

**A Persuasive Television Remote Control
for the Promotion of Health and Well-Being**

by

Jason Paul Nawyn

A.B., Cornell University (1997)

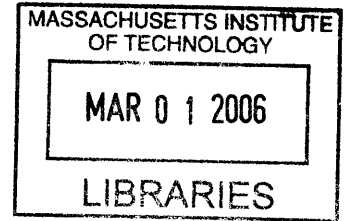
Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of
Master of Science

at the

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Abstract

New forms of media technology that enter the home often fundamentally transform the way that people spend their time. In the present day, daily “screen time” with televisions and other entertainment systems continues to rise [1]. Within this climate of escalating media consumption, experts in the medical community have repeatedly voiced concerns about the public health crisis that looms over a largely sedentary U.S. population. Principal among these concerns is the continuing upward trend in lifestyle-related disorders such as obesity and Type 2 diabetes. Within the last two decades, substantial epidemiological research has linked excessive television viewing with both obesity [2] and Type 2 diabetes [3, 4].

This work describes the design, implementation, and evaluation of a ubiquitous computing system intended to simultaneously decrease a user’s television viewing while increasing his or her frequency and quantity of non-sedentary activities. This system, called *Vito*, employs a residential sensing infrastructure to recognize an individual’s television viewing and uses wearable accelerometers to detect physical movement. The primary user interface consists of a handheld computing device that serves as a wireless remote control for a television and home theatre system, as well as an interface for planning and reviewing daily activity. This device tracks daily activity patterns and uses theories of behavior modification to non-intrusively persuade users to decrease their daily television use while increasing physical activity. Results from a 14-day case study evaluation revealed examples of how persuasive interface design elements might influence user behavior without inducing a burden of annoyance.

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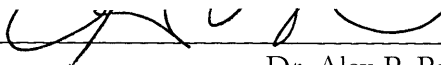
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Thank you.

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1. Introduction

The average American watches over 3 hours of television each day [1]. As time spent in sedentary media consumption each day increases, the amount physical activity one incurs typically decreases. This is an unsettling fact of life for many people. For example, nearly 50% of Americans feel they presently watch too much television and would like to reduce the amount they watch [5]. Meanwhile, rates of obesity have increased markedly in recent decades (Figure 1-1), and millions of Americans report engaging in weight-control efforts such as dieting on a regular basis [6]. However, few people actually succeed in substantially altering their long-term physical health outlook in spite of accumulating evidence of the positive correlation between sedentary behavior and obesity (Figure 1-2) as well as lifestyle-related medical disorders such as Type 2 diabetes [7].

Television viewing, particularly unstructured “grazing” behavior (i.e., channel surfing), represents a common sedentary activity in which time invested routinely spirals out of control [8]. Successfully reducing the time spent in this pursuit over the long term could produce meaningful gains in an individual’s overall health, especially if this activity is replaced with less sedentary alternatives. Further benefits may also be derived from decreased TV use, including the reversal of television’s suspected negative impact on social, emotional, and intellectual wellbeing [9].

The challenges of reducing television viewing are as compelling as the reasons for wishing to do so. Television habits are notoriously difficult to modify, often exhibiting the resilience of

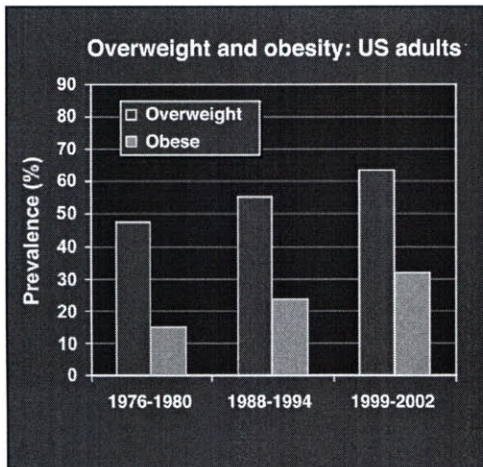


Figure 1-1: Obesity since 1976
Age-adjusted prevalence of overweight (BMI > 25) and obesity (BMI > 30) among US adults aged 20-74 years. (Source: National Center for Health Statistics)

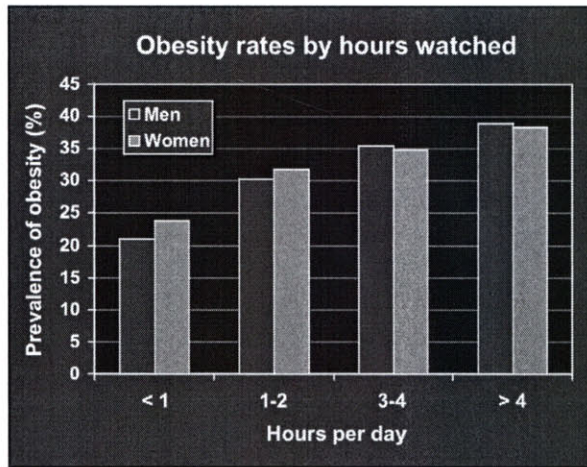


Figure 1-2: Television viewing and obesity
Prevalence of obesity in American adult populations by hours of television watched per day. (Adapted from [3, 4])

chemically based addictions [8]. The nature of the television viewing experience explains its addictive properties: the intrinsic rewards of watching television, such as relaxation and passivity are immediate and self-reinforcing. Unfortunately, these rewards diminish over time, and after periods of extended use, TV viewers often feel worse than before they started [10]. Nevertheless, many users find difficulty in extracting themselves from the viewing situation.

In contrast, the goal of increased physical activity is routinely impeded by the perceived high costs of entry into the pursuit. Engaging in exercise is typically thought to involve getting dressed, going to the gym, working out, showering, and then returning home. As a further impediment, the rewards of exercise—unlike television viewing—are not immediate, often to be noticed only months or years down the road. In fact, the main short-term effects of physical activity may be unpleasant ones, as captured by the common expression, “no pain, no gain.”

The problem of modifying television viewing and physical activity patterns can therefore be formulated as one of short-term behavioral conditioning [11]. Television viewing is instantaneously rewarding while exercise is instantaneously aversive. In this work, a two-pronged approach is taken to counter this fundamental behavioral phenomenon: (1) use of technology to preempt or disrupt the stimulus-reward cycle of TV watching and (2) use of technology to decrease the costs of physical activity, while providing immediate positive reinforcement.

The physical embodiment of this intervention is a multifunction handheld device called *ViT0**. This device, built on a personal digital assistant (PDA) platform, is intended as a seamless replacement for the user's existing television remote control. It has been designed to provide value-adding features not presently available in commercial remote controls. These features, including an easy to use graphical interface, built-in program listings, access to a media library, integrated activity management, and interactive games are used to entice users into adopting the persuasive remote control technology into their TV viewing routines. Figure 1-3 shows the device as implemented and Figure 1-4 depicts a representative usage scenario.

Over time, the device deploys a series of behavior change strategies aimed at helping the user make more informed decisions about his or her viewing practices. It attempts to elicit the user's activity goals and suggest alternatives to TV watching in a timely manner. In conjunction with wearable acceleration sensors, it also functions as an electronic personal trainer, both prompting and rewarding physical activity.

A single-user case study evaluation was designed to test the viability of the device both as a research tool and as a technology for behavior change. This two-phase experimental design allowed assessment of user reaction to a non-persuasive PDA-based remote control as well as the complete *ViT0* system. The two main goals of this exercise were: (1) to identify relevant and measurable changes in participant behavior between conditions and (2) to

* Name is a reference to a popular TV enhancement product, *TiVo*. It should be noted, however, that the persuasive remote control does not attempt to "veto" or prohibit viewing, but rather to encourage users to take their own steps toward watching less television and getting more physical activity.

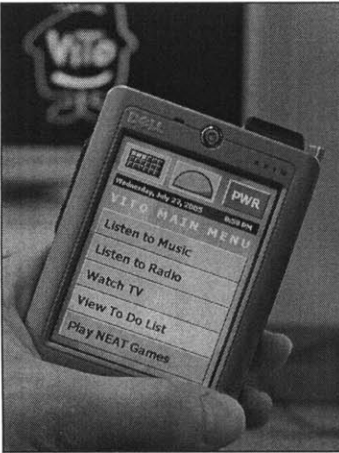


Figure 1-3: ViTo remote
PDA-based prototype of a persuasive remote control.

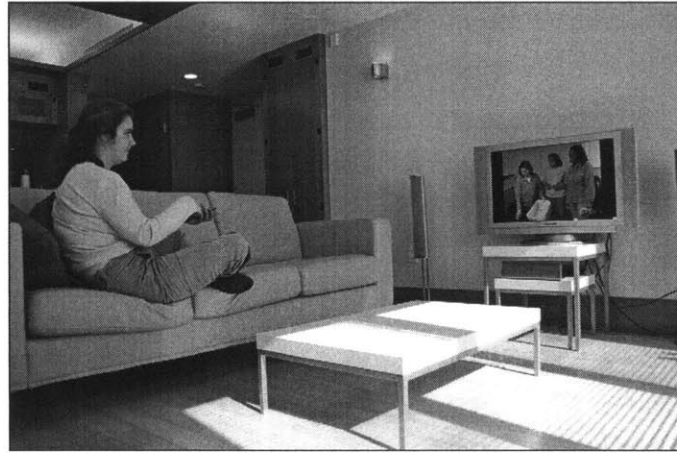


Figure 1-4: Usage scenario
ViTo is designed to replace any consumer grade television remote control device.

engage user feedback in evaluating the overall design of the device. Results from this study have been used to formulate a large-scale evaluation of ViTo's efficacy as a behavior change technology. Details of this study are available in Appendix J.

2. Background

Ninety-four percent of all U.S. homes contain at least one television with a remote control device [12]. The remote control has become a central component of the TV viewing experience, and in many ways has transformed the very nature of the activity [13]. The ability to remotely control a TV set has led to an increase in so-called “grazing” or “channel-surfing” behaviors, which have been identified as the most problematic of habitual viewing practices [9]. Because of its centrality to the viewing experience and its proximity to the user, the remote control provides an ideal platform for the delivery of strategies for behavior change. As the technological landscape of the home evolves, it is anticipated that a single multifunction device will interact with many additional home technologies, and, as in the case of the mobile phone today, provide a possible point of interaction within many contexts of use.

Within the field of human-computer interaction (HCI), the design of *ViT0* represents the convergence of three distinct areas of study: ubiquitous computing [14], context-aware computing [15], and persuasive computing [16]. Together these developments can help enable new applications with the unprecedented levels of personalization and customization necessary to produce sustained behavior change.

2.1 Ubiquitous computing

The proliferation of small, powerful computational devices has in recent years served as a catalyst for the design of new forms of personal technology. The personal digital assistant (PDA) ranks among the more successful of these, and provides a convenient platform for the delivery of new personalized ubiquitous computing services. *ViTo*, as prototyped on a wireless PDA, serves as an example of how persuasive mobile technologies can be used to deliver valuable services when and where user chooses [17]. By seamlessly interacting with other consumer electronics, including a laptop PC and a home theatre system, *ViTo* also illustrates the potential of ubiquitous computing devices to overcome their inherent limitations by exploiting the strengths of other existing technologies.

2.2 Context aware computing

The advent of inexpensive, unobtrusive sensor technologies enables further personalization of mobile computing devices by providing contextual cues about the user's actions and environment. Recent work on sensor rich home environments begins to address the infrastructure requirements for deploying context aware applications that respect the complexity of daily life [18]. *ViTo* takes advantage of this development by using information from an existing home sensor network to react appropriately to the present state of the user's environment [19]. For the current project, awareness of context focuses on the state of the television, sound system, and PDA, as well as coarse knowledge of the participant's physical activity levels.

2.3 Persuasive computing

The advances in context aware computing begin to address one of the principal challenges to designing technology for behavior change: how to deliver tailored behavior change strategies at precisely the right time and the right place for optimal results [15]. The emerging field of persuasive technology [20] has identified rich opportunities for the use of such "just-in-time" intervention techniques, and the current project seeks to extend and deepen this area of

research through the design of a persuasive technology intended to modify established lifestyle behaviors.

3. Related Work

This project builds upon prior work relevant to the motivation of lifestyle change. Knowledge campaigns and clinical interventions are the two most common approaches to the problem thus far. A smaller number of studies have investigated the use of technology in reducing television viewing and increasing physical activity, but there remains much opportunity to explore the application of mobile, context-aware persuasive technologies in this domain.

3.1 Knowledge campaigns

The interrelated problems of excessive media consumption and inactivity are generally well acknowledged in the public health community. Much prior research in the public health community has focused on the goal of helping people reduce time spent in sedentary activities and to become more physically active. The most common approach has been public awareness campaigns targeting reductions in television viewing [21] and increases in moderate exercise [22].

