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Using Commercially available Tools for multi-faceted health assessment: Data Integration Lessons Learned

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Abstract

Health monitoring data collected from multiple available intake devices provide a rich resource to support older adult health and wellness. Though large amounts of data can be collected, there is currently a lack of understanding on integration of these various data sources using commercially available products. This article describes an inexpensive approach to integrating data from multiple sources from a recently completed pilot project that assessed older adult wellness, and demonstrates challenges and benefits in pursuing data integration using commercially available products. The data in this project were sourced from a) electronically captured participant intake surveys, and existing commercial software output for b) vital signs and c) cognitive function. All the software used for data integration in this project was freeware and was chosen because of its ease of comprehension by novice database users. The methods and results of this approach provide a model for researchers with similar data integration needs to easily replicate this effort at a low cost.

Keywords

Informatics; Health promotion; Aging

Introduction and Background

Addressing older adults' well-being across multiple dimensions of physiological, social, spiritual, and cognitive health has been recognized as important to maintaining a continuum of balanced health¹. Health monitoring data collected in an older adult living environment can provide an integrated measure of wellness². For most independent retirement communities or long term care facilities, it is not feasible to design and implement new hardware and software for such multi-faceted assessment; as such commercially available solutions can provide platforms for assessment of multiple wellness parameters. Though the collection of health data from multiple intake sources has been shown to be feasible, there is a current lack of understanding on integration of these various data sources using commercially available products^{3–5}.

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Conflict of interest statement

There is no financial interest to report.

Integrating heterogeneous data sources is challenging due to the diversity of data schemas, naming conventions, and levels of abstraction^{6,7}. Existing techniques for data integration span the breadth of biomedical informatics and have been applied towards clinical data sources, neuroscience databases, and bioinformatics and genomics databases^{7–12}. There are different data integration architectures, loosely classified into 1) data warehouse 2) database federation 3) database federation with mediated schema¹³. In a data warehouse, all data is consolidated with a generalized global schema resulting in a single database. A mapping exists from each data source to the data warehouse. In a federated database, all data are at the local source, distributed across a network. A schema maps across different sources for integration. A mediated schema is generalized across all sources, therefore the schema map does not have to be specific to the data source. Ontologies have also been proposed as important towards data integration by providing a common vocabulary to be shared across different data sources^{11,14–16}. These existing data integration techniques can often be challenging and difficult to implement. Within the scale of our project and the range of technical experiences of our intended users, a formal database integration structure does not fit within our context, though it may be appropriate towards generalization and scalability. We seek to describe considerations and lessons learned from integration of health monitoring data using freely available software.

Prior work in home health monitoring has focused on techniques of data collection, transfer, and analysis^{17–19}. Previous studies have described systems which collect information from electrocardiograms, blood pressure monitors, pulse oximeters, and health questionnaires^{17,20}. In these instances, the health monitoring data are sent wirelessly to a central enterprise server where they are analyzed and in some cases integrated into a decision support engine^{17,20,21}. Though an emphasis is placed on how to transfer information to a central location using communication protocols such as Bluetooth, ZigBee, WLAN, and GPRS, there is less focus on database integration^{19,22}. A range of databases are used to store information from home monitoring systems, including MaxDB, MySQL, or PostgreSQL^{23,24}. These database software were selected for flexibility of data storage, cost of the software, and support features for advanced database operations^{23,24}. To our knowledge, there has been limited work describing techniques for integrating health monitoring information into a common database.

One difficulty has been the lack of developed standards for medical devices within a home environment. The ISO/IEEE 11073 Personal Health Data (PHD) standards have been proposed to support interoperability of light weight personal health devices²⁵. Use of ISO/IEEE 11073 PHD has been demonstrated within home health monitoring and wireless wearable sensor systems^{20,26,27}. Though these standards promote interoperability, adoption is still limited and only recently has a formal certification program been established for compliance with the standards²⁸. Data collected from our pilot study were from a disparate range of sources and required integration into a common database. We address these issues of database integration and provide an approach that is both low cost and accessible to novice database users.

Design

This work is based on a two-month pilot study on the viability of using commercially available resources to assess and help improve wellness in older adults. The pilot study findings regarding their utility for wellness have been previously published^{2,29}. Here we report case study findings on the lessons learned from integrating health data collected using commercially available tools into a common database for analysis and visualization.

Sample and Setting

Participants were recruited through information sessions from a retirement community in Seattle, WA. Participants were restricted to older adults at least 62 years old within the community and were screened for eligibility including independence in activities of daily living, being ambulatory (with or without use of assistive devices) and the ability to provide written informed consent. A convenience sample of 27 participants between the ages of 78 and 94 years old were recruited for the study. All participants were introduced to the health monitoring system and trained in its appropriate use. The system was placed in a community room in the retirement community with secure access for study participants.

