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Persuading Physical Activity Engagement with a Behavior Modification Sensor System

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ABSTRACT

The use of computing technologies to persuade behavior change has been an active research domain in recent years; yet, the question of the impact of persuasive messages generated from an understanding of a person's daily living pattern from wake through sleep remains unanswered. This paper describes a recently completed study of a behavior modification sensor system that was developed and embedded in the home of an elderly Hispanic female. The developed information system supported real-time user monitoring of physical activity and in-home living activity for the purpose of building "information rich" persuasive-based messages intended to promote behavior change in daily physical activity and not linked to a sports-based activity. Initial findings from a three month exploratory study posit that understanding and using a person's daily living pattern can support more "information rich" and stronger persuasive messages and improve physical activity within the message recipient.

Keywords

Behavior modification, physical activity, wireless sensor network, living patterns, persuasive technology.

INTRODUCTION

With a continual rise in healthcare cost and the number of baby boomers in the United States, whose population that belongs to the 65-85+ category predicted to be greater than 18% by 2025, research is actively being conducted on in-residence monitoring that can assist the elderly in maintaining a more healthy and independent life (Dishman 2004). These "smart homes" often leverage wireless sensor networks to collect real-time logs of physical activities and health parameters for examination by health professionals or caregivers, support the detection of anomalous behavior patterns or physical conditions that may forewarn of an impending health problem, and provide peace of mind for adult children who can remotely monitor their loved ones (Fogarty, Hudson, Atkeson, Avrahami, Forlizzi, Kiesler, Lee and Yang 2005). While the merits and attributes of wireless sensor networks are not discussed in this paper (the reader is referred to (Price, Kosaka and Chatterjee 2005) for a review on this subject), a position is taken that they can be an effective component of persuasive computing technology—e.g., a computing system, device, or application intentionally designed to change a person's attitude or behavior in a predetermined way.

The purpose of this paper is to give the reader a better understanding of how one wireless sensor network and supporting technology was instantiated in a "Smart Home" configuration. The goal here is not to make a smart home but to make "smart people" through use of technology that is grounded on persuasive ideologies. Specifically, this paper will described a recent study that evaluate the impact of persuasive messages on changing behavior associated with physical activity linked to daily living and not to a sports-based activity. Integrating health data including physical activity levels with a person's pattern of interaction within their home was hypothesized to support a richer information base that could be used to create a stronger persuasive message.

This paper is organized as follows. In Section 2, we provide an overview of a persuasive technology system referred to as a Behavior Modification Sensor System that we developed for the purpose of investigating the impact of "information rich" persuasive messages on improving physical activity. We follow with a brief literature review of selected work related to the study in Section 3. In Section 4, we describe our three-month experiment. Section 5 covers our findings and provides a brief discussion of our study implications. Lastly, we conclude in Section 6.

THE BEHAVIOR MODIFICATION SENSOR SYSTEM

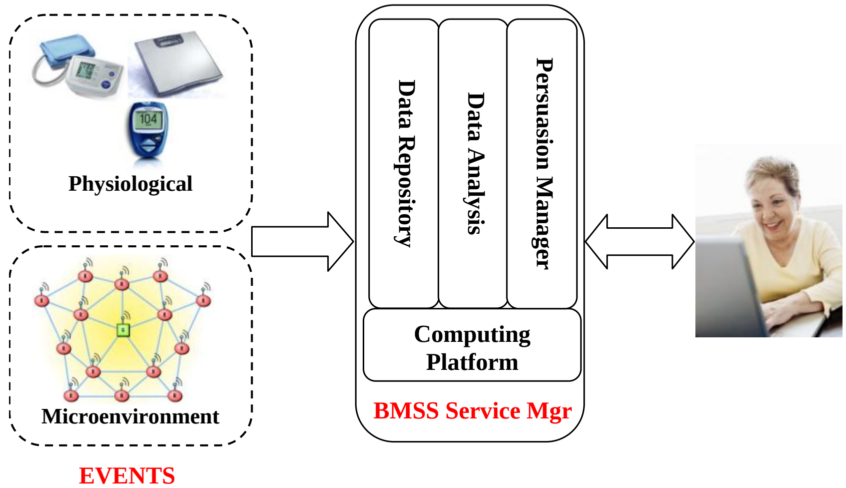

Figure 1: Behavior Modification Sensor System Framework

Figure 1: Behavior Modification Sensor System Framework was used to instantiate the development of a behavior modification sensor system or "BMSS" from this point forward. The BMSS was developed and used to guide the development of an information system for the collection, analysis, and presentation of disparate health and home environmental data by means of different computing-based technologies with an intent to identify behaviors and actions for the purpose of providing useful data to a user; and, a system and service that supported persuasive computing ideologies that for this study included the use of information rich persuasive messages intended to reinforce positive health behavior vis-à-vis improving physical activity.