While the intent of these efforts is commendable, the effectiveness of this strategy is questionable. Research into the efficacy of knowledge campaigns suggests that the success rate in inducing behavior change is low relative to other health intervention techniques [23]. Although awareness of the deleterious consequences of inactivity may affect an individual's

motivation to change, failure to provide concrete and timely assistance in achieving those goals decreases the overall likelihood of success.

3.2 Clinical exercise interventions

Several well controlled medical studies do, however, suggest that the goal of replacing television viewing with moderate physical exercise can, in fact, lead to near-term reductions in mean body mass index (BMI) in overweight individuals [24, 25]. These studies succeed in part because a network of researchers and resources are in place to ensure compliance with the exercise regimen by carefully monitoring subject behavior and making sure they follow the specified protocol. These studies do not typically address the issues of motivation, entry costs, and other barriers that may impede long-term behavior change after the study ends. Nevertheless, this work does provide support for the overall goal of reducing obesity-related conditions by changing an individual's balance of sedentary and non-sedentary activities

3.3 Non-Exercise Activity Thermogenesis

One promising avenue toward a less resource-intensive intervention involves rethinking the type of physical activity that is necessary to achieve the end goal. Research by Levine *et al.* [26] suggests that simply augmenting sedentary behaviors with movements requiring minimal exertion may reduce an individual's propensity to obesity. This work suggests that increasing non-exercise activity thermogenesis (NEAT) may be a viable alternative to volitional exercise (i.e. "working out") for overcoming the caloric surplus introduced by extended sedentary media consumption. NEAT can be increased with small bouts of simple body movements – standing, talking, fidgeting – that rapidly accumulate and readily integrate into everyday routines.

Among American adults, weight gain per averages almost 2 pounds per year. This fact may be the result of an energy imbalance of as little as 50 kilocalories per day – less than a typical cookie [27]. A recent study contrasting NEAT in lean and obese adults purports that the NEAT differential between these populations accounts for an energy surplus of more than

300 kcal per day in obese individuals [28]. Although this result is somewhat controversial given the reported magnitude of difference, even smaller increases in energy use may have an impact on adult weight control.

3.4 Technologies to reduce television viewing

To date, no other research has investigated the viability of using a TV remote control as a point-of-behavior tool for modifying the user's viewing and physical activity habits. Prior efforts at using technology to reduce television viewing have focused primarily on devices for children. The majority of these served as primitive electronic gatekeepers to limit a child's access to the TV. Specific examples include a key locking mechanism [29] and a token access system [30].

Several technology-related projects have attempted to simultaneously address the problems of television viewing and inactivity by creating exercise-contingent television activation systems [31]. One such system, *Telecycle* (see [20]), requires the user to pedal a stationary bicycle continuously in order to maintain a fully resolved television picture. While this approach is appealing in concept, it is designed to improve quality of exercise, not to reduce quantity of television viewing. Although suitable for a gym environment, a bicycle-based intervention would be inappropriate in a home setting due to the size of equipment and incompatibility with multiple viewers. Furthermore, the long-term effectiveness of any intervention that demands physical activity in exchange for television time should be suspect, since it obstructs a principle objective of television viewing – seeking relaxation.

Another recent attempt to address the problem of sedentary lifestyle and TV takes the form of a step-counting insole, *Square Eyes* [32], that allows a child to earn a daily television allowance based on their amount of walking. As in the case of the *Telecycle*, this approach effectively uses a short-term goal orientation to reward physical activity. However, as is the case for many existing television interventions, it does so by framing television as a conditional reward stimulus, opening up the possibility that it may ultimately increase the user's motivation to watch TV [33].

At the present time, none of these technologies have been studied in naturalistic settings for extended periods, so their long-term effectiveness remains unknown.

3.5 Technologies to increase physical activity

Research into the use of technology to increase physical activity independent of television viewing is more extensive. In this body of literature, several approaches are suggestive, including the use of open-loop feedback on increasing the user's daily physical activity [34, 35]. Employing inexpensive step-counting pedometers to measure daily ambulation, these studies suggest that feedback is one promising tool in the effort to increase overall physical activity. The current market proliferation of consumer-grade pedometers provides testament to the desire and willingness of individuals to adopt technologies that simply and non-intrusively assist in their quest to become more active.

Another intriguing case for the use of feedback in promoting physical activity is a popular type of arcade game that uses lower-body movement as an interface to game play. One such system, *Dance Dance Revolution*, provides a persuasive multimedia gaming experience that uses real-time responsiveness to reinforce dance-type movements. Preliminary research [36] suggests that games like *Dance Dance Revolution* may be successful in producing short-term motivation for physical activity among otherwise sedentary children. Anecdotal evidence further suggests that the activity induced might have an overall positive impact on the child's physical health for the short-term.

4. Design Challenges

The work described herein seeks to provide a tool that reduces television viewing without coercion and without treating TV as a reward. Simultaneously, it uses real-time feedback and game-style interaction to promote physical activity in a low cost, low impact manner that integrates cleanly into the user's existing home-life patterns. Producing a persuasive technology that meets these criteria requires attention to the design of the interface as well as to scenarios of use that are likely to have implications for long-term adoption. Intille [37] highlights some of the issues relevant to achieving success in the design of persuasive technologies motivate healthy aging. The key interface challenges identified in this work are listed below alongside discussion of how *VITo* addresses each concern.

4.1 Achieving subtlety

VITo's functionality is designed to provide high value to the user independent of the individual persuasive strategies it employs. Persuasive elements have been deployed so they do not obstruct normal use. All strategies that involve proactive interaction with the user are subject to a time-out period between presentations to prevent overexposure, which may lead to habituation or, worse, annoyance.

4.2 Detecting the right time

The use of a television remote control intrinsically provides information about the user's current context of use. Several key points of decision that have been identified as targets for persuasive content can be reliably inferred from input to the device: starting to watch TV, changing channels, and turning off the television. Other points of intervention, such as engaging in physical activity are inferred from sensor activations. When neither user input nor sensor activation is available for detection, a "Wizard of Oz" style simulation is used. This is the case for signaling the onset and offset of TV commercials, both important decision points when watching TV. In the current implementation, a remote operator reviews the participant's television programming in real-time and manually flags commercial segments using a web-based interface.

4.3 Sporadically interacting in time

All of the proactive interface strategies deployed on *ViTo* have been reviewed to ensure that they can be quickly understood and responded to by the user. The points of decision targeted by the device may be very brief, so it is critical that the user can respond efficiently without unnecessary interruption to their activities. Because *ViTo's* behavior change objectives look toward long-term impact, providing an interactive experience that is convenient and not burdensome will increase the likelihood that the user will continue using the device over time.

4.4 Avoiding over-reliance on external justification

A key goal of *ViTo* is to promote self-awareness of the user's activity patterns over the long term. Interfaces that motivate behavior using only external justification (e.g., rewards and incentives) may fail in time if the external incentives are removed [38]. Although external justification is one of the strategies employed by *ViTo*, its primary function is to help the user overcome the initial barriers to behavior change. Over time, it is anticipated that habit and occasional self-reflection will result in sustained change even if the rewards are removed.

4.5 Leveraging consumer technologies

As an application that exploits commercially available technologies, a *ViTo*-like system could be economically deployed in virtually any home. Although the research prototype contains some custom components, the user experience is one that could be reproduced on a mobile phone or other wireless computing device for wide-scale deployment. Positioned as an extension to an existing mobile computing device, it is expected that *ViTo* will enhance, rather than replace, the existing technology.

4.6 Motivating the "healthy" (not the ill)

ViTo is formulated as a tool for preventive healthcare, one that attempts to prevent rather than respond to health problems. The goal of keeping people healthy requires that the device effectively serve individuals who may not be particularly concerned about changing their behavior. Whereas an ill person might be externally motivated to change his or her lifestyle using the device regardless of its design, *ViTo* is specifically engineered to appeal to healthy users through the inclusion of elements that are fun, interesting, and satisfying.

4.7 Proving efficacy

The overall value of using persuasive technology to effect behavior change has yet to be convincingly demonstrated through empirical study. Most examples have been design concepts or research prototypes not formally tested. *ViTo* is offered a tool for further study of this question. All of the user interactions with the system are logged and stored for later analysis, so that over time a substantial body of data from multiple users can be statistically analyzed. It is expected that the data produced by this system will enable evaluation of the individual and combined effects of the persuasive strategies it employs. In the current work, a case study user evaluation was conducted in an effort to understand the challenges and opportunities for testing the efficacy of persuasive behavior change technologies.

5. System Overview

The final *ViTo* system was the product of an iterative design and prototyping process aimed at addressing the challenges raised in Section 4. Details of the design process are presented in Appendix A.

The *ViTo* persuasive remote control is proposed as a “universal” replacement for the standard units typically bundled with consumer-grade television sets. The device provides the basic functionality of a standard remote, but enhances it with a graphical user interface that supports additional capabilities such as digital audio control, activity management, and simple games. By combining these functions into a single interface, *ViTo* begins to achieve the ubiquitous computing vision of a multifunction device that the user will be motivated to use outside the single context of television viewing.

Although a great deal of engineering and system integration went into the creation of a satisfying user experience, it was conducted with the goal of producing a technology that appears simple and is easy to use. In attempting to achieve its fundamental goal of providing value to the user, *ViTo* enables the following activities:

- Controlling a TV tuner and display to easily watch network programming.
- Controlling a DVD video player in order to watch personal or rented movies.
- Accessing and playing back the contents of a digitally recorded music library over a home stereo system.

- Selecting and playing streaming radio sources over a home stereo system.
- Reviewing a list of “to do” activities as entered through a personal computer interface.

The activities above represent traditional functionality that might be enabled by a multifunction media control device, independent of its persuasive goals. As discussed in Section 8, specific strategies for motivating behavior change are layered on top of this functionality, such as:

- Initiating TV-based display of curiosity-engaging games that respond to bodily movement.
- Reviewing history of television viewing on a handheld display.
- Setting goals and making commitments about activity plans.
- Viewing real-time quantitative feedback about bodily movement.

6. System Design

In order to study the use of this device under naturalistic conditions, a complete *ViTo* prototype system was developed and deployed for evaluation in a home environment. At the present time, *ViTo* has been tailored for a single-user, single-television home. Although future versions will be enhanced to accommodate multiple users in more complex environments, the system described below represents the minimum apparatus needed to deploy *ViTo* for evaluation.

6.1 Hardware components

The major hardware components of *ViTo* are as follows:

- *ViTo* handheld: primary user interface device
 - Enables media control functions
 - Evaluates context of use for tailoring of message delivery
 - Delivers persuasive content
- *ViTo* server: back-end data processing and logging
 - Processes input from sensors and handheld PDA
 - Determines timing for delivery of proactive persuasive content
 - Transmits control commands to TV and home theatre
 - Stores and plays recorded digital audio

- Presents TV-based stimuli for interactive games
- Logs history of application use from PDA and server software
- Wearable sensors: detect, encode, and broadcast physical movement data
- Wearable sensor receiver: receives movement data from wearable sensors
- Desktop/laptop computer: enables customization of *Vito* content
 - Encoding music from compact discs
 - Managing to-do list items
- WiFi and Ethernet routers: provide interconnectivity among *Vito* devices
- Television/DVD player/home theatre system

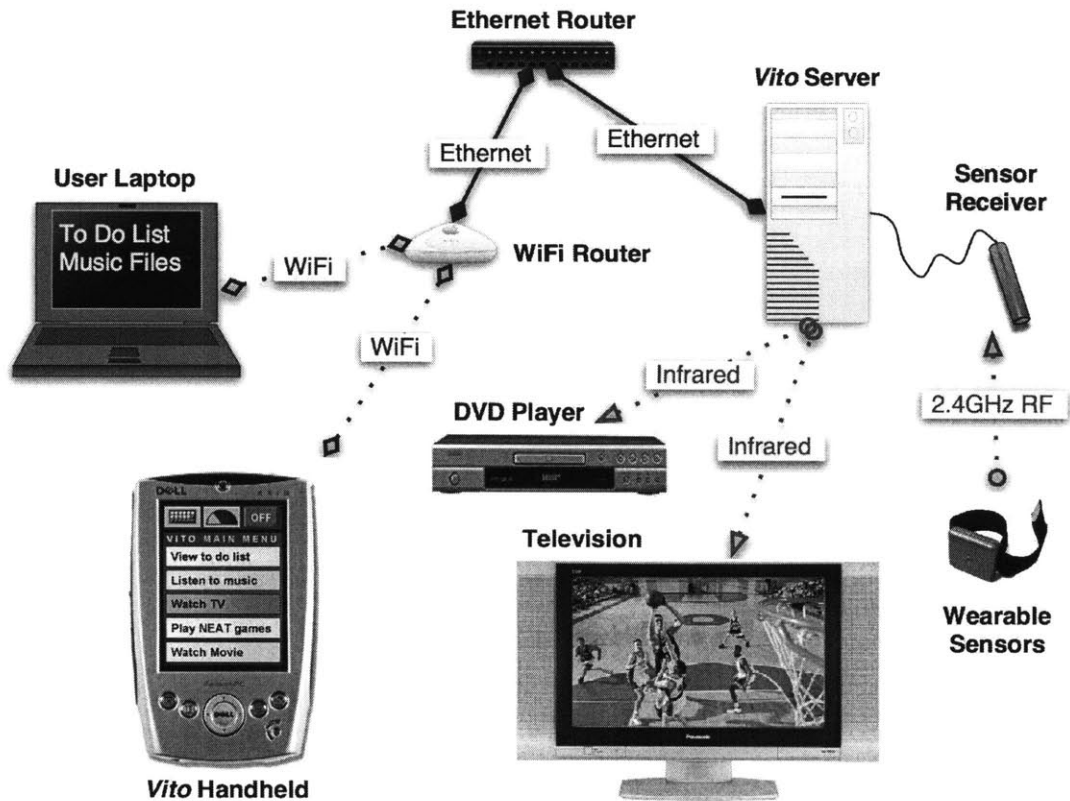


Figure 6-1: System design map
The major components of the *Vito* infrastructure and their interconnections.

