Personal Medical Monitoring Devices

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I INTRODUCTION

With the commoditization of consumer electronics has come a surge in the number of electronic devices available at low price points and small sizes. Devices with embedded microprocessors typically have either a digital display or several buttons or both, and are capable of basic internal calculations (sums, averages, etc.) and memory (tracking usually up to a dozen quantities).

This revolution has affected the health-care industry as well, and over the last few years it has become possible to buy low-cost digital health monitoring devices at many pharmacies and supermarkets. For those interested in tracking their health, the choice whether to buy, and if so which product to buy, can become very confusing. Further, once a choice is made, devices tend to be small and therefore potentially hard to use, since each button may have more than one function and the display may need to cram a lot of information into a small space.

This paper explores some of the current commercial personal health-care devices available in several different categories. The list of products will not be comprehensive, as new products are emerging weekly, but it is useful to discuss some of the leaders in the field and provide a starting point for further investigation.

Academic research, to the extent that it exists on the subject, will be discussed, followed by suggestions for making product decisions and future research, as well as a description of a direction for the industry as a whole to take.

Many of these devices come bundled with software, either to run on a PDA or a home PC. As these fall more into the category of personal health recordkeeping, this paper will not discuss them in detail, even though as more integrated solutions are sold, they will become an increasingly important part of the entire package.

There are many health-related devices that will also remain outside the scope of this paper. Hospital-based devices are much larger and more expensive, and are not relevant to the individual. The wide array of fitness devices (nautilus machines, weights, etc.) while aiding in personal health, are by and large not “devices” in the sense that they do not have any ability to interact with the user (memory, input, output, etc.) outside of their direct function.

Finally, there are entire sub-categories of devices tailored to special-needs groups, such as infants, the elderly, diabetics, etc. Each of these is worthy of study in its own right, and while applications may be touched upon, this paper will not handle them in detail.

II COMMERCIAL DEVICES

Overview

Walk into a pharmacy or health aisle of a local supermarket, and you will see more than a dozen electronic devices for personal health monitoring. Prices range from $10 to more than $100, but there is a remarkable amount of technology available for the money.

Omron [Omron Healthcare] is one of the leaders in this field, with a range of offerings in most of the categories described below. CVS has store-brand versions of similar products [CVS] in some of these categories, as does Eckerd [Eckerd]. The following sections contain discussions of some of the parameters involved in each kind of device, with some specific products as examples, but without doing a comprehensive market study of the relative merits of the various specific products. For this information, Epinions [Epinions] and Consumer Reports [Consumer Reports] are usually good places to start.

Pedometers / Step Counters

Pedometers and step counters serve a dual purpose. First, they measure an exercise regimen, such that if it advised a 2-mile walk every other day, the pedometer could inform the wearer when that objective had been met. Second, they allow the wearer to keep track of walking patterns during a regular day, outside of an exercise program.

In principle, a pedometer measures the distance walked, while a step-counter counts the number of steps taken. Each uses the same technology (motion of your waist rising and falling while you walk [California WIC Association], but a pedometer allows input of the stride width, which then enables a simple calculation of distance traveled. Since it takes an average stride width, the distance reported is inevitably an estimate, although devices don't seem to report a margin of error. In any case, the measurement becomes problematic if gait is a changing parameter, for example when alternating between running, jogging, and walking.

Interestingly, entire programs have sprung up around the use of pedometers, such as Creative Walking [Creative Walking] and America On The Move [America On The Move], complete with communities of other people who are pursuing the same program. Each of these tries to provide additional motivation for adhering to an active lifestyle, with a book (Creative Walking), or a public web-based tracking system (AOTM). However, even the higher-tech web-based solution does not yet include an automatic uplink from the device to the computer; the user still needs to enter the information manually into her walking history.

In addition to these organized programs, there are several [ShapeUp America] [Health Partners] [The Walking Site] programs oriented towards encouraging 10,000 steps a day (about 5 miles). A step-counter is sufficient for these programs, and they do not require keeping a logbook or any kind of online support.

Some features to look for are step counting, distance, stopwatch, clock, calories, total calories, and multi-day memory. The FitSense [HeartMonitors.com] by FitMed Inc. works differently by putting the sensor on the shoe rather than on the waist. It includes a watch that monitors heart rate, a heart strap for full cardiovascular feedback, and the ability to download the details of the workout session to a PC [HeartMonitors Pedometers].

A good comparison of some pedometers can be found at HeartMonitors.com [heartmonitors.com]. For advice on buying a pedometer, look at the walking section of About.com [About.com Walking].