Figure 1 is divided into three parts: 1) Events of medical and lifestyle interest that are captured and sent to a 2) Behavior Modification Sensor System Service Manager that processes and exchanges information with a 3) User of the system. Each component of the framework is briefly summarized as follows:

Events—Physiological/Psychological and Microenvironment

Within the Events domain, various states exist that can be used to gauge general health. They include: blood pressure, blood glucose, body weight, cardiac health, cognition, and physical activity. This study monitored and considered blood pressure and body weight as indirect health outcomes but focused on daily physical activity associated with walking steps as a direct and testable parameter that can be impacted by persuasive messaging.

Physical activity is "any force exerted by skeletal muscles that results in energy expenditure above rest (Edwards and Tsouros 2006)". This study measured physical activity vis-à-vis daily walking steps, aerobic steps (10 minutes or more of continuous movement), distance, and calories burned through use of a commercially available pedometer—e.g., the Omron HJ-720ITC Pocket Pedometer (Omron 2010)—that the study participant wore on a daily basis. This device captured daily physical activity that was uploaded to the BMSS for analysis of the impact of persuasive messages on improving the number of walking steps taken in a day.

The microenvironment is the residence or living space of a home's inhabitant. Within the microenvironment, various objects including kitchen appliances (e.g., stove, microwave, and refrigerator), bed, TV, and sitting objects such as a couch or chair can be monitored and used to deduce the activity of a resident as they transverse a daily living rhythm from wake to sleep. By monitor the usage of these objects, physical activity states can be deduced. For example, sitting on a couch and watching TV for long periods of time represent a physical activity reducer. Understanding what reducers exist and how a person utilizes their residence space over time can aid in developing or reinforcing the type of persuasive message that is communicated to the receiver of the message.

Figure 2 shows the study participant's microenvironment. The study participant's 611 square foot apartment has one main entry door, one bathroom, one bedroom with a small television (TV), a small dining area and kitchen, and a small living room with one TV placed in front of a couch. A wireless sensor network consisting of two sensor nodes from Crossbow Technology Inc., (Technology 2008) was used to capture room presence (e.g., movement within each room) and object usage information (e.g., TV, refrigerator, sleep patterns, etc.) of the study participant. The wireless sensor network handled data collection within the microenvironment domain and allowed for changes in living patterns to be determined. Change in living patterns is a validated indicator of possible changes in physical and mental states in humans (Chen, Yang, Malkin and Wactlar 2007).