The major components of the *ViTo* system and the communication path among them are illustrated in Figure 6-1. Figure 6-2 shows what information exchange occurs between these components.

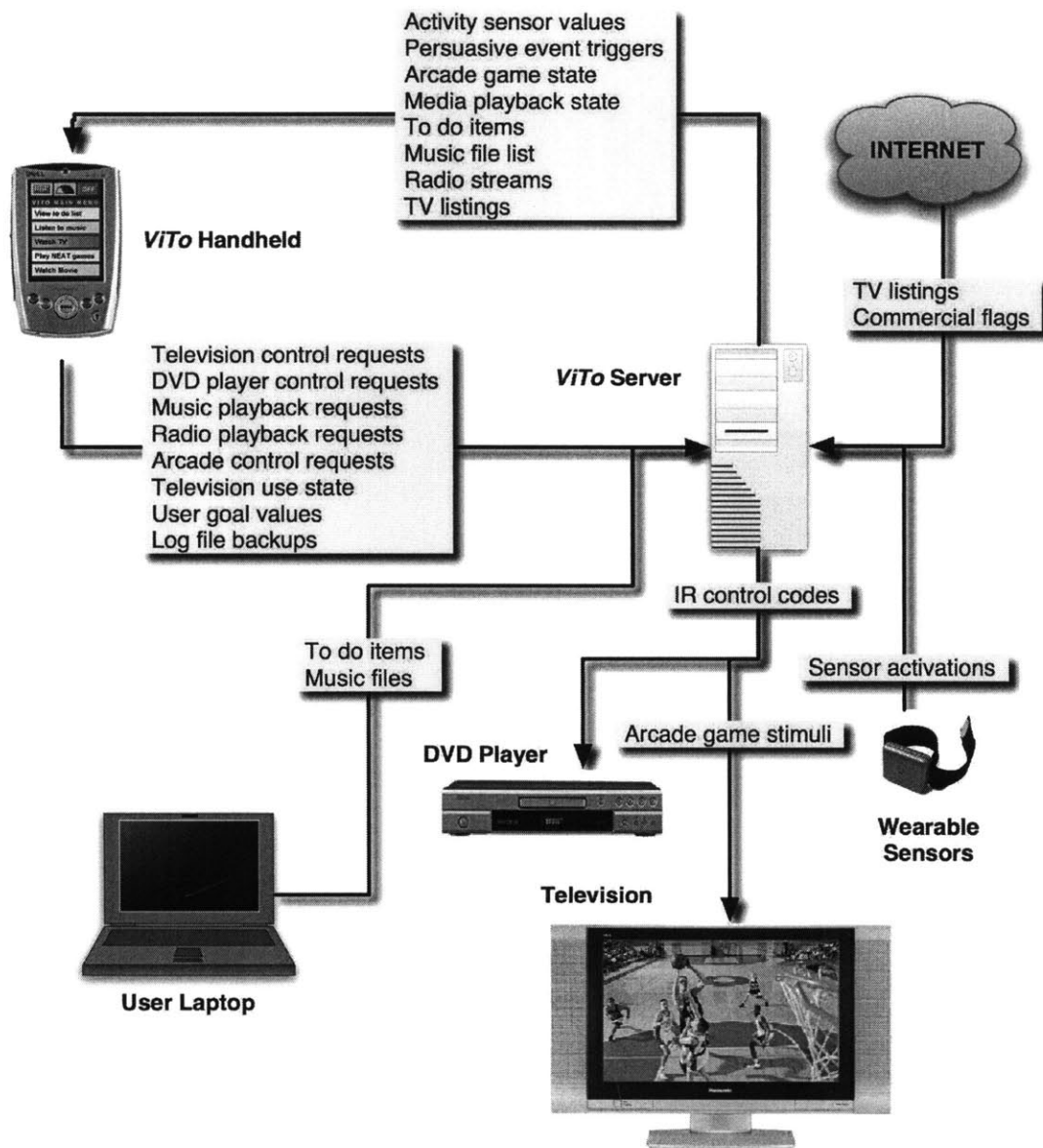


Figure 6-2: System information flow
Type and direction of information communicated between devices.

6.2 Software components

The main *ViTo* user interface is deployed as a single application on the handheld PDA. In addition to providing system control and persuasive content, this application logs user input for later data analysis purposes.

The *ViTo* Server runs five independent applets designed to encapsulate specific back-end functionality as follows. Images of the user interface for these applications are provided in Appendix B.

- *ViTo* Activity Server
 - Computes and tracks activity counts from wearable sensor receivers
 - Triggers persuasive strategies based on real-time calculation of activity features
- *ViTo* Media Server
 - Stores music library in MP3 format
 - Provides up-to-date library content listings to *ViTo* handheld
 - Plays back recorded music on request from *ViTo* handheld
 - Plays back streaming audio sources on request
- *ViTo* TV Controller
 - Learns infrared transmission codes from consumer-grade remote controls
 - Transmits appropriate codes based on commands received from *ViTo* handheld
- *ViTo* Arcade Server
 - Starts or stops interactive games on request from *ViTo* handheld or remote web service
 - Randomly selects game type and stimulus from a pre-defined library
 - Listens to activity data from wearable sensors and advances game accordingly
 - Weights game type selection and difficulty according to user history
- *ViTo* Commercial Server

- Reports current TV status to a remote server for manual detection of commercials
- Transmits remote commercial markers to *ViTo* handheld and Arcade Server

As a collection of discrete hardware and software components, the *ViTo* system is designed to be modular, flexible and extensible. Wherever possible, functionality has been encapsulated in ways that will allow future developers to easily add on to the basic components and to deploy the system on a variety of devices. The specific technologies used in the prototype installation are presented in Appendix C.

7. Interface Design

A key challenge to designers of behavior change applications is producing a technology that users might realistically adopt for an extended period of time. Relying on the user's internal motivation may work in some cases, but – particularly in the case of physical activity – the outlook is not promising. Consider, for example, the tendency of exercise equipment such as treadmills to be relegated to storage after a short period of time. Although owners of these products may wish to become more active, the inconvenience of using the equipment often obscures its value toward that end.

Vito is therefore designed to deploy its behavior change objectives on top of an otherwise value-adding mobile computing interface. The PDA form factor was chosen for *Vito* in part because it approximated that of a standard TV remote control. Anything larger would likely prove unwieldy and inconvenient. Anything smaller would introduce input/output limitations. Leveraging the features available on the PDA in order to provide a more satisfying experience was therefore a key objective of the design process. On the PDA, input options include both hardware buttons and a touch-sensitive color display. A combination of both input techniques is used in the final design. Those functions not directly relevant to the persuasive intent (i.e., power, volume up/down, and mute) were assigned to hardware buttons on the PDA faceplate. Operations related to content selection are conducted using a graphical user interface (GUI) on the touch-screen display. All graphical interface elements have been designed to accommodate finger input; no stylus is necessary. In order to address

the lack of confirmation feedback on touch screen devices, all input to the screen generates audible feedback in the form of a quiet clicking sound.

7.1 Main Menu

All of the primary capabilities enabled by this device can be accessed from the *ViTo Main Menu*, shown in Figure 7-1. Clicking on any of the five menu buttons initializes the television and home theatre system for that activity, and also calls up a sub-menu with further task-specific options.

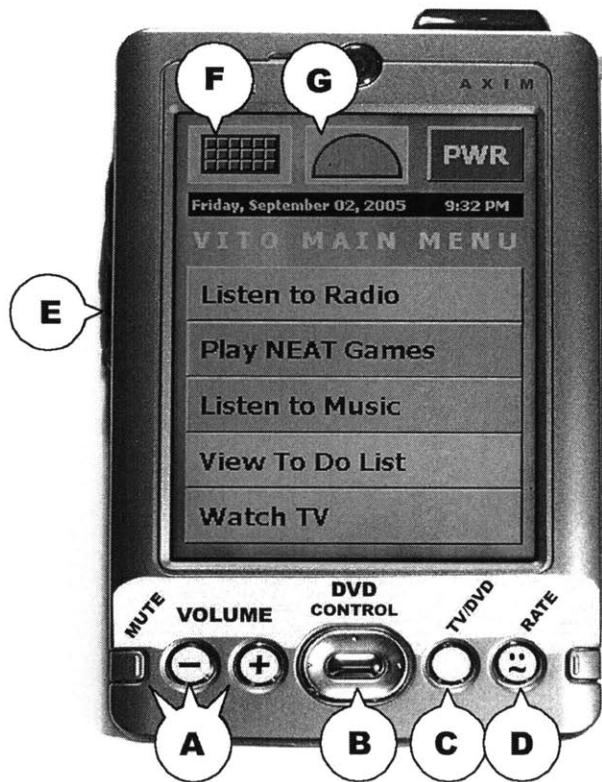


Figure 7-1: *ViTo* Main Menu
Callout markers 'A' through 'E' indicate hardware buttons implemented by *ViTo*. Marker 'F' shows the NEAT Meter and 'G' shows the TV Meter.

7.2 Watching television

The *ViTo Television Menu*, shown in Figure 7-2, provides a list that presents all of the programming choices available at the current time. By default, these programs are sorted alphabetically by name. The currently selected program appears highlighted in red, and two on-screen buttons allow the user to scroll through all of the pages in the list. When the user clicks on any of the other available programs, *ViTo* relays the appropriate channel information to the television tuner. Control of the of the home theatre's audio output is enabled through three hardware buttons (7-1A) that are accessible whenever the device is powered on, irrespective of its present mode. Another hardware button, (7-1C) is only functional when the *ViTo Television Menu* is active. Clicking this button activates the *Movie Menu* as shown in Figure 7-3. The on-screen interface provides basic control capabilities for a standard DVD video player. Navigation of the DVD's onscreen menu is enabled through the PDA's built-in directional pad (7-1B).

Clicking the "TV OFF" button from either the TV or DVD menu powers down the television/home theatre system and restores the *ViTo Main Menu*.

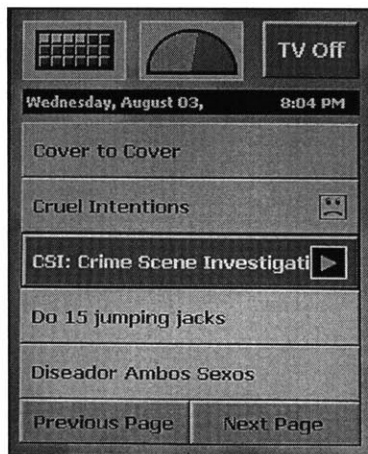


Figure 7-2: Television Menu

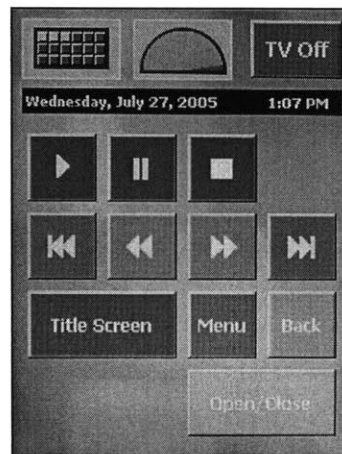


Figure 7-3: Movie Menu



Figure 7-4: Music Menu



Figure 7-5: Radio Menu

7.3 Listening to digital audio

The *ViTto Music Menu*, as depicted in Figure 7-4, provides access to a music library consisting of the user's legally acquired digital music files. The "look and feel" of this interface resembles that of the TV menu. All available music files are presented alphabetically according to artist's name and song title. When the user clicks on a new song, the selected file is highlighted in the list and played over the home theatre system. Successively clicking a track toggles between "play" and "pause" mode according to the state indicated by a playback status icon. When the current track ends, *ViTto* randomly selects and automatically plays another song from the music library. The user may at any time manually induce random play by nudging the "shuffle" switch on the side of the PDA (7-1E). Clicking the "MENU" button stops all currently playing music and restores the main menu.