Instruments

A wellness platform consisting of three components: a telehealth kiosk (Healthanywhere, Inc, Mississauga, Ontario, Canada), a survey collection tool (WebQ, University of Washington, Seattle, WA) and cognitive assessment software system (CogniFit Ltd., Yoqneam Ilit, Israel) were installed within a common room open to study participants. The telehealth kiosk captured vital signs including heart rate, blood pressure, blood glucose level, blood oxygen, and weight through standard wireless medical devices. Questionnaires were implemented through WebQ and included the 12-item Multidimensional Scale of Perceived Social Support (MSPSS)³⁰ and the 10-item Spiritual Perspective Scale (SPS)³¹, along with questions on activities of daily living (ADL)^{32,33} and instrumental activities of daily living (IADL)³⁴. CogniFit was used to monitor cognitive ability through brain fitness software and has been shown to be reliable and valid compared to the full Cambridge Neuropsychological Test Automated Battery³⁵. A full description of the pilot study and instruments can be found in Demiris et al., (in press)² and Thompson et al. 2011²⁹. The methods used were approved by the Institutional Review Board (IRB) of the University of Washington.

Procedures

The data in this study were sourced from a) electronically captured participant baseline and exit surveys, and existing commercial software output for b) vital signs and c) cognitive function. On intake, participant height and grip strength were recorded, as well as the participants answers to activities of daily living (ADL), instrumental activities of daily living (IADL), social support (Multidimensional Scale of Perceived Social Support-MSPSS) and spirituality (Spiritual Perspective Scale-SPS) questionnaires using WebQ. These were repeated upon completion of the study, and all data points stored individually. Over an 8 week period, participants were asked to visit the study room three times a week to use the cognitive assessment software and to use the health kiosk to capture for vital sign assessment at least once during the week although subjects could use the system more frequently per individual preference²⁹.

For this study, the commercial telehealth kiosk collected information on participant weight, pulse, blood pressure, blood oxygen, and blood glucose. The choice of which of these physiological parameters was assessed and at what frequency, belonged solely to the participant. At the end of the study period, the telehealth kiosk vendor provided us with a download of all the individual data points collected from the medical devices. The cognitive function software package collected data throughout the study as performance results on different computer-based exercises. At the end of the study, the cognitive software vendor provided us with individual participant z-scores for 14 different cognitive tests at baseline and at the end of the study period that were calculated using a normative sample³⁶.

Data Storage

Of the several free SQL databases available, we chose to use SQLite as our data storage solution. First, we wanted to store the database on our dedicated research drive, where only those associated with the project could access the data. Second, we wanted a solution where non-database experts could access and use the database with very little programming or database knowledge.

SQLite has several properties that helped us achieve these goals. As a zero-configuration database, this database requires no lengthy software installation or setup, nor server process administration. The entire database is stored as a single file, making it easy to store at any location desired. Since it is self-contained and platform independent, team members using different operating systems were able to use the database without any workflow interference.

Finally, to provide the non-database experts with an intuitive way to use the database, we used the free Firefox SQLite Manager add-on, a graphical user interface (GUI) for the database. Both Firefox and the SQLite Manager add-on are point and click installations.

Data Preprocessing and Import

Prior to data integration, data integrity checks occurred during the data input stage as part of the vendor software. For example, values out of a clinically acceptable range for blood pressure would result in a prompt requesting that the subject rest for 5 minutes and then recheck blood pressure. In addition, any value out of range would send an immediate electronic alert to the research nurse for further assessment. Further data integrity checks for questionnaires included the use of format-specific inputs for answers (e.g., specifying number of characters and type of entry) and the ability to display an error message to enable correction of any improperly formatted entry prior to submission. In addition, the research team also reviewed data sets to ensure data validity. There were no challenges related to data cleaning and instead, this work focuses on integration of various data sources.

Although data can be imported into SQLite using standard SQL techniques, the graphical user interface (GUI) allows a novice database user to import data from CSV files. As the data collected electronically during participant intake into the study were already kept in flat Excel spreadsheets (column labels in the top rows, with each individual given a separate row), converting these to CSV was relatively simple, with the exception of compressing multiple label rows into one.

More complicated was the conversion of participant data from the two commercial systems. In each of these cases, the data were provided to us in a single Excel file, subdivided into worksheets. The vital sign data received from the company were separated into worksheets corresponding to a single variable assessed (ex. blood glucose, blood oxygen level, pulse systolic blood pressure, weight, etc.), where each row in a specific vital sign worksheet corresponded to a participant sample. Each worksheet had a category labels in the top most row. For further processing, we manually divided the worksheets into separate CSV files.

In the case of the cognitive function data, each participant was given a separate worksheet. Within a worksheet, category labels were given in the first column, and the calibrated improvement scores were given in rows in the second column. Note that this layout was a 90-degree rotation from what was provided in any of the other data formats, and that participant data were separated. As database storage is row-based, all data (and labels) per participant must first be rotated and then all participant data must be collected in one single file. To do this, we manually divided the worksheets into separate CSV files. Then we wrote and used a customized Perl script to read each of these CSV files, and write out the

participant data into a single composite file, where each row corresponded to a single participant with corresponding labels in the top row.