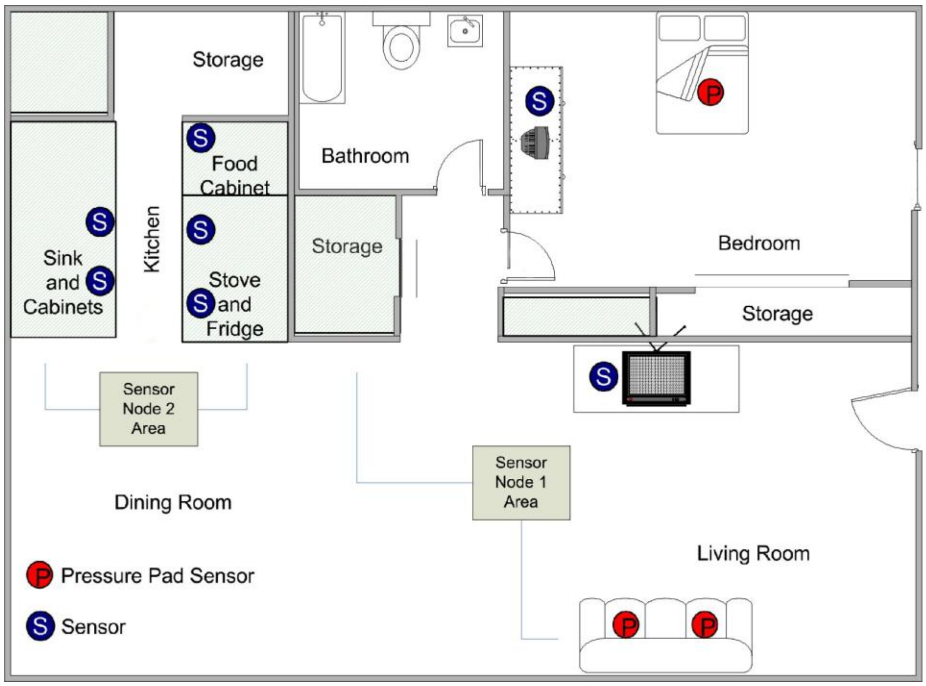

Figure 2: Microenvironment Sensor Domains

Each wireless sensor node monitored six analog or digital inputs with each input wired to a specialized sensor, dependent upon the type of measurement of interest. Room presence was monitored using a simple passive infrared (PIR) sensor circuit (Parallax 2010) that was built and placed above the doorway or in the movement path of each room. Sleeping patterns, or couch usage, was measured using commercially available pressure pad sensors. To measure kitchen activities (e.g., refrigerator and microwave usage, etc.) simple switches were used. Lastly, television (TV) usage was determined using a visible light sensor; its circuit was built and discreetly placed in front of each TV screen. Light changes indicated when a TV was operating (e.g., the presence of light represented a state when a TV was on and no light represented a state when the TV was off).

To augment the collected physical activity data, a commercially available blood pressure monitor and weight scale was used (A & D Medical 2008; A & D Medical 2008). Each device captured and uploaded its associated data via a wireless link to a computer that was setup by the researchers in the study participant's home. This computer was used as the computing platform for the BMSS. Blood pressure and weight information was collected less-frequently than physical activity data (e.g., weekly instead of in real-time) and it was used to reinforce the type of message that the study participant received. For example, *"Your weight was three pounds lower this month than last month. See how walking more can improve your health,"* represented a typical sub-message that was used to reinforce the impact of improving physical activity.

Behavior Modification Sensor System Service Manager

The BMSS Service Manager is "the system" to the user. The service manager links collected event data to a health information database that was analyzed by the researchers and used to present notification of health and living domain states on a daily basis. The study participant interfaced with the BMSS Service Manager through the viewing of a JPEG converted PowerPoint slide that contained the intended daily persuasive message. The persuasive message was setup to run as a screen saver using the My Picture Slideshow setting in Microsoft XP on the study participant's home computer. This computer was located in a high traffic location, and the persuasive message ran continually throughout each day of the study. A post-study interview validated that the study participant read the daily message. All major functions associated with system operation including data collection by the BMSS Service Manager were invisible to the test subject.

Commonly available software packages and applications were used in the development of the service manager. MoteWorks™ — a software platform from Crossbow Technology provided a complete software development environment for the wireless sensor segment of the BMSS and included: a network stack and operating system at the sensor device level, database logging, and a standard C language pre and cross complier that was used to develop the embedded software loaded in each sensor node. Data associated with physical activity, blood pressure and weight was handled by the associated software that came with each device (e.g., The Advanced Omron Health Management Software that came with the pedometer handled all database functions associated with physical activity information and software from A&D Medical supported extraction of blood pressure and weight data).

The data sets associated with the BMSS included: data from with wireless sensor network, data from the pedometer, and data from the blood pressure and weight scale devices. Each data set was captured and stored in the BMSS. Extraction of all the data sets from the BMSS to a computer located in a research lab was done using freely available remote monitoring software (GmbH 2010). Daily remote logins by the researches and between two computers allowed the raw data associated with the events section of the BMSS to be extracted, analyzed, and used to create a persuasive message that was manually uploaded to the study participant's home computer.