Like the music menu, the *ViTto Radio Menu* shown in Figure 7-5 provides a means of accessing digital audio content through the home theatre system. A selection of streaming radio stations is provided in list format. Clicking on any of these causes the stream to commence playback. Clicking successively on a button pauses and restarts that stream. The behavior of the "MENU" button is identical to its function within the music menu.

7.4 Reviewing to do activities

Figure 7-6 shows the *ViTo To Do Menu*. This screen provides a list of activities that the user has indicated he or she would like to complete. Clicking on an item in this list calls up a separate, more detailed display that that presents the user's self-reported motivation for wishing to complete the activity. See Figure 7-7 for a sample screen. Due to limitations of input into the PDA, the content of the to-do list is managed through a desktop PC-based application as shown in Figure 7-8. Items entered here are automatically synchronized with the mobile device.

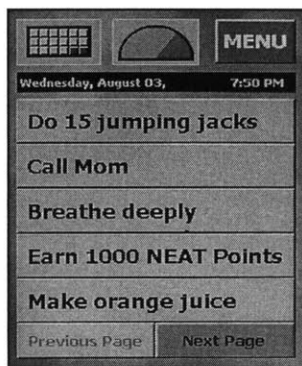


Figure 7-6: To Do Menu

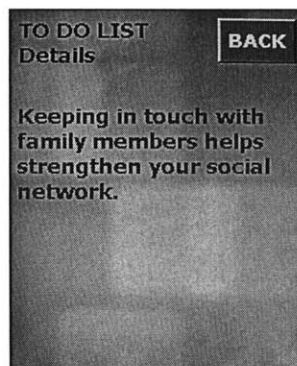


Figure 7-7: To Do Details

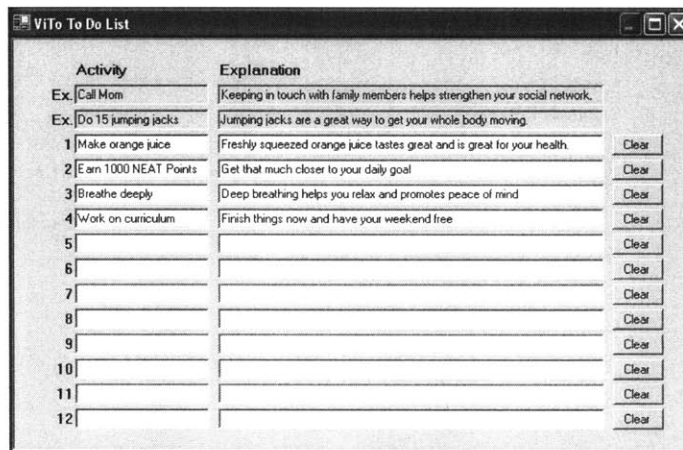


Figure 7-8: To Do List Desktop Application

7.5 Playing interactive games

The final option available from the main menu launches the *NEAT Arcade*. The NEAT Arcade consists of simple puzzle games that are displayed on the television screen. There are 4 basic game formats as shown in Appendix D. Each game begins with the presentation of provocative but incomplete information. As the user activates wearable movement sensors, he or she is rewarded with more information. An array of squares at the bottom the screen provides a meter representing the user's progress toward final resolution. Each square is successively illuminated until all 9 have been filled, at which time the final answer is delivered. The four NEAT games play out as follows:

- *Music Game*. Each game begins with 5 seconds of music played from the *ViT0* music library. Each successive step in the game meter delivers 5 more seconds of music. When the 9th square is attained, the song's artist and title are displayed on the screen, and the song plays until completion or until it is stopped by the user.
- *Trivia Game*. This template presents in textual format a question drawn from a trivia database. After the user completes all nine steps in the game meter, the NEAT Arcade delivers the answer to the question.
- *Zoom Game*. In this game, the user is presented with a highly magnified view of an image randomly selected from a photographic database. For each of the nine game steps, the photograph is shown with decreasing magnification until it has been completely revealed. At the ninth step, a description of the photograph is revealed on the screen.
- *Pixel Game*. This game is similar to the *Zoom Game*, except that photographs are shown initially blocky and unidentifiable. Each illuminated square in the game meter is associated with further resolution of the image until it is completely clear at step nine.

Figure 7-9 shows a user interacting with a Pixel Game. When the NEAT Arcade is active, a NEAT control screen (Figure 7-10) appears on the PDA and provides a real-time graph of

physical activity. Clicking on the “STOP” button at the top of the screen stops the current game and returns the PDA to the previous activity.



Figure 7-9: NEAT Arcade in action
Physical movement, such as running in place, advances game play.

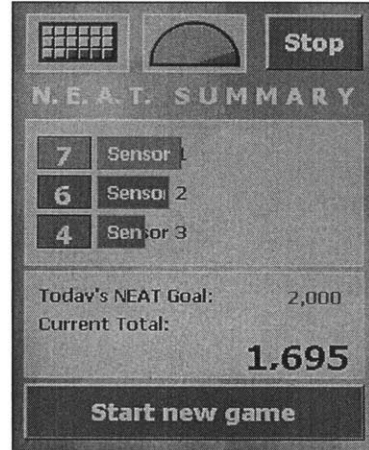


Figure 7-10: NEAT Screen
The bar graph reflects amount of movement instantaneously.

8. Persuasive Strategies

To date, a number of health-related applications have been designed explicitly for the delivery of persuasive behavior change strategies. For example, *Alcohol 101* [39] is a CD-ROM-based educational tool that uses simulation and other strategies to promote safe use of alcohol. Another example, *QuitNet* [40], is an online community that uses social support strategies to encourage smoking cessation. These applications typify the predominant approach to behavior change technologies: a stand-alone desktop computing interface distributed via CD-ROM or the Internet. The advantage of this approach is that such applications can be widely and economically deployed to potential users. The main disadvantage is that these technologies require that users be sufficiently motivated to stop most of their other everyday activities to launch and run the application for extended periods of time.

As discussed in Section 2, recent advances in mobile and context-aware computing technologies will now enable deployment of applications for health and well-being that integrate more realistically into everyday life. *Vito* is proposed as such a technology. What follows is a discussion of how *Vito* was designed to be persuasive and what specific strategies it employs.

8.1 Value integration

Vito's persuasive user interface elements are layered on top of the basic entertainment system functionality described in Section 7, and were designed to not obstruct the normal course of operation. By integrating behavior change strategies into an otherwise useful product, *Vito* achieves the goal of *value integration*, delivering persuasive content in a way that is always available but not disruptive to other activities enabled by the device.

8.2 Ease of use

The participative design and usability testing process described in Appendix A ultimately serves to prevent any irritating behaviors that might otherwise prompt the user to discontinue using the system. By offering a straightforward interface characterized by *ease of use*, *Vito* increases the likelihood that users will continue using the system after an initial trial period.

8.3 Convenience

Handheld computing devices provide a new level of mobile *convenience* [20] not possible with their desktop and even laptop predecessors. Persuasive devices that are small enough and mobile enough to accompany the user through their day-to-day lives stand a much greater chance of success than those that require directed effort to use.

8.4 Reduction

The principle of *reduction* [20] refers to the process of decreasing the complexity of a task in order to increase the likelihood that it will be performed. *Vito* reduces the complexity of using a television and home theatre system not to increase television viewing, but to increase the likelihood that the remote control device will be utilized in spite of any negative associations that might be naively ascribed to its persuasive intent.

ViTo attempts to meet the goal of reduction through the elimination of many features available on typical remote controls that are infrequently used during normal operation. Research from the field of human factors indicates that users typically utilize a small subset of the buttons available on a remote control devices [41], and further suggests that a simplified design would ultimately prove more usable and emotionally satisfying [42]. For the current implementation, *ViTo* performs a subset of the functions available on two separate remote controls. These are program selection, volume adjustment and muting, power switching, video source selection, and DVD navigation.

The principle of reduction is also employed toward the goal of promoting non-sedentary behavior through the encouragement of small incremental changes in physical activity rather than the more involved gym-style workout.

8.5 Tunneling

By amalgamating content selection features into a single display interface, *ViTo* is able to capitalize on the principle of *tunneling* [20], a strategy in which an interaction sequence is carefully laid out to provide maximal exposure to persuasive strategies. Through the course of using *ViTo* to control a television, the user is exposed to a series of interface elements—some static, some variable—that serve the device’s persuasive intent. Unlike a standard remote control device with one interface level, *ViTo* capitalizes on the sequential display of related interfaces to produce an interaction tunnel.

The first step in the interaction tunnel is the Main Menu screen shown in Figure 7-1. As the user navigates into the individual submenus, *ViTo* attempts to present persuasive content in a contextually relevant way. For example, a pre-commitment screen asking the user to specify how long he or she wishes to watch TV is presented prior to entering the Television Menu. Upon exiting the Television Menu, the user is presented with a feedback screen including a reminder of his or her intended viewing time.

8.6 Suggestion

One central strategy employed by *ViTo* is that of *suggestion* [20]. Many studies in experimental psychology have demonstrated that people can be biased toward a specific course of action through even very subtle cues, such as piped-in music in a supermarket [43] or appropriately placed prompts [44]. *ViTo* deploys this strategy through repeated exposure to other activities as alternatives to television viewing.

The Main Menu selection list (Figure 7-1) provides one example of this principle in action. Four alternative activities are presented on this screen. Because the Main Menu represents a pivotal point of decision in the viewing process, successfully intervening here could substantially reduce overall television use. Two of the distracter options, listening to music and listening to streaming radio, are relatively passive pursuits that would service the user's initial goal of relaxation. Unlike television viewing, however, these are not screen-linked, and therefore may be less likely to promote extended sedentary behavior. The other two distracters, a list of to-do items and a selection of NEAT games, are targeted at users who may have turned to television for lack of other activities to pursue. Reviewing the to-do list provides an option intended to appeal to the user's desire for better time management which ultimately serves to enhance feelings of self-efficacy. The NEAT games provide a low cost yet interesting opportunity to exercise one's body without a specific workout in mind.

ViTo again employs the principle of suggestion in the Television Menu. As shown in Figure 7-2 items randomly selected from the user's to-do list and music library are interspersed among the programs listed in the television menu. While the list is at first sparsely populated with distracters, if the device detects channel surfing (inferred from function of repeated channel changing), *ViTo* increases the number of alternatives presented. When the user clicks on a music track, the song plays through the TV. After that track finishes, *ViTo* asks the user if he would like to listen to more music instead of watching TV, another invocation of the principle of suggestion.

8.7 Encouraging incompatible behaviors

ViT0 uses prompting in an effort to *encourage incompatible behaviors* [45]. The alternative activities that are offered were selected because they are incompatible with watching TV (i.e. listening to music or radio), incompatible with sedentary behavior (i.e. NEAT games), or incompatible with passive behavior (i.e. to-do list tasks).

Research and intuition support the notion that giving users other activities to occupy their time will decrease the amount of time they spend watching TV [1]. The aforementioned principles of reduction and simplicity are employed toward this end, as *ViT0* provides the capabilities to easily transition away from watching TV into the alternative activity

8.8 Interrupting habitual behaviors

The activity suggestions in the Main Menu are designed to *interrupt habitual behavior* [46] as the user begins to watch television. Much of television viewing is habitual in nature, and experts in the remediation of bad habits recommend avoiding circumstances that permit the behavior to persist [47]. In order to prevent reflexive pressing of the “Watch TV” button, the order of items in the menu list is randomly shuffled upon each use. While this behavior may conflict somewhat with the ease of use principle, it represents a conscious trade-off of functionality.

ViT0 attempts to interrupt the habit of channel surfing through the removal of the channel up and channel down buttons that enable this behavior. By replacing these buttons with on screen program listings, *ViT0* delivers this option as a value-added proposition, rather than a coercive tactic. Whereas channel surfing relies on serendipity in the selection process, the program list interface encourages higher-level cognitive involvement. By using program titles as the basis for decision, the user may be more likely to select familiar content, thereby reducing exposure to new (and potentially seductive) programming.

