than expected	longer than expected
Overall Experience		3	3	3	3
Comments	Network response time needs to be addressed. Kiosk UI should fit screen resolution of hardware. Need separate graphs for blood pressure monitor and pulse oximeter	Need separate graphs for pulse oximeter.	I don't like to poke myself to get blood. Need a separate alert from measurement. Need to modify text at time of acquisition. On graphs: Need a way to show multiple points on a day. Change light green color to something darker. Use larger symbols on the graphs. Network problems are very frustrating.	All displays (graphs) need a simple facility to allow the viewer to focus in on a desired temporal range of measurements. Also need a simple means of focusing in on the vertical scale. The chart/table of measurements will get very long when the associated device is used over a long period of time.	

Table 2B Formative Evaluation Results

9. If applicable, describe the status of FDA approval for your product, process, or service (e.g., continuing pre-IND studies, filed an IND, in Phase I (or II or III) clinical trials, applied for approval, review ongoing, approved, not approved).

Not applicable -- The Elder Social Support platform acts as a pipe, transmitting information between older adults and family members. We have been informed by an FDA consultant that this use of the platform will not require approval.

10. Describe how your company has benefited from the program and/or the technology developed (e.g., firm's growth, follow-on funding, increased technical expertise, licensing agreements, spin-off companies, public offering [include stock exchange and symbol]).

The company benefited by developing a demonstrable interface between home health devices and the Elder Social Support Platform. The integration of sensor-based home health devices can now be demonstrated to potential strategic partners. The company also benefited by being able to test the feasibility of integrating home health devices with the platform and conducting the first level of formative evaluation to determine what improvements need to be made in order to develop a commercial product. The first level of formative evaluation was conducted within the team. Now that the evaluation process has been developed and tested internally, the company is now in a position to test the commercial feasibility of the next version of the Sensor-Enabled Elder Social Support Platform.

11. List of the generic and/or commercial name of product, process, or service, if any, that resulted from STTR funding. If applicable, indicate the number of products sold.

The Phase I grant demonstrated the feasibility of integrating sensor-enabled home health devices into the Kinnexxus Elder Social Support Platform. The next step (for which we are applying for a Phase II grant) is to commercialize the Sensor-Enabled Elder Social Support Platform. We have received positive feedback on the utility and usefulness of a home-based system that allows family caregivers, professional care providers, and the older adult him/herself to monitor the older adult's vital signs along with self-reports and observations of daily living (ODLs). Integrating sensor-enabled home health devices so that data can be captured, tracked, graphed over time, and shared with members of the older adult's circle of care increases the value and usefulness of capturing such data.

12. Provide the current number of employees (total full time equivalents [FTEs]).

Two FTEs

References

[A&D] http://www.andmedical.com/and_med.nsf/html/UA-767PC .

[Bayer] http://www.simplewins.com/sections/Monitor/meters/breeze2/Overview

[Boehm 1981] *Software Engineering Economics*, Prentice-Hall, 1981.

[Fischer & Fischbeck] Fischer, G. and P. Fischbeck. *Multiattribute Preference Models: A Brief Overview*. Working Draft. Undated.

[Horney 1992] Horney, M. *Authoring hypertext: Issues and problems from experience*. Paper presented at the annual convention of the American Educational Research Association, San Francisco.

[JSON] *JSON (JavaScript Object Notation): a lightweight data-interchange format, http://www.json.org .*

[Kaufman 1996] Strategic Thinking: A Guide to Identifying and Solving Problems. Arlington, VA. & Washington, D.C. Jointly published by the American Society for Training & Development and the International Society for Performance Improvement.

[Keeney & Raiffa 1993] Keeney, R.L., and H. Raiffa. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs (2nd Edition)***,** Cambridge University Press, 1993.

[Kinnexxus 2009-2011] *Kinnexxus*, Inc., http://www.kinnexxus.com/.

[Kirkpatrick 2009] Kirkpatrick, D. The Official Site of the Kirkpatrick's Four Levels™ Evaluation Model, http://www.kirkpatrickpartners.com/.

[Nonin] http://www.nonin.com/PulseOximetry/Fingertip/Onyx9560 .

[Sensor-Enabled Technical Report #1] *Development of a Descriptive Framework of Attributes and Weights according to Multi-Attribute Utility Theory*, Technical Report #1, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, September, 2010.

[Sensor-Enabled Technical Report #2] *Collecting Measurements from Multiple Devices*, Technical Report #2, Sensor-Enabled Elder Social Support Platform, Grant Number: 1R41AG035452-01, December, 2010.

[Tanita] http://www.tanita.com/en/hd351bt .

[Tessmer 1993] Tessmer, M. *Planning and conducting formative evaluations*. London: Kogan Page Limited.

[Tessmer 1996] Formative Evaluation. In P. Kommers, S. Grabinger, & J. Dunlap (Eds.) *Hypermedia Learning Environments: Instructional Design and Integration* (pp. 187-210). Mahwah, NJ: Lawrence Erlbaum.

[Tockey 2004] Tockey, S., *Return on Software*, Addison-Wesley, 2004.