RELATED WORK

Wireless sensor networks are finding more use in healthcare applications. UbiMon (Ubiquitous Monitoring Environment for Wearable and Implantable Sensors) provides continuous and unobtrusive patient monitoring for the capture of life threatening events and CodeBlue, a wireless sensor network model that supports a range of medical applications including hospital monitoring, stroke patient rehabilitation, and disaster response scenarios exemplify various real-time patient monitoring projects (Dagtas, Natchetoi and Shapiro 2007). Exemplars of wireless sensor networks used in "smart homes" are noted in literature. Oregon Health & Science University piloted a program where 300 homes in the Portland area were wired with tiny sensors to track the movement of elderly residence. They concluded that changes in movement patterns over time could be used as indicators for the prediction of the early stages of dementia and Alzheimer's (Neergaard 2007). CAST—Center for Aging Services Technology—has built a five room house with various infrared sensors, monitoring devices, and biosensors to help debilitated elderly track their normal movement activity and to provide alerts when non-normal living is detected. The goal of their project was to provide seniors with the data they need to more effectively manage their health and to forecast changes in their living patterns that could be a sign of an immediate or future health issue. Lastly, the MobiHealth project at Georgia Tech is working on a system for the remote collection of body signals for the purpose of providing health professionals with easier monitoring of patients in their homes (Ahamed, Haque and Stamm 2007). Each of these studies highlights the use of technology to improve the monitoring of health by having access to information that has typically been unavailable.

Wireless sensor networks are also finding applications outside of direct patient monitoring. According to Mukhopadhyay et al. (Mukhopadhyay, Gaddam and Gupta 2008), "Sensor networks permit data gathering and computation to be deeply embedded into the environment". These technologies can manifest and support context-aware systems that deduce a person's activity from their environmental state. Research in context-aware systems are exemplified in Hassan and Chatterjee (Hassan 2007; Hassan and Chatterjee 2008) that evaluated the impact of persuasive messages triggered by knowledge of a user's location on a college campus and in Chen et al. (Chen, Yang et al. 2007) that used visual and audio sensors to track social interaction patterns among geriatric patients in a nursing home. Chen et al. concluded that simple changes in walking speed, changes in room movement, and changes in social interaction behaviors were often signs of changes in mental and physical states that often do not get detected or recorded during brief medical examinations by a physician.

Common to all the studies above is the need to have relevant and timely information to maximize healthcare. While the studies involving smart homes and sensor-based monitoring dealt with the use of technology to monitor activities within a closed environment, few addressed the use of technology to directly persuade behavior change; data collected in the studies were typically analyzed ex-post to an action or used to trigger an alert only—e.g., a test subject has fallen, which may indicate a medical emergency. The use of technology to monitor activity within an environment and to drive a real-time behavior change is first seen in Hassan and Chatterjee (Hassan 2007; Hassan and Chatterjee 2008). While their work considered a user in a macroenvironment (e.g., outside the home), the study described in this paper looks at a user in a microenvironment through intensive in-home monitoring that melds physiological and home-living pattern data with a purpose of identifying behaviors and actions that can be used to construct effective persuasive messages intended to improve one component of healthy living—i.e., daily physical activity.

STUDY DETAILS

This study is classified as a field experiment and exploratory system prototype with the instantiation of the BMSS placed in the home of the test subject for a period of three months to conduct an experiment on the impact of persuasive messages on physical activity improvement. The study participant was a 64 year old single Hispanic female that has been diagnosed with pre-diabetes and told by her physician to improve her physical activity and diet as prevention to a worsening state. Selection of the study participant was done based on a convenience sample; she is the mother of a former work colleague to one of the researchers and was selected for her willingness to participant in the study. No relationship between the study participant and the researchers existed before the study. While low external validity is noted with a single sample, the usage of a single sample allowed the researchers to test the basic premises of the study; refinements to the frameworks and the BMSS will be done for use in a future study that will use a larger sample pool.

The study was conducted with the establishment of a baseline of daily physical activity and home living patterns for a period of one month. During the baseline phase, the study participant was given a pedometer that she wore daily to capture her physical activity and a log book that was used to record her self-perceived daily living activities. This data was augmented by real-time collection of home presence and activity by the wireless sensor network and its associated sensors. No persuasive messages were sent during this period and all pre-study data was used as a control. The baseline period was followed by a two month experiment phase in which the study participant received daily messages that promoted physical activity involvement. Guiding the generation of each day's persuasive message, Figure 3 was developed and used. Since the study was interested in improving physical activity, the primary data set was limited to daily walking steps. Secondary data was used provide to "information richness" or "information granularity" to a persuasive message. Examples of secondary data included: living patterns, weight, blood pressure, calories burned from walking, "reasons for engagement"—e.g., medical positions on why increasing physical activity can improve health—and ancillary information that included daily weather and external events the study participant regularly attended. The primary and secondary data was obtained from the BMSS while the "reasons for engagement" and daily weather information were obtained from freely available Internet sites; external event data was obtained from the study participant vis-à-vis a pre-study survey.