8.9 Goal setting

In order to motivate individuals to take charge of their behavior change efforts, *ViTo* encourages short-term *goal setting* [45] for daily television and physical activity levels. According to scientists who study the psychology of motivation, setting concrete, achievable goals is an effective tool for behavior change since it helps orient the individual toward a single definable outcome. In contrast to vague objectives such as “getting more exercise,” *ViTo* promotes goals based on quantifiable values. Daily TV viewing goals are set according to the maximum amount of time the user wishes to watch television for the day. Physical activity goals are specified in terms of daily “NEAT Point” totals based on the number of wearable sensor activations. Figures 8-1 and 8-2 show prompting screens used to encourage goal setting for television viewing and physical activity.

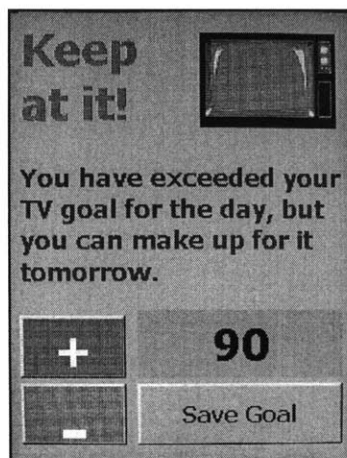


Figure 8-1: TV Prompt

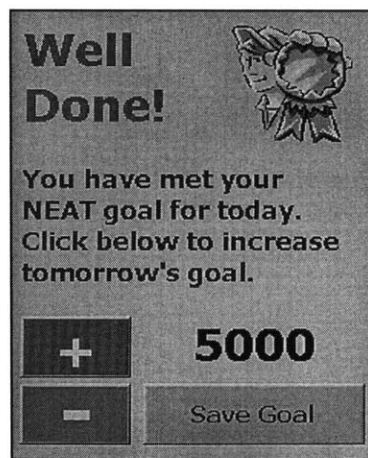


Figure 8-2: NEAT Prompt

8.10 Self-monitoring

At the top of the *ViTo* graphical user interface, the NEAT Meter (Figure 7-1F) and the TV Meter (7-1G) provide ready access to the user’s current state of progress toward their daily activity and viewing goals. These meters, which appear throughout the interface, are designed to present useful information in a way that can be quickly and easily decoded.

The NEAT Meter and TV Meter aid the overall persuasive goal of *self-monitoring* [20]. Much work in the behavioral sciences supports the notion that individuals who are motivated to change their behavior can do so more effectively when they are able to set goals and evaluate progress toward those goals [48]. For an “invisible” phenomenon such as sedentary behavior, tracking progress is challenging, since it does not lend itself to measurement. *Vitō* helps users overcome this limitation through the use of technology to tracking of bodily movement and time spent watching TV.

The TV Meter uses a visual analogy to a fuel gauge to represent the number of minutes the user has watched television as a function of his or her intended daily allowance. A full meter is entirely green, indicating that the user hasn’t watched TV for the day. The “needle” drifts counter-clockwise as the user expends minutes of TV watching. When less than 20% of the daily allowance remains, the meter turns red, providing a subtle advisory cue.

The NEAT Meter reflects the user’s current point count against their predetermined daily goal; each bright yellow square represents 1/18 of the goal. By allowing the user to evaluate his or her progress toward a goal, feedback is a key component of any behavior change process. Within *Vitō*, statistical feedback is readily accessible by clicking on the NEAT Meter or TV Meter. The NEAT Summary screen shown in Figure 7-10 provides real-time feedback about the user’s movement (see Section 8.11). The sensor status bar graph plots the most recent values received from each of the three wearable sensors.

The Viewing Summary screen, shown in Figure 8-3 offers feedback about the user’s inferred television watching for the day. Television viewers tend to underestimate the amount of time they spend in the activity [49], in part because session timing information is generally unavailable. *Vitō* attempts to address this issue by providing summary statistics in an easy-to-interpret format. It is expected that over time users may begin to recognize patterns in their viewing history and ultimately develop a more accurate model of their TV behavior. A numerical reminder of the daily goal is also provided.

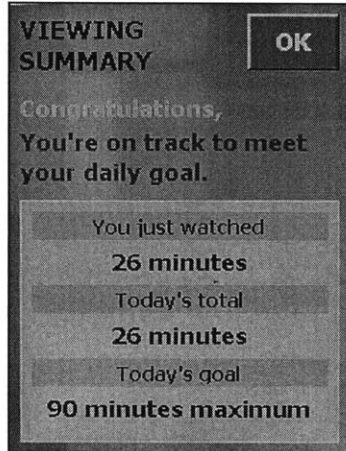


Figure 8-3: TV Summary

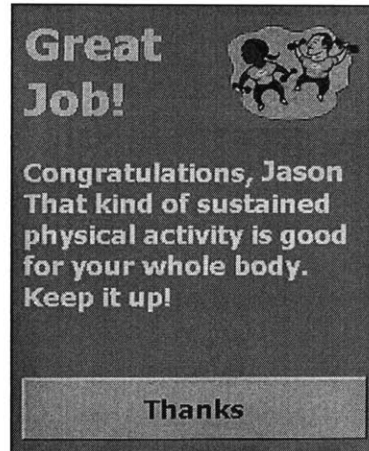


Figure 8-4: Workout Award

8.11 Proximal Feedback

As a general rule of behavior change, *proximal feedback* [48], that which occurs during or immediately after an activity, is more effective than distal feedback, which is temporally removed from the behavior. Computational technologies are particularly well suited to the task of providing timely feedback, as is illustrated by the real-time graphing display on the NEAT Summary page. In contrast to pedometers and other self-monitoring technologies for bodily movement, *ViTo* is not restricted to a specific kind of movement such as walking. Rather, it captures a detailed record of activity, including small NEAT-producing behaviors like fidgeting.

As part of an effort to elevate the user's awareness of the amount of movement involved in activities of daily living, the status graph is designed to provide a novel experience that may provoke the user's curiosity about their movement patterns. Research suggests that the appeal to novelty and curiosity may ultimately give an interface a seductive – and therefore more desirable – quality [50].

8.12 Operant conditioning

When the TV is powered down at the end of a viewing session, this event is always accompanied by audible feedback, a pleasing “whoosh!” sound that is intended to reinforce the act of turning off the television. This kind of association capitalizes on the principle of *operant conditioning*, the idea that a target behavior can be increased by pairing it with a rewarding stimulus [11]. Although there is no guarantee that the user will find the sound effect rewarding *per se*, its intent is to associate a stimulus with the act of turning off the TV, which is otherwise characterized only by the *removal* of a stimulus—a transition which is generally considered less desirable when the original stimulus is not aversive.

On a higher level, *ViTo* employs the principle of operant conditioning in its overall approach to encouraging behavior change. Progress made toward the goals of reducing TV viewing and increasing physical activity is rewarded with points and milestones as well as congratulatory displays. Section 8.13 discusses this in more detail.

8.13 Positive reinforcement

Although conditioning may use negative reinforcement (punishment) to shape behavior, this approach is generally avoided in *ViTo*, since it would violate the objective of providing a pleasurable experience for the user. *Positive reinforcement* [51], however, is used extensively throughout the interface. For example, the Viewing Summary screen (Figure 8-3) features a text-based motivational message such as “Congratulations! You’re on track to meet your daily goal” which is designed to reward users who remain below their daily maximum viewing goal. Additional reward messages are presented occasionally in response to desirable behaviors, such as sustained activation of wearable sensors. For this behavior, the user might receive the Workout Award shown in Figure 8-4.

8.14 Variable reinforcement

Intended to selectively strengthen certain kinds of user behavior, reward screens are delivered on a *variable reinforcement* [52] schedule in which their appearance is not predictable. Research suggests that varying the predictability of a reward is an effective tool for maintaining an existing target behavior [45]. Therefore, although the Workout Award and other rewards are based on thresholds of acceleration data, exactly what kind of movement will earn this reward is not deterministic.

Using a variable reinforcement schedule also serves *ViTo*'s goal of reducing habituation to the persuasive messages it employs. Each of the activity based reward messages is subject to a time-out between presentations in order to reduce the overall number and frequency of exposures. Thus, while a user may exceed a reward threshold several times a day, he or she will only receive the message screen once or twice.

8.15 Shaping

The concept of *shaping* [53] is an approach to conditioning that focuses on transforming a pre-existing behavior into a more desirable one. *Shaping* is a fundamental aspect of *ViTo*'s strategy for increasing the user's physical activity. Persuasive elements such as rewards that respond to bodily movement are designed to automatically increase their activation threshold for each successive exposure. In practice, this means that the user must work slightly harder to earn each reward. Experts in the art and science of behavior modification suggest that small incremental changes are the most effective for shaping, so *ViTo* uses a +1% threshold adjustment for each successful delivery.

The NEAT Arcade (Section 7.5) provides an example of how this works: although the successful resolution of each game requires illumination of 9 squares, the number of sensor activations needed to illuminate each square increases by 1% with each successfully completed game. Over time, it is expected that the imperceptible increases in activity will accumulate and have a measurable impact on the user's daily NEAT Point average.

8.16 Clicker training

Clicker training [45] is a behavior shaping technique that uses operant conditioning and successive approximations to extend and refine existing behaviors. Popular among animal trainers, this technique involves the use of a cue stimulus, typically an audible click, to mark each time the animal makes progress toward the desired outcome. By associating clicks with the promise of a reward, trainers have been able to teach complex new behaviors with remarkable speed.

VitO uses a form of computer-assisted clicker training in an effort to encourage users to move their bodies even briefly when they would otherwise be idle. The marker stimulus produced by the PDA is a recorded clicking sound intended to notify the user that he or she has done something positive. A succession of 3 or more clicks is rewarded by a chiming sound. All clicker training sounds are accompanied by a flashing icon on the *VitO* handheld interface.

The clicker training procedure uses data from the wearable sensors to detect when the user has been idle for five minutes. At such a time, the device enters a training mode wherein it will reinforce any measurable movement with a click. After the first click, the user has up to 30 seconds to earn two additional clicks in order to receive the reward chime.

If no movement input is detected during the five-minute training mode, *VitO* will deliver the first click proactively. All of the parameters for clicker training (movement threshold, number of clicks, reinforcement time window) are adjusted by $\pm 1\%$ for each successful training episode. After each episode, a minimum timeout of 30 minutes when watching TV and 60 minutes otherwise is activated to prevent overexposure to this feature.

The overall goal of the clicker training procedure is to help users integrate small amounts of moment into otherwise sedentary behaviors, such as watching TV, using a computer, or reading. At baseline thresholds, simply standing up and sitting back down is sufficient to earn the clicker training reward.

8.17 Intrinsic motivation

Psychologists and scientists who study human behavior generally identify *intrinsic motivation* [54] as one of the most powerful forces for generating and sustaining interest in an activity. Malone and Tepper [55] suggest that incorporating elements of challenge, curiosity, and control into an activity will be effective in appealing to a user's intrinsic motivation. The NEAT Arcade (Section 7.5) component of the *ViTo* system was explicitly designed with this goal in mind. NEAT Games incorporate the characteristics of intrinsically motivating activities as follows:

- Goals
 - The goal of each game is to reveal hidden information over time
 - NEAT Games help users earn NEAT Points toward their daily goal
- Uncertainty
 - The type of game selected is determined at random
 - The resolution or answer to the game stimulus is withheld until the end
 - Difficulty of games is variable and increases over time
- Feedback
 - Stimulus delivery serves as built-in feedback
 - Status bar provides an estimate of progress toward completing each game
- Self-Esteem
 - Textual positive reinforcement is displayed at the top of the display screen
- Relevance
 - Game stimuli are selected according to user preferences on a questionnaire

Wherever possible, these attributes were also reflected in the design of the complete *ViTo* system. As another example, the NEAT Feedback meter (Section 8.7) is designed to engage curiosity and exploration, both central components of intrinsic motivation.

8.18 Consistency

Intrinsic motivation also operates on an interpersonal basis. One aspect of this phenomenon is an individual's desire to control his or her public image in service of self-esteem. Social scientists have demonstrated that this tendency can be effectively employed in service of compliance gaining in a variety of situations [56]. The desire of individuals to demonstrate *consistency* between what they say and do is routinely exploited by con artists and salespeople alike.

ViT0 employs this principle through the user of a pre-commitment strategy [57]. The Commitment Screen show in Figure 8-5 appears each time the user indicates he or she would like to watch television, and prompts the user to specify how long he or she plans to watch. A response must be provided before the remote control will activate the television. A simple two-button interface allows specification of viewing time in increments of 10 minutes. This method was selected to permit rapid input, and to subtly discourage long viewing periods by requiring a long chain of repeated button presses.