Scales

Precision Weighing Balances [balances.com] sells bathroom scales by Tanita [tanita.com] with some of the following features: multiple data storage modes, guest mode, differing weight capacities (308lb, 440lb, etc.), differing resolutions (.2lbs, .5 lbs), percent body fat, and some graphical displays (see http://www.balances.com/%7Ebody-fat-scales.html for a tabular comparison of some of them).

Several scales include printers to get a hard copy of progress. Tanita also sells a Health Management Software package which claims to interface with the scales and body composition analyzers, to automate tracking.

Thermometers

Digital Thermometers come in several different forms, including oral, rectal, ear, and forehead. They are all easier to read than traditional thermometers, and don't contain mercury, which is a known health risk if the thermometer breaks.

The more expensive models promised results in less time, an especially attractive feature for those models aimed at young children or infants. On one end, the Timex AccuCurve takes 30 seconds to produce results, and at the other, Braun and Vicks each has a model that takes only one second.

Skylark Device & Systems makes a thermometer that is built into a pacifier, with memory for the last measured temperature [Skylark Device & Systems].

Heart Rate Monitors

Most heart rate monitors resemble wristwatches, and many come with features that have been on digital watches for a long time. They include a chest strap that does the actual measurement, allowing the readout device to stay on the wrist.

Reebok sells several heart rate monitors, ranging in price from $60 to $120. The highest-end model comes with a pyramid display for exercise intensity, 99-lap memory stopwatch, average heart rate, and other features. None of the monitors has the ability to interface with a PC.

Blood Pressure Monitors

Blood pressure monitors typically have a cuff that goes around a finger, the wrist, or the upper arm.

Omron makes several kinds of blood pressure monitors [Omron Blood Pressure Monitors]. Features include fast measurement, memory, a printer, and different sized cuffs. Some models have electronic inflation (automatic), and some require you to use a pump (manual).

Body-Fat Analyzers

Body-fat analysis can be used as a metric to measure progress in personal fitness programs or weight-control, and has the potential to be a better metric than absolute weight.

Accu-Measure FatTrack [Linear Software] is a measurement system that uses calipers to measure body fat, provide a fitness rating, and remember up to three personal profiles. Omron

makes a body fat analyzer that just requires the user to squeeze two handlebars, which could be more comfortable than calipers, although a side-by-side comparison of results would be important to see before making a qualitative judgment.

Pushing the Envelope
An article in the Chicago Tribune reported in December of 2000 [Environmental News Network] on a Smart Toilet manufactured by Matsushita of Japan. The toilet checks blood pressure, temperature, and blood sugar, while the user is presumably otherwise occupied.

Smart Fabric, or interactive textiles, are designed to monitor heart rate, body temperature, etc. The Smart Sneaker dynamically adjusts sole support [VDC Corp].

III ACADEMIC RESEARCH

There are several interesting papers that discuss the possibilities inherent in small, portable, inexpensive health-monitoring devices.

Users can wear a vital signs monitor directly on their bodies in the form of a wireless device that monitor heartbeat, heart and breathing rates, and attitude (i.e. notice if the wearer falls) (McGarry, Matthews, & Brereton). The monitor sends the information to a base station next to user's PC, which then relays the information to a hospital or other monitoring organization, over the Internet. The remote monitoring group can then intervene if necessary.

There are three requirements [Riedel] to use wireless technology in remote health monitoring:

1. Small Form Factor
2. Extremely Low Power
3. Protocol for Low Latency / High Scalability / High Responsiveness

With these in place, devices are possible that monitor vital signs on individuals 24/7, no matter where they go or for how long.

One such system [Schwaibold, Gmelin , von Wagner, Schochlin, & Bolz] is based on Bluetooth communication among sensory units on the patient, a mobile information unit or base station, a rescue service, and a digital online patient record. It is able to monitor vital parameters and patient location, save that data to the patient's permanent data record, allow for manual input of patient actions, such as food intake or exercise, and provide a context-sensitive reaction, such as local emergency information.

The PHMon system [PHMon] has an identical structure, with a central database more clearly defined, and with messages going over the public Internet. The project description points out the potential for large savings at the hospital, if patients can be efficiently monitored remotely.

Alternately, the cell phone could be used as the transmission device [Abascal & Civit]. In response to a single button press, measurements could be taken and immediately sent over the

user's cell phone to an emergency service. This could be done in conjunction with other functions that the cell phone would have during regular usage.