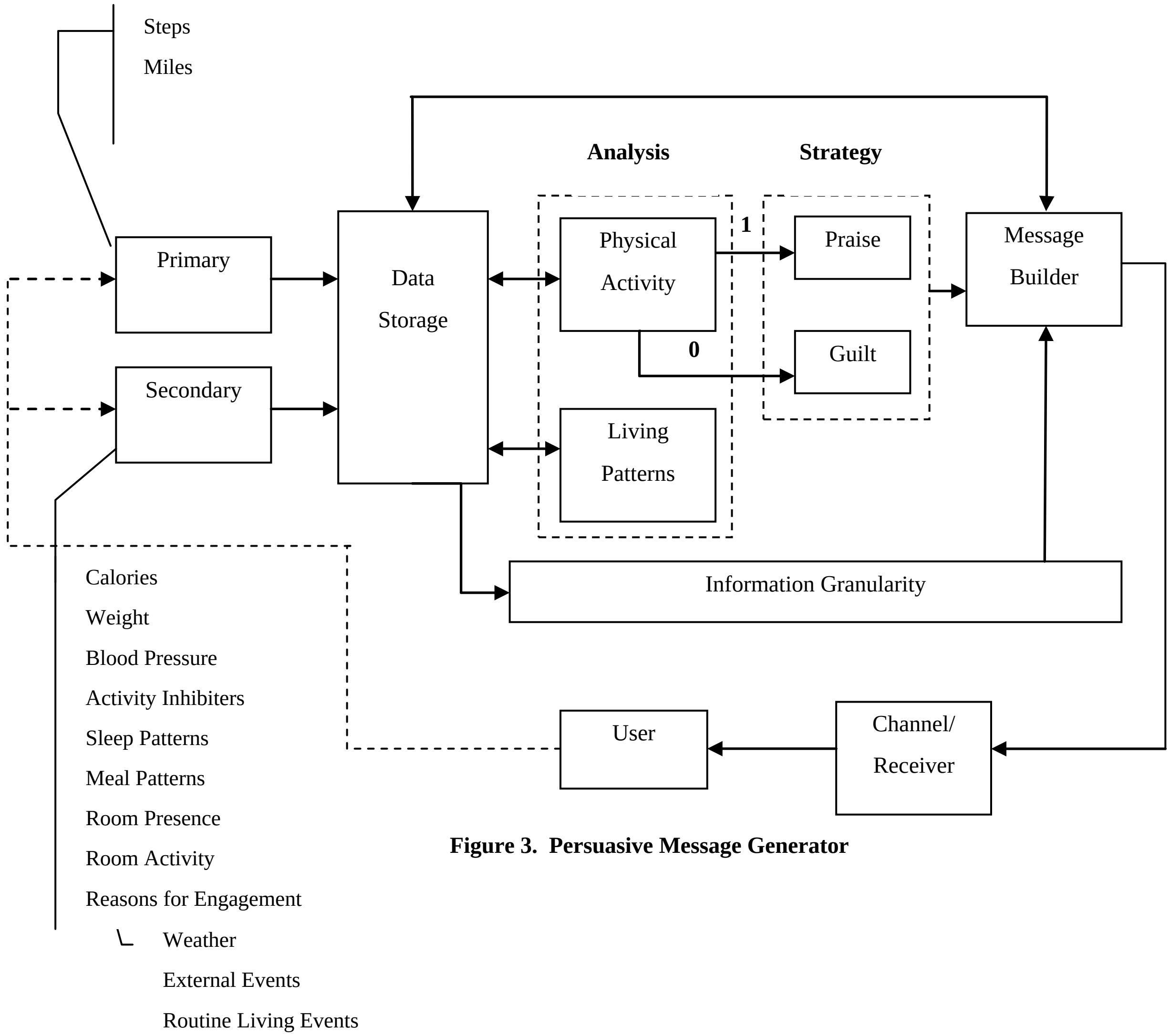

Figure 3. Persuasive Message Generator

Message building and deliver of a persuasive message was done once per day by the researchers using both primary and secondary data. Analysis of each preceding day's physical activity results was done against an established walking goal to determine the impact of the associated persuasive message. A weekly goal was set by averaging the three highest walking days of the previous week and multiplying the average by a gain factor that typically represented a three to six percent goal improvement from week-to-week. A daily goal was set by using a linear function that ensured each day would be progressively higher than a previous day and supported the study participant in meeting the weekly goal at the end of a seven day week. Guiding the creation of a persuasive message, two types of motivation strategies were selected. A persuasive strategy of praise was used when the study participant met or exceeded a set daily walking goal and conversely, a guilt strategy was adopted when not.