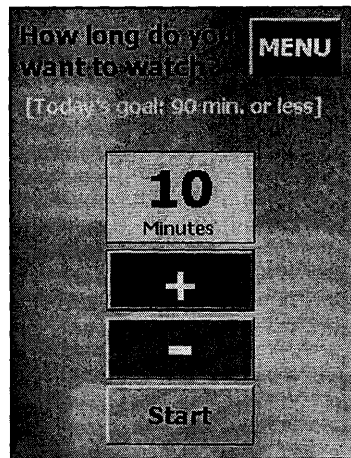


Figure 8-5: Commitment Screen



Figure 8-6: Reminder Screen

The principle of consistency operates on two levels in this interaction. First, because many people hold the opinion that watching too much television is inherently bad [10], their desire to demonstrate consistency between their beliefs and actions is likely to bias responses

toward shorter viewing periods. Second, by asking the user to specify his or her intended viewing duration up front, *ViT0* establishes an implicit agreement with the user, whose desire to demonstrate consistency may dispose him or her to stop watching after the period has elapsed. At that time, *ViT0* gently prompts the user to keep watching or to turn off the television with the Reminder Screen shown in Figure 8-6. Because much unintended television viewing occurs when the user is tempted into watching additional programming after their initial selection has ended, shutting off the TV at this time could reduce overall viewing time substantially.

In order to capture the user's attention, a non-intrusive chiming sound is produced every 15 seconds until a response is received, or until 3 minutes have elapsed. Clicking on the "Keep watching" button results in the reappearance of the original Commitment Screen. If *ViT0* receives no response in that time, it will shut off the TV automatically. While this action may appear slightly coercive, it is likely that users tolerate this sort of prompting because it depends on a contingency with their own input. Moreover, since the users have actively committed to a specific viewing duration, they may actually welcome the reminder.

One final implementation of the consistency principle relates to the use of a quality rating scale for content and activities supported by *ViT0*. The Feedback Screen shown in Figure 8-7 allows the user to rate content on a five-point scale using affective icons. This interface is delivered proactively in an experience sampling method (ESM) paradigm [58] in order to build up a ratings database; it can also be invoked manually by clicking the button indicated in Figure 7-1D. The user's responses are subsequently integrated into the menu grid for future reference as in Figures 7-2 and 7-4. During television viewing, sampling prompts are delivered at 23 and 53 minutes past the hour, when viewing affect is hypothesized to be lowest (though further study on this point is required). It is speculated that the user's desire to demonstrate consistency and discernment in choice of activities, will bias selection away from low-rated content in favor of more highly rated activities.

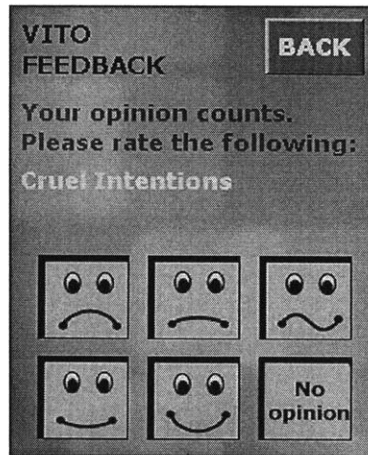


Figure 8-7: Feedback Screen

8.19 Normative influence

Another socially oriented persuasive principle employed by *Vito* is that of *normative influence* [20]. More commonly known as “peer pressure” this phenomenon relates to the use of social signals in order to decide what is an appropriate course of action. This form of leading by example is used in the *Vito* To Do List desktop interface shown in Figure 7-8. In an effort to encourage users to reflect on larger, lifestyle related behaviors rather than discrete tasks to be completed, the To Do List is seeded with examples such as: “Call Mom [because] Keeping in touch with family members helps strengthen your social network.”

8.20 Optimal timing

As noted in the discussion of design challenges for persuasive behavior change applications, a likely factor in the overall success of *Vito* will lie in its ability to deliver behavior change strategies at the right time and place to influence the user’s decision-making process (Section 4.2).

As a mobile technology, *Vito* achieves the goal of optimal placement through its ubiquity—the ability to be anywhere at any time. The objective of optimal timing is serviced through the presentation of persuasive content at critical transition points: deciding to watch TV,

deciding what to watch, onset of commercial breaks, end of commitment period, turning off TV, and achievement of goals. A discussion of these follows.

- *Deciding to watch TV.* When the user decides to watch TV, he or she is presented with the Main Menu, where feedback in the form of the NEAT Meter and TV Meter is always available. A randomly ordered list of alternative options is also presented. The pre-commitment strategy for how long to watch is also inserted at this point in an effort to facilitate more closed-ended viewing sessions.
- *Deciding what to watch.* Alternative activity suggestions, quality ratings, and feedback on viewing time are all presented to the user as he or she reviews the program listings.
- *Onset of commercial breaks.* Using a private web site interface that reports the TV station the participant is watching, a remote operator watched the same programs as the participant, and flagged when commercials breaks began and ended. At these time, *ViT0* switched automatically into NEAT Arcade mode. This serves three major purposes: (1) to prevent channel surfing by providing an interesting distraction (2) to prevent exposure to advertisements for upcoming programs (3) to frame the commercial break as an opportunity to engage in physical activity. By entering NEAT Arcade mode, the system also opens the possibility that users will continue playing games and not return to watching television at the offset of the commercial break.
- *End of commitment period.* As noted in Section 8.18, users may be receptive to reminders to stop watching TV if they have made a prior commitment to a specific duration. By presenting a reminder at the moment the committed period expires, the system exploits the consistency principle at its most salient point.
- *Turning off TV.* As they turn off the TV, users are likely to be maximally aware of their affective response to the time they just spent watching. By presenting statistical feedback at this time, *ViT0* may help users create a better understanding of how their experience correlates with viewing duration.

- *Achievement of goals.* When the user achieves a NEAT Goal or exceeds a TV Goal, *ViTo* acknowledges this and provides an opportunity to revise future goals. It is anticipated that the user's goal revisions will be influenced by their emotional response to current message – NEAT Goals should increase while TV Goals should decrease.

8.21 Strategies avoided

The option to produce a device that nags, punishes, or otherwise inconveniences the user was expressly avoided in this work. Although coercive strategies such as negative reinforcement or obstruction might result in short term behavior change, the possibility that users would tolerate this form of intervention is extremely low. As a rule, people prefer to avoid situations where they are subject to authoritarian tactics, and certainly would not want a technology that tells them what to do.

9. Evaluation

The ultimate objective in evaluating any technology intended to motivate behavior change should be to establish its efficacy in producing the desired outcome. In cases such as *ViTo* where the goal is long-term lifestyle change, a complete evaluation is inherently time and resource intensive. A thorough investigation would require multiple participants to use the device in naturalistic settings over the course of months or years. Due to the practical constraints on conducting such an investigation, an initial short-term case study approach has been undertaken to explore user reaction to the device and to provide a preliminary dataset that may serve as justification for further study.

The *ViTo* case study involved deployment of the system in a specially instrumented research apartment known as the *PlaceLab*^{*} [19]. The *PlaceLab* is a one-bedroom apartment located in a residential neighborhood of Cambridge, MA. This facility had been designed to allow academic and industry researchers the opportunity to collect rich datasets about the lives people lead at home. For the current study, data from audio and video recordings, as well as several low-bandwidth environmental sensors, were used to identify and evaluate behaviors of relevance to the current project.

One participant, a 33-year-old male elementary school teacher, was selected to live in the *PlaceLab* for a total of 14 days. The selected participant was identified from a database of

* The *PlaceLab* is an MIT House_n and TIAX, LLC collaborative initiative.

potential *PlaceLab* volunteers who had responded to a community recruitment effort using materials such as the flyer shown in Appendix E. Inclusion and exclusion criteria for the present study were as follows:

- Participant is at least 18 years of age
- Participant maintains a permanent residence in the local metropolitan community
- Participant lives alone at the above residence
- Participant is not a student or employee of the principal investigator's sponsoring institution
- Participant is willing to use the research apartment as his or her primary residence during the study
- Participant reports watching television for at least one hour per day.

The selected individual was recruited to participate in a larger study of life in residential environments, for which prior institutional review board (IRB) approval had been granted (see Appendix F). Following the procedures outlined in the IRB application, informed consent was secured from the participant.

In collaboration with other researchers using the *PlaceLab* facility, the following schedule was determined:

- 7 days in the *PlaceLab* for baseline data collection with a non-persuasive remote control (Figure 9-1)
- 12 days at his permanent residence with a portable kit of sensors
- 7 days in the *PlaceLab* for intervention data collection with the *ViTo* persuasive remote control



Figure 9-1: Non-persuasive remote control

This device features three interaction screens that were designed to resemble the *Vitò* interface but offer only standard remote control features.

Prior to beginning the study, the participant was issued a series of questionnaires designed to elicit information about his media use patterns, for example:

- What television programs do you watch regularly?
 - Name:
 - Network:
 - Time:
 - Duration:
- How many televisions do you have in your home?
- When are you most likely to listen to music?
 - While at home
 - While at work
 - While commuting (e.g. in the car)
 - During some other activity outside the house (e.g. jogging)

The complete survey is included in Appendix G. Participant responses were later combined with observational data from the baseline *PlaceLab* study to tailor the *ViTo* system to his lifestyle for the intervention phase.

In order to ensure experimental control, a researcher experienced in working with human subjects was present at the start of the study to explain the study procedure. The participant was informed that he would be involved in research about everyday activity, and that while he was staying in the *PlaceLab* he would be testing an experimental remote control to for the TV and home theatre system. The baseline device shown in Figure 9-1 was specifically designed to resemble *ViTo* but did not deploy persuasive strategies. For the intervention phase, the participant was issued the complete *ViTo* system described in this document. A second researcher was again present to introduce the device and ensure that the principal investigator would not inadvertently bias the user. For this phase, the participant was informed that he would again be testing an experimental remote control, and that his opinions about the device would be discussed in a post-study interview. To control for potential placebo effects, the participant was not instructed that this was a study of behavior changes related to television viewing and physical activity. While it is possible that the participant may have been able to infer the intent of this research, his post-study responses discussed in Section 11 do not clearly support that possibility.

Both prototype remote control devices used in this research have been built with logging capabilities that enable generation of quantitative data sets that are easily integrated with concurrent *PlaceLab* data. For the qualitative portion of the system evaluation, video and audio recordings from the *PlaceLab* were reviewed to better understand the contextual factors that may have affected the user's behavior. Observations from the qualitative investigation were also used to construct a post-study interview questionnaire intended to gauge user's reaction to specific features of the device with questions such as the following (see Appendix H for the full questionnaire):

- During your first stay at the *PlaceLab*, on how many separate occasions did you listen to music? During your second?

- Tell me about some of the differences between the remote control software you used during your first stay and your second stay.
- How many times did the TV remote control ask you to rate a program while you were watching it?
- If you were going to tell a friend about this study, how would you describe it?

The goal of the quantitative analysis is to address issues of reliability and validity in measuring behavior change outcomes. While no definitive conclusions should be drawn from data produced in this single-user case study, several key questions relevant to future long-term evaluations are investigated:

- Do *Vito's* inferences about television viewing duration correspond to observations based on video annotation and audio annotation?
- What type of media did the participant use, and how often?
 - Television
 - DVD/Movie
 - Music/Radio
- Were there meaningful differences in viewing duration between baseline and experimental phases?
- Were there meaningful differences in channel surfing behavior between conditions?
- Do *Vito's* measures of physical activity (NEAT Points) correspond to observable movements according to video annotation?
- How often and in what manner did the participant use each of the implemented persuasive strategies during the study?
- Was there any measurable falloff of use of various persuasive strategies?
- How did the participant respond to the goal setting strategies, such as commitment?

The next section addresses these questions first with data from the experimental procedure described above. A discussion of these results with reference to more qualitative observations based on audio-video recordings and interview data follows thereafter.

10. Results

Because each *PlaceLab* stay began and ended midday, the first and last half days of each study were not included in the final analysis. Each experimental phase therefore produced 6 days of data (Monday through Saturday).

10.1 Quantitative results

The experimental design used in this evaluation is intended to serve as a pilot study for a larger multi-subject investigation as described in Appendix J. Although data collected during the case study evaluation are presented quantitatively, caution should be exercised in drawing conclusions from this data. As is typical of small-*n* research designs, effects of intervention may be confounded the participant's temperament and motivation as well as other situational factors. Section 11 presents a discussion of some of the factors relevant to the interpretation of these data.

10.1.1 Media use

Figure 10-1 shows media usage patterns during the participant's stay at the *PlaceLab*. The shaded areas represent activity blocks determined through audio and video review. Vertical tick marks represent a change of channel on the TV.