At this point, all the CSV files were in the appropriate format (1 label row at top of file, subject data entered in rows below) and we could import them into the database through the Firefox SQLite Manager. Briefly, once the Firefox SQLite Manager is opened, the user is able to browse and select the CSV file(s) to be imported. Once the preliminary read test is satisfied, the user marks the primary key for the table, selecting the appropriate checkboxes to complete the data import.

Discussion

The data integration efforts in our pilot study demonstrated that integration from multiple data sources is feasible allowing system designers to rely on commercially available solutions for parts or all of their data collection needs. However, such integration is not without challenges. Our work highlighted the use of freeware and novice-friendly technologies to solve these challenges, and discussed best practices for similar data integration needs. Though alternatives exist for data integration, the method currently described requires limited knowledge of database systems, enough to set up the database for storage. Importing the data was then facilitated by freely available software. In addition, the robustness of a database management system such as SQLite allows for compactness of data storage and flexibility in queries that balances initial learning curves of using the database system.

The single file that is used for the entire SQLite database worked well for our project, where our preliminary study contained a total of 26 individuals with a maximum of 734 data-points per individual (mean 155). When working with a larger dataset, one may be concerned whether SQLite performance would degrade. As SQLite can support terabyte-sized databases and latest performance test are on par with other common freeware database solutions (MySQL, PostgreSQL or FirebirdSQL), we believe that this not need be a concern.

There is software available to separate worksheets, the best-known being Excel Worksheet Separator, but it is expensive and works on only Excel 2000–2007 files. In this project, with two files (one with 9 worksheets and the other with 21 worksheets) it was possible to separate them into 30 individual CSV files without taking away from the work time of any one individual participating in the project. With larger projects this worksheet-separation step may become prohibitive, and recommend that if commercial data sources are to be used, that final data format be agreed upon early.

The programming skills required to write the script for reformatting the commercial cognitive functioning data are covered in most initial computer science courses and does not, therefore, require extensive expertise or training. It should be noted that with 26 subjects, the data in the multi-worksheet Excel file could be manually transcribed into a single file, but with increasing numbers of participants, the person-hours to do so would become prohibitively high. Additionally, whenever manual data transcription is used, the error rate is likely to increase requiring further person-hours to be devoted to audits. Therefore, although writing and testing a text manipulation script can take some time, in the end it is a more efficient use of human resources in a project.

With all the data already preformatted into CSV files, the information could not only be integrated into a database, but also into one large spreadsheet for statistical analysis. To support the research practices of all the team members, we chose to both setup a database and use a Perl script to integrate the CSV files directly into one large spreadsheet. It should be noted that the flat spreadsheet can be extracted from the database using SQL commands,

and we recommend that data input or corrections should always go through the database, with large analysis files to be created on a need basis. To ensure optimal data storage, it is important for all study updates to be made directly to the database rather than to individually extracted files.

Although this approach worked well for our group, we recommend that any group working on a similar data integration approach assess the needs and resources of their group members before choosing their own freeware data storage solution.

Finally, in order to support low cost data integration from multiple sources generated by commercial entities or vendors, it is important to have established appropriate data transfer agreements with vendors to receive data sets in appropriate frequency and format. This calls for a careful consideration not only of technical implications but also security, privacy and other legal requirements that may be relevant in cases where personal health information and other identifiers may be stored in one or more databases. Prior to initiating our study, we carefully prepared data transfer agreements with each of the participating vendors and determined the necessary frequency of data transfers (although we were limited in the choice of data formats by what the vendors already supported). For the telehealth kiosk data transfer, the vendor organized two training sessions to familiarize our own research team members with the design and details of their spreadsheets and other files.

Our approach towards data integration was required to combine disparate sources of information from health technologies which were not interoperable. As standards for medical devices within home environments are more prominently addressed, the standards can promote a shift towards health systems which can better communicate with each other. This has been demonstrated for health systems which have successfully implemented standards to collect and transfer data from medical devices within home environments^{20,26,37}. The vision of an integrated health system which can communicate, collect, and transfer data from its monitoring constitutes in real time becomes more feasible as commercially available devices begin to adopt standards for interoperability. These devices can be incorporated into the health system in a plug-and-play manner, supporting the broader goal of flexibility for system design. Data integration is an important component of a successful health technology system. Nurse engagement with information technology can be difficult to facilitate due to issues related to acceptance, utilization, and integration of information^{38,39}. Nurses rely on technology in both the care of patients and the improvement of systems of care delivery and the integration of multiple data sources is essential to provide consolidated reference of information for this work. In addition, nurses are focused on the holistic care of patients. In current practice it is not enough to know a single piece of information such as blood pressure or level of pain, but rather have an integrated assessment of the patient in order to provide the best overall perspective on a patient. An integrated database allows for the consolidation of disparate sources of health information. Our future work seeks to develop visualizations of holistic wellness for older adults and healthcare providers using data from such an integrated system to monitor longitudinal trends. A complex construct such as wellness involves different aspects of health including physiological, social, spiritual, and cognitive health. The ability to assimilate data from diverse health information technology tools into a single integrated database is an important step in facilitating their use with the goal to ultimately improve patient care and clinical outcomes.

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