Figure 4 and 5 shows an example of a praise and guilt- driven persuasive message used in the study. A newspaper structure was identified in a pre-study survey as the most appropriate delivery vehicle for presenting information; the study participant is not computer literate and was use to receiving important information in this format. Noted in each example is a summary of the previous day's physical activity and secondary information that provided "information richness" to the message. Ancillary information was also added to provide an impetuous for message reading. For example, the study participant stated in a post-study interview that she would check each day's message to learn about the daily weather forecast and, in the process, would read the intended persuasive message.

ANA MARIA TIMES

no.203.078 Walking Towards Better Health - Monday, December 28, 2009

ANOTHER GREAT WEEK…!

You kept moving…

You walked an average of **6053** steps or **3.2** miles for each of the three highest days that you walked. **Great Job!**

Your weekly goal is to continue with 6000 daily steps. With efforts like last week, you can do it.

Curious of when you were most active yesterday? The following chart shows that you walked the most between 1 and 2 PM.

Yesterday's activities allowed you burned an extra 128 calories. See how walking can help you to lower your weight?

Keep up the fantastic efforts and make today "**Another Great Day!**"

Remember When?

Let's take a walk down memory lane. Do you remember when…

A gallon of gas was 35 cents?

24 oranges were 88 cents?

The Fugitive was a popular TV show?

Be My Baby was a popular song.

In the Heat of the Night won five Oscars.

Did you figure it out? **All happened in the 1960's.**

Today's Weather

Today: Cloudy skies. High near 70F.

Tonight: Low 41F.

Today's Events

Bible Study—12:30 & 6 PM

Thought for the Day

"It's amazing to see all the wonderfully amazing things that can happen in a day in which you participate."

Steve Maraboli

Keep walking towards better health.

Figure 4. Persuasive Message—Praise Strategy

ANA MARIA TIMES

no.203.078 Walking Towards Better Health - Tuesday, January 05, 2010

UNDER THE WEEKLY GOAL

Yesterday…

You walked **5208** steps or **2.79** miles and you burned off an extra **152** calories. This was better than the day before but under the week's goal of 5600 steps.

TV Time

Yesterday, you watched almost four hours of television. You need time to relax but don't let too much TV time keep you from moving. Walk outside or in your apartment to remain active.

Blood Pressure & Weight (Last Reading)

Blood Pressure: **138/74**

Weight: **146.2 lbs**

Today's Weather

Today: Sunny. High 79F.

Tonight: A few clouds. Low 44F.

This week's weather is sunny and warm. **Great opportunity for walking**

Quote for the Day

"Everyone is entitled to be stupid, but some abuse the privilege." **Author Unknown**

"I missed my goal"

Figure 5. Persuasive Message—Guilt Strategy

RESULTS AND DISCUSSION

During the baseline period, 16 out of 25 days of physical activity and living pattern data was collected and used as a control for the study. This data set represented whole days that the study participant resided in her home; the remaining days was time outside of her residence (e.g., typically two days per week living at her daughters home). The control month was followed by two months in which 30 out 49 whole days of residence was used in the experiment phase of the study. Table 1 detail the pre and post states of the average and rounded daily physical activity data obtained.

		Total Steps		Aerobic Steps		Calories		Distance (Miles)	
	N	Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.
Pre	16	3242	1010	107	428	79	35	1.74	0.54
Post	30	4914	1090	1315	1107	135	39	2.63	0.59

Table 1. Average Daily Physical Activity (pre and post study)

Table 2 shows an example of one day's living pattern captured during the experiment phase of the study. Room Presence (e.g., minutes spent each hour in a 24 hour day inside and outside the home) and Room Activity (e.g., usage of common household appliances) is shown. Total operating times of the microwave, food cabinet, or refrigerator was not determined; the times listed for those attributes are for open-close states only and used to determine when daily meal preparation occurred. One attribute of interest was the total time sitting on the couch and watching TV (denoted by Couch-TV). This represents a time of non-physical activity. Reporting this information to the study participant was often included in a daily persuasive message as a trigger to reduce inactivity states and engage in more physical activity.