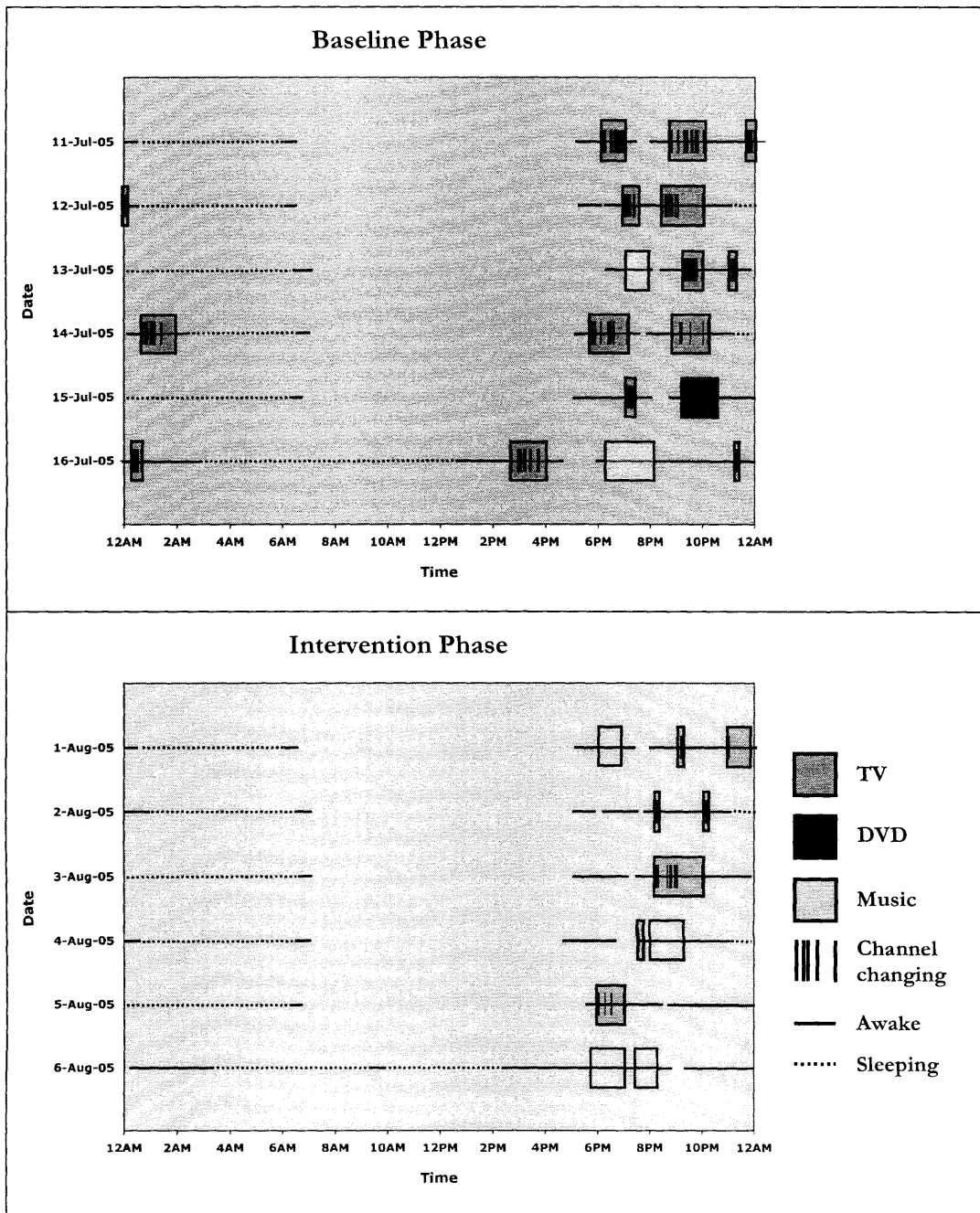


Figure 10-1: Media use timeline

Time series plots show use of media technologies during baseline and intervention phases. Colored blocks indicate type of use. Vertical tick marks represent transmission of control codes for selecting media content. Solid horizontal lines represent time spent in the *PlaceLab*. Dashed lines indicate sleeping.

For this quantitative analysis, only whether the state (i.e., on/off) of the television and audio systems is assessed; no claims are made about the user’s actual consumption of the media, since the goal of reducing overall television use is best serviced by a reduction in the total amount of time the TV is turned on. Most television programming is explicitly designed to provide a visually and aurally compelling experience, and as a result readily captures the attention of would-be viewers [59]. Although the use of TV as “background noise” is a common practice in many homes, the possibility that it will lead into more sedentary viewing behavior is a risk worth avoiding.

Baseline Phase				Intervention Phase			
Date	Day	TV (hours)	Music (hours)	Date	Day	TV (hours)	Music (hours)
11-Jul-2005	Mon	2:43:02		1-Aug-2005	Mon	0:53:40	0:50:51
12-Jul-2005	Tue	2:08:26		2-Aug-2005	Tue	0:14:20	
13-Jul-2005	Wed	1:00:00	0:50:00	3-Aug-2005	Wed	1:49:04	
14-Jul-2005	Thu	4:02:24		4-Aug-2005	Thu	0:11:21	1:15:10
15-Jul-2005	Fri	1:40:11		5-Aug-2005	Fri	1:00:04	
16-Jul-2005	Sat	1:43:53	1:51:48	6-Aug-2005	Sat		2:14:30
Total		11:58:49	2:41:48	Total		4:08:29	4:20:11
Mean		2:13:02	N/A	Mean		0:41:28	N/A

Table 10-1: Media use distribution
Comparison of television and music use totals between baseline and intervention phases of the study.

The media use distribution is presented quantitatively in Table 10-1. Media use during the baseline stay was roughly consistent with the participant’s self-reported responses on a pre-study questionnaire. He reported watching 1-2 hours of television per day and 2-3 DVD movies per week. In a post-study interview, the participant speculated that the lack of access to his movie collection during his stay at the PlaceLab may have translated into more broadcast TV watching. On the pre-study questionnaire, the participant reported listening to music approximately one hour per day. In the post-study questionnaire, he reported bringing a dozen or more compact discs to the *PlaceLab*, but only listening to 3-4 of them.

One-way analysis of variance (ANOVA) was used to test the hypotheses that television use would decrease during the intervention week and that music use would increase. The results

of this test are presented in Table 10-2. This analysis revealed a significant ($p < 0.05$; 2-tailed $p < 0.05$) difference in viewing time between the two conditions. Small sample size and limited number of observations restrict the extent to which this finding can be generalized, as discussed in Section 11. Nevertheless this result supports the main hypothesis that individuals using the *ViT0* system will experience less overall exposure to television. Although the participant also listened to more music when using the *ViT0* system during the intervention phase, this difference was not found to be significant.

Mean daily media use in minutes		
Phase	TV	Music
Baseline	133	54.27
Intervention	41	65.43
	F (1,11) = 8.79	F (1,4) = 0.9
	p < 0.05	n.s.

Table 10-2: Media use ANOVA
One-way analysis of variance for differences in media use between baseline and intervention.

10.1.2 Channel surfing

One of the ways *ViT0* is intended to curb television viewing is by reducing the amount of channel surfing the user engages in. For this analysis, channel surfing is operationally defined as the number of TV channels displayed over a unit time. To measure channel surfing, the *ViT0* server system recorded all control codes sent to the television tuner during both conditions. Channels displayed were identified by the following codes: “channel up,” “channel down,” and a 2-digit numeric dyad such as “04”. Table 10-3 shows the comparison of channel display counts across conditions.

As shown in Table 10-4, one-way ANOVA reveals a significant ($p < 0.01$; 2-tailed $p < 0.01$) difference in the number of channels displayed per minute of television watched. Although this result should also be viewed cautiously given a sample size of $n = 1$, it supports the secondary hypothesis that channel surfing behavior will be reduced through the use of content-based program selection. Within the current case study, the reduction of channel

surfing may in part explain the main effects of reduced television viewing, since it necessarily reduces the number of potential programs the viewer may be enticed into watching.

Baseline Phase					Intervention Phase				
Date	Day	TV (min.)	# chan.	Chan. /min.	Date	Day	TV (min.)	# chan.	Chan. /min.
11-July	Mon	163	399	2.447	1-Aug	Mon	53	14	0.264
12-July	Tue	128	232	1.812	2-Aug	Tue	14	15	1.071
13-July	Wed	60	194	3.233	3-Aug	Wed	109	21	0.192
14-July	Thu	242	250	1.033	4-Aug	Thu	11	6	0.545
15-July	Fri	20	88	4.400	5-Aug	Fri	60	17	0.283
16-July	Sat	103	206	2.000	6-Aug	Sat	0	0	0
Total		716	1369		Total		247	75	

Table 10-3: TV channel surfing distribution
Comparison of the number of channels displayed on the television between baseline and intervention phases.

Phase	Channels per minute of TV
Baseline	1.91
Intervention	0.29
F (1,11) = 14.03	
p < 0.01	

Table 10-4: Channel surfing ANOVA
One-way analysis of variance for differences in channel display counts by phase.

10.1.3 Physical activity

While the goal of reducing an individual's exposure to television programming may have merits on its own, the greater objective of improving an individual's long-term wellness forecast is better served if a corresponding increase in physical activity is also produced. Utilizing inexpensive wireless wearable acceleration sensors, *ViTo* deployed a series of strategies to detect and increase low-exertion physical activity.

Due to technical failure* during the baseline phase of this study, no physical activity counts (NEAT Points) were collected for the first week, rendering analysis of intervention effects impossible. However, substantial variation exists in the movement data for the intervention phase, enabling useful qualitative analysis of how *Vito* intervention strategies may impact physical activity levels. Figure 10-2 shows time-series plots of accumulated NEAT Points for each of the six days in the intervention phase. Values are only available for times when the participant was in the *PlaceLab*.

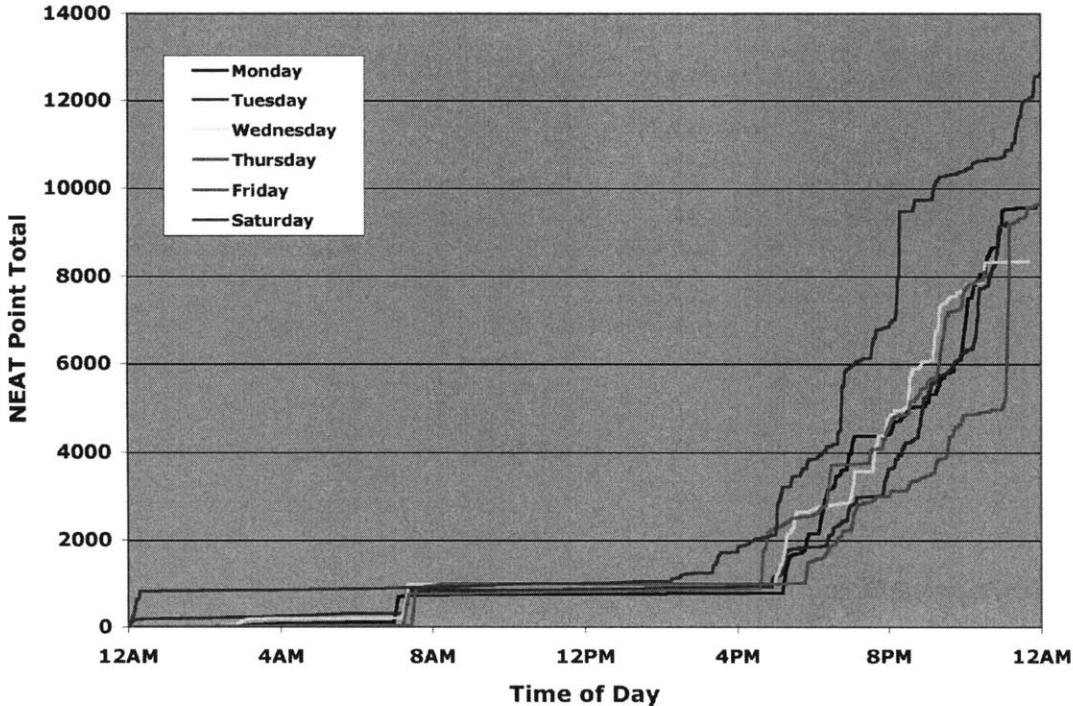


Figure 10-2: Daily NEAT Point totals
Each line represents the accumulation of NEAT Points over the course of a day. Low slope (horizontal) regions indicate that the sensors are idle or not within range of the *PlaceLab* receivers. High slope (vertical) regions suggest intensive physical activity.

* Participant improperly inserted batteries into wearable sensors.

According to this graph, the participant exhibited consistent daily living patterns from Monday through Friday. The plateaus from 12AM to 7AM and 7AM to 5PM represent sleeping and working outside the home respectively. The evening hours show varying levels of activity, including periods of rapid rise that suggest intensive activity.

Figure 10-3 presents a closer examination of physical movement data during the evening hours. Each black or white dot represents a reading from the wearable sensors. Clusters of points suggest sustained activity, with higher points indicating rapid, vigorous movement of the sensors.