Agent technology can be used for applications in telemedicine, in which a presentation agent goes over a stream of data from a medical device (such as a blood pressure monitor) and renders it in a graphical format that is meaningful to someone monitoring the patient or user [Obrenovic, Starcevic, Jovanov, & Radivojevic]. By moving the heavy graphic processing to a PC, the device is free to only be involved in data collection, thus reducing the necessary size and alleviating some of the interface issues.

While personal devices today are largely if not completely external, the next generation may be implanted under the skin. Such devices [Schwiebert, Gupta, & Weinmann] could include artificial retinas, glucose monitors, organ monitors, cancer detectors, and general health monitors. They include many unique challenges but have the potential to give people an unprecedented view of what goes on inside their bodies.

IV INTEGRATED SYSTEMS

If the devices marketed until now are small, standalone units, and the academic research has begun to describe full systems that use variations on those units, it would seem that the future of this field will be in integrated, multi-tier systems, containing inexpensive devices equipped with wireless capability, an EMR (Electronic Medical Record) in a database on the back end, and PDA-enabled reading and writing to the database from anywhere.

iMetricus [iMetricus] is selling a variant of this kind of wireless health care monitoring system, although it was not clear if devices other than a respiration monitor for asthmatics were already in production. The data is downloaded from the "MediCompass" device, where it can be sent to physicians, and integrated into the patient data record.

IBM researchers in Zurich have also created a wireless solution for personal home health monitoring, which includes a wristband blood pressure and heartrate monitoring device, and "smart" pill boxes [IBM Research].

KickStart [KickStart Technologies] describes a system that will use both conventional and wireless communication between health-monitoring devices, and that will take advantage of the mobile phone to transmit the information as it is gathered. It also allows the user to manually enter data into a mobile phone, to provide compatibility with existing devices that do not yet have wireless capabilities.

V DIRECTIONS FOR FUTURE RESEARCH

Intel's Proactive Health research page [Intel Research Labs: ProHealth] describes the project in three phases, only the last of which is wellness, fitness, etc. The first two phases review precisely the systems not covered in this paper, specifically those for the elderly and chronic

sufferers (special-needs). Why do personal health devices play third fiddle? Is it because they sell for less money and therefore profit is less of a motivator? Do insurance and coverage play a role? Is it harder to design and manufacture products that sell in the millions instead of to niche markets in the thousands? Or do aging and chronic conditions just draw more attention because there is more demand to fix problems than there is to prevent them?

User interface becomes an important discriminator among these small devices. Dynamic Living [Dynamic Living, Inc.] describes several devices that use speech to inform the user of blood pressure and thermometer readings, and the contents of a prescription bottle. It would be interesting to use medical devices as a case study in the design of user interfaces for small consumer devices, and perhaps generate some hard usability facts about number of buttons, feel and size of the buttons, organization of a small LCD, etc.

The topic of sensors in general is a logical extension of many of these devices. Intel research describes a user scenario [Intel Research Labs: Wireless] in which sensors around an apartment alert friends when the user is getting ready to go for a run, cook dinner etc. These "proactive sensor networks" pose serious privacy questions, certainly threaten the user's locus of control, and are in a different category from the "reactive sensor networks" that are described in this paper. It would be interesting to examine the ethical questions involved in these two categories of sensors, and learn if the proactive sensors are reasonable extensions of the reactive sensors, or if they would be perceived and used in a completely different way.

Of the devices mentioned above, especially those that play a part in integrated systems, some need to have a wireless connection to the computer (a bathroom scale, for example), whereas others might be able to just plug into a USB or Ethernet port on a PC (pedometer at the end of the day). Is there a way to divide up personal health devices along these lines, and perhaps define requirements for devices more clearly in terms of whether they need a wireless connection or not?

Natural extensions of this technology should also be examined, along the lines of the Smart Toilet. That particular idea may or may not be a commercial winner, but the principle is interesting: Take a device and put it in an unusual place and see if there's a hidden benefit. Perhaps a blood pressure or pulse monitor in the driver's seat of a car would allow a driver to consciously calm himself down in traffic and reduce accidents. Maybe a muscle tension detector in an office chair would let a worker relax their shoulders if a red light went off indicating too much stress. The possibilities for embedded sensors are vast, and the Smart Toilet provides a good jumping off point for examining others.

Finally, whenever possible, it will be important to tie into standards, as do the various wireless integrated solutions that ride on top of Bluetooth security [Bluetooth Security Paper], for example. This prevents redoing work that was already done, and lets future developers build on working technology. Standards will need to be developed for communicating personal medical readings between devices, so that a blood pressure monitor from one company can send its information to a software program written by another, allowing market players to specialize in a certain area without worrying about compatibility.

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