Date: Tuesday, December 08, 2009 Week 2 Home Y

	Room Presence							Room Activities					Walking		
Hour	Dining Room	Kitchen	BedRm	Bed	BathRm	LivingRm	Outside Home	Couch-TV	TV-BedRm	uWave	Food Cabinet	Fridge	Steps	Aerobic Steps	Meal
0:00:00	0:00:00	0:00:00	0:59:56	0:59:56	0:00:00	0:00:03	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
1:00:00	0:00:00	0:00:00	0:59:59	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
2:00:00	0:00:00	0:00:00	0:59:59	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
3:00:00	0:00:00	0:00:00	0:59:59	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
4:00:00	0:00:00	0:00:00	0:59:59	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
5:00:00	0:10:48	0:00:45	0:43:19	0:42:23	0:04:38	0:00:29	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	15	0	
6:00:00	0:37:37	0:02:38	0:04:15	0:00:00	0:03:45	0:11:44	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	53	0	
7:00:00	0:09:20	0:00:34	0:26:57	0:00:51	0:06:10	0:16:58	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	143	0	
8:00:00	0:46:35	0:10:37	0:00:40	0:00:00	0:01:16	0:00:51	0:00:00	0:00:00	0:00:00	0:00:00	0:00:04	0:00:00	111	0	
9:00:00	0:33:54	0:08:47	0:02:43	0:00:00	0:04:16	0:05:11	0:05:08	0:00:00	0:00:00	0:00:02	0:00:02	0:00:00	1339	0	Breakfest
10:00:00	0:06:05	0:03:06	0:00:15	0:00:00	0:02:56	0:47:37	0:00:00	0:44:24	0:00:00	0:00:00	0:00:00	0:00:00	178	0	
11:00:00	0:28:06	0:00:59	0:01:16	0:00:00	0:00:35	0:29:03	0:00:00	0:27:26	0:00:00	0:00:00	0:00:00	0:00:08	157	0	
12:00:00	0:22:19	0:08:15	0:01:12	0:00:00	0:17:18	0:10:55	0:00:00	0:08:36	0:00:00	0:00:03	0:00:10	0:00:14	154	0	Lunch
13:00:00	0:03:01	0:00:27	0:04:01	0:00:00	0:02:48	0:23:29	0:26:13	0:18:34	0:00:00	0:00:00	0:00:00	0:00:00	1106	0	
14:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	187	0	
15:00:00	0:07:35	0:02:32	0:07:05	0:00:00	0:05:43	0:21:27	0:15:37	0:18:51	0:00:00	0:00:00	0:00:00	0:00:03	1600	1299	
16:00:00	0:01:17	0:08:45	0:00:20	0:00:00	0:04:05	0:45:32	0:00:00	0:29:19	0:00:00	0:00:04	0:00:43	0:00:36	118	0	Dinner
17:00:00	0:00:00	0:00:29	0:01:24	0:00:00	0:05:10	0:21:25	0:31:31	0:19:06	0:00:00	0:00:00	0:00:00	0:00:10	280	0	
18:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:59:59	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
19:00:00	0:01:19	0:02:22	0:01:27	0:00:50	0:03:20	0:23:30	0:28:01	0:21:15	0:00:00	0:00:03	0:00:02	0:00:00	166	0	
20:00:00	0:00:00	0:04:35	0:03:23	0:00:25	0:13:11	0:38:50	0:00:00	0:35:05	0:00:00	0:00:00	0:00:00	0:00:00	129	0	
21:00:00	0:00:14	0:00:25	0:23:52	0:21:33	0:03:03	0:32:25	0:00:00	0:30:14	0:12:20	0:00:00	0:00:00	0:00:00	74	0	
22:00:00	0:00:00	0:00:00	0:55:59	0:55:59	0:00:00	0:04:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
23:00:00	0:00:00	0:00:00	0:55:59	0:55:59	0:00:00	0:04:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0	0	
Sub Total	**3:28:10**	**0:55:16**	**8:53:59**	**7:57:52**	**1:18:14**	**5:37:29**	**3:46:28**	**4:12:50**	**0:12:20**	**0:00:12**	**0:01:01**	**0:01:11**	**5810**	**1299**	

TOTAL		SLEEP		GOAL			WEATHER
Steps:	5810	Total Hrs:	8:15:40			Met?	52/S
Aerobic:	1299	Interupted:	N	Weekly:	3650	Y	
Miles:	3.11			Strategy:	Praise		
Calories:	150						

Table 2. Example of Daily Living Pattern

Initial analysis of pre and post study data validates published research that persuasive messages can impact a behavior change associated with physical activity improvement. Analysis of the pre and post study physical activity data shows that the study participant was able to change her behavior and improve her daily physical activity by 51% (e.g., 4914 post-study average daily steps versus 3242 per-study average daily steps). Improving physical activity also posits a change in daily living patterns. As the study participant increased her walking activities, changes in room presence (e.g., time spent in her home environment) and selected living activities (e.g., TV watching time) were noted. Table 3 shows a comparison between the experiment and baseline data for a partial sample of all the days captured in the study (note: Table 3 is limited to 25 out of 30 days of experiment data and five out of 16 days of baseline data. Therefore, the daily walking and aerobic steps listed are lower than when all days are considered. The reader is referred to Table 1 for the final outcome associated with physical activity improvement resulting from this study). As the study participant changed her behavior from a limited mobility state to one that incorporated more walking, the time spent outside her home increased and the time spent sitting and watching TV—a physical activity reducer—was lower. Changes in the frequency of movement between rooms were also noted in the initial analysis of the data but are not detailed in this paper. This indicates the study participant became more physically active within her microenvironment as the study proceeded from start to finish.

Room Presence and Activty		Dining Room	Kitchen	BedRm	Bed	BathRm	LivingRm	Outside Home	Couch-TV	TV-BedRm	Steps	Aerobic Steps
Avg Time	Study (N =25)	2:07:05	1:06:01	10:20:43	9:30:32	1:14:04	5:52:54	3:23:08	4:08:31	1:54:30	4777	1287
	Baseline (N = 5)	1:55:26	1:29:36	10:18:45	9:33:44	1:28:08	5:54:08	2:53:34	4:34:12	0:55:57	3659	343
Std Dev	Study (N = 25)	0:51:47	0:25:39	1:55:07	1:52:21	0:17:48	1:41:53	1:57:36	1:23:50	1:26:45	995	972
	Baseline (N = 5)	1:00:32	0:24:38	0:30:04	0:26:05	0:10:35	1:21:32	1:41:02	1:26:29	0:31:19	1663	767

Table 3. Comparison between Experiment and Baseline Data

Due to the recent completion of the study in January 2010, the scrubbing of the study data and associated analysis is still ongoing. Regardless, findings in this study posit that understanding and using a person's daily living pattern that for this study was limited to a home environment can allow for more "information rich" and stronger persuasive messages. Building messages that included how much time was lost to TV watching, messages that included the daily events offered in her apartment complex (i.e., art classes, social gatherings, etc.) that could allow her to be more physical active, or messages that reported her recent sleeping patterns added to the strength of the persuasive message over the reporting of daily walking steps alone. Due to the recent completion of the study, the details of this premise and the impact of the type of persuasive message (e.g., guilt versus praise) are still being assessed and will be reported in future publications.

CONCLUSION

Driving good health is having the right information to make healthy decisions. With research advancements in wireless sensor networks and the availability of inexpensive sensors, we now have the ability to autonomously capture the details that make up our daily lives from wake through sleep. While knowing the living pattern of a person may seem to be an academic curiosity, the value of this information occurs when context is deduced from a living activity to support a broader and more meaningful persuasion strategy. In this study, knowing how many walking steps a person takes in a day was secondary to understanding the barriers that impede physical activity and to use this information to create more effective persuasive messages. Research has shown that a persuasive message is most effective when it's structured to the intended goal and triggered by an associated event. This mandates that we first understand the goal barriers that impact moving a person towards a motivated state and to create a persuasive message that can help to reduce or eliminate those barriers. In this study, the goal was to change behavior associated with improving physical activity. This required that we first understand the living patterns of a person as they spent their time within their microenvironment and to use this information to identify the barriers that impact goal obtainment. This driver is not limited to physical activity. Capturing living patterns and deducing associated living events can be a keystone in persuasive computing strategies that impact other health behaviors including alcoholism, smoking cessation, or social systems that benefit from a greater understanding of context in which its members reside. This study was a first step in understanding how an elderly person that is primarily home-bound transverses their waking hours and to use this understanding to build more effective persuasive messages. Extending the ideas presented in this paper to domains outside the home is a fertile ground for future persuasion computing research. The time is right. Are the researchers, designers, and users of the technology ready for it?

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