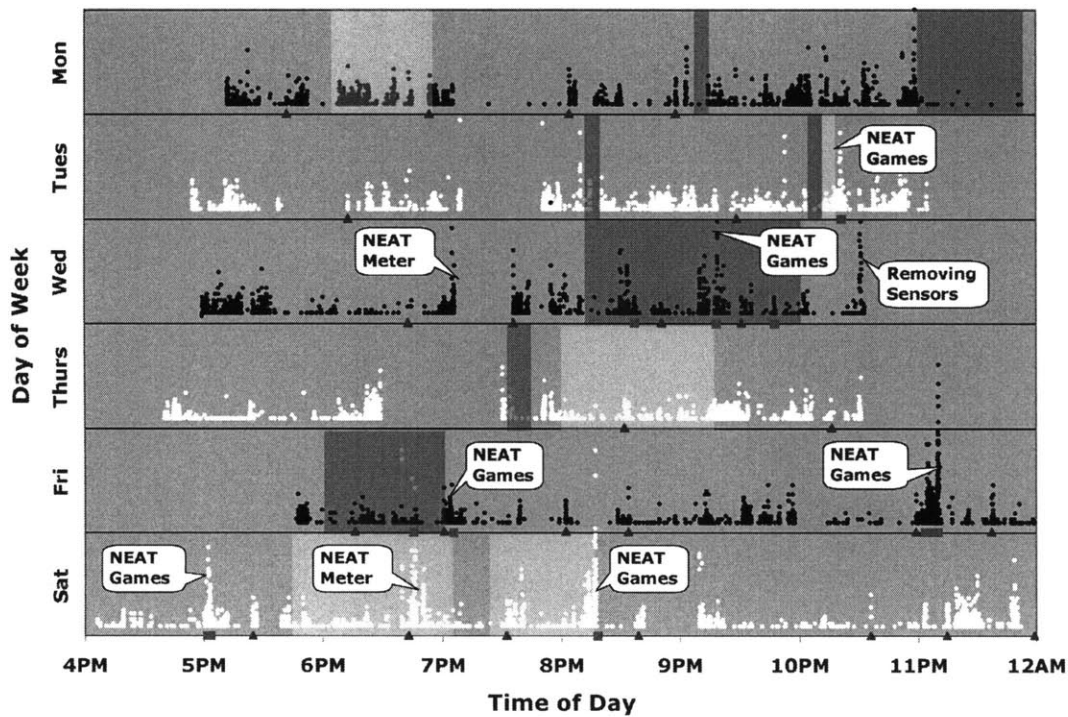


Figure 10-3: Evening activity plots

Instantaneous NEAT Point counts are plotted as dots across the evening hours by day. Clusters of points represent sustained activity. Tall peaks indicate rapid movement. Media use blocks are overlaid for TV viewing (blue/dark) and music listening (yellow/light). Red triangles indicate delivery of clicker training stimuli. Green squares indicate NEAT Games. Activity peaks were manually labeled with observations from video recordings.

Figure 10-3 also begins to show how some of the persuasive elements played out during the *Vito* intervention phase. Periods of intense movement were compared against *PlaceLab* video recordings to determine what activities they were associated with. The areas marked *NEAT Meter* indicate that the participant was actively holding the PDA as he moved around the apartment engaging in different kinds of physical activity. Video review confirmed the participant's report in the post-study interview that on several occasions he used the NEAT Meter to understand how his movement affected NEAT Point totals.

The graph in Figure 10-3 also illustrates the effect of NEAT Games on the participant's activity levels. In the post-study interview, he responded favorably to the novelty of a whole-body game interface, and reported using a variety of movements such as dancing to advance the game play. Overall, activity levels tended to spike sharply during NEAT Games.

The series of triangular markers running across the X-axes in the evening activity plot indicate the delivery of clicker training stimuli (see Section 8.16). The activity totals immediately following the clicker stimuli tend to correlate with a momentary spike in NEAT Points, suggesting that the intervention did have an effect on user behavior.

10.2 Qualitative results

In order to better understand how the participant used and responded to the *Vito* system, the post-study interview was designed to elicit the user's feedback about the persuasive interface elements he encountered. At the time of this conversation, the participant had not yet been explained the intent of the study. The researcher who conducted the interview had previously interacted with the participant, and summarized some of his traits that may be relevant to interpretation of these results as follows (see Appendix I for the complete summary):

“I would describe the participant as upbeat, high-energy, and accommodating ... [He] expressed strong affinity for new technologies or gadgets [and] was accommodating when given study requirements ... on several occasions sought

confirmation that his participation was meeting the needs of the study.”

The following discussion incorporates commentary from the interview alongside observations from *PlaceLab* video recordings to describe the overall user experience.

10.2.1 Value integration

From the user’s perspective, *ViTo* is first and foremost a tool that enables or simplifies daily activities in the home.

Question: “What would you tell someone considering purchasing a remote control like this?”

Answer: “Well I’d explain that you could use [it] as a remote control and whatnot ... I just like the fact that it gives you the choice of what TV shows are on. You can go right to a CD or song that you like without having to swap CDs and the DVDs. Um, yeah. The only thing it doesn’t do is open and close the curtains.”

Although *ViTo* is designed as a persuasive technology, the participant’s reactions focused largely on the value offered by an integrated device. Several questions attempted to gauge the participant’s reaction to aspects of the device that might be considered irritating, but did not reveal any evidence that this was the case. His responses suggest an overall favorable reception, with no indication that he found the persuasive strategies to be annoying or intrusive. While the user’s reaction suggests an orientation toward some of novelty aspects of the device, he also reported finding value in convergence of traditional mobile computing devices:

Question: “What additional capabilities, if any, would be valuable to users this device?”

Answer: "...maybe act as a portable phone, so if the phone rings you can use the PDA to pick up the phone."

10.2.2 Ease of use

During the pre-study instruction session, the participant appeared very comfortable exploring the *ViTo* user interface, and had no questions about how to operate it. Only one unexpected behavior was observed – that the user consistently misjudged how long to hold down the volume control buttons to reach the desired level. He was then instructed to press these buttons in a repeated sequence rather than holding them down until the desired volume was reached.

This incident as well as evidence from video footage suggests a discrepancy in the user's mental model of how the device functions. Although the RF-based device is not sensitive to line-of-sight restriction on control transmission, the user repeatedly pointed the PDA's infrared transmitter at the home theatre system when pressing the hardware buttons. No such behavior was observed for screen-based input.

Overall, the user's response to the interface indicated no major user interface issues that might jeopardize long-term use. The participant's reaction to adverse behavior of the device pertained principally to technical failure:

Question: "Describe some incidents where the PDA did not behave as you expected it to."

Answer: "Well it crashed [once] and I had to call [the researcher] and let him know what had happened and then he just told me how to reset it. My reaction ... well, I don't know ... I understood that things do happen and you need to kind of work it out, work out the kinks."

10.2.3 Convenience

One of the goals in designing *ViTo* is to produce a device that users would be willing to use often and in various settings.

Question: “What would need to be improved to make this a viable commercial product?”

Answer: “Maybe the appearance of it. I mean, to be honest, it looks like a PDA. But maybe if you just switched it around, or just changed the appearance of it ... it would be alright, but then why would you, because all the buttons are on the screen ... Maybe a little more comfortable to hold too.”

The participant’s response to this query suggests that the objective of providing a convenient form factor was acknowledged, if not overwhelmingly successful. His recommendations about changing the feel and appearance of the device may be relevant to improving the overall response to the device for future deployment.

10.2.4 Reduction

As noted in Section 10.2.1, the participant reacted well to the simplification of tasks enabled by *ViTo*. Although he was provided with the standard TV and home theatre remote controls to use if he found *ViTo* annoying or lacking control capabilities, the participant did not use these at any time. While it is possible that this phenomenon emerged from an intrinsic desire to please the researchers by using the experimental device, the post-study questioning suggests otherwise:

Question: “How many times did you use the original remote control that came with the TV? ... The home theatre? ... Why or why not?”

Answer: “None ... None. I didn’t use them ... I liked using the PDA ... I liked having the shows listed, plus the music and NEAT stuff.”

Progress toward the second reduction goal of lowering the costs of becoming more physically active is supported by the data shown Figure 10-3 as well as video review. Both data sources indicate that the participant voluntarily increased his activity in response to NEAT games and using the NEAT meter.

Question: “What would you tell a friend about the wearable sensors?”

Answer: “I’d explain how NEAT, how the NEAT works. Non Exercise Activity Thermogenics [sic] ... And how when you shake it, it adds up points and ... it would encourage you to work and encourage you to hit a goal.”

The value of using technology to reduce the barriers to physical activity is well supported by the following exchange:

Question: “How many times did you visit the [condominium building] fitness room?”

Answer: “You know what, I think I only visited once, with you and [the researcher]. I know I said I was going to really get up there and try to get more exercise and I really wanted to, but I guess just with dealing with [work] and everything ... I just wanted to kick back and relax.”

Although the efficacy of using small NEAT-related movements to improve an individual’s health outlook remains to be demonstrated, it is likely to be more effective than an aggressive intervention with which the user is will have difficulty complying.

10.2.5 Tunneling

Data collected by the PDA during evaluation show that the participant was exposed to the commitment/menu/feedback sequence each time he watched television. While it is not yet clear whether this sequence succeeded in inducing behavior change, the participant reported no irritation with the extra interface levels beyond what is offered by a standard remote control.

10.2.6 Suggestion

Table 10-5 presents the number of times the user selected each of the items on the *VITo* Main Menu. “Watch TV” represents the equivalent activity to using a standard television remote control. The remaining options are offered as suggestions for alternative activities.

Menu Option	# Uses
Watch TV	7
Listen to Radio	1
Listen to Music	5
View To Do List	2
Play NEAT Games	4

Table 10-5: Main Menu selection frequency

It is difficult to ascertain the user’s motivation for clicking on each of these, although it is likely that novelty effects partially explain the behavior. “Listen to Radio” was selected only on the second day of the study, and “View To Do List” was selected only on the first and third days. In post-study conversation with the participant, the researchers sought to understand his reasoning with respect to alternative activities:

Question: “Do recall any situations when you planned to watch TV but changed your mind?”

Answer: “Yeah, I think that happened maybe 2 times. So I decided, well, I don't want to watch anything ... I'll turn on some music instead or not turn on anything at all.”

Question: “What changed your mind?”

Answer: “Mood, I guess. So I listened to music or went to do something else.”

There is no direct evidence of how the alternative activity suggestions or other persuasive features factored into the participant’s decision-making process, although it could be argued that the ease of listening to music using *ViT0* may have increased its attractiveness as an alternative.

While the participant was watching television, he was also exposed to individual music tracks and to do items as alternative suggestions. Of these, he once clicked on a to do item, and twice clicked on music tracks.

10.2.7 Encouraging incompatible behaviors

On one occasion (Tuesday night around 10:10pm – see Figure 10-3), the participant selected a music suggestion item that appeared in the television program list. After the song finished, he responded affirmatively to a prompt to stop watching television and started listening to music for about 14 minutes. This sequence represents a successful demonstration of how suggesting incompatible behaviors might ultimately produce an overall reduction in television viewing.

10.2.8 Interrupting habitual behaviors

Although he was not asked explicitly about the randomization of items on the *ViT0* Main Menu, the participant did not mention this in the course of post-study conversation, suggesting it was not a notable inconvenience. Neither was the absence of channel-up and channel-down buttons on the *ViT0* device:

Question: “In a TV remote control, would you rather use channel up/down buttons or program titles to select what to watch.”

Answer: “I think its a lot easier to use titles ... you know what's on without looking at all the channels.”

When asked to discuss his decision making process when using program titles in contrast to a standard remote, the participant responded as follows:

Question: “Did the design of the remote control affect what you watched?”

Answer: “Yeah, I think it did. That way you know you don't have to scroll through channels and whatnot, you can just look at the remote and see what's on.”

Although this discussion reveals little valence of the direction of change (it is conceivable that the program listings might *increase* viewing), it does support that hypothesis that redesigning the remote control will interrupt the habitual practice of channel surfing.

10.2.9 Goal setting

In the current implementation, the TV Prompt (Figure 8-1) is only delivered when the user exceeds his or her daily viewing goal as part of a “trade-off” strategy. Because the user watched substantially less television using *ViTo* than the baseline week, he never triggered this interaction, which was based on a goal set by the researchers. In the course of the interview, he did, however, mention that he didn’t pay attention to the TV Goal because “I didn’t really anticipate watching [that amount],” confirming the theory that goals should be appropriate to the individual’s current state of progress [11].

When twice faced with the NEAT Goal Prompt (Figure 8-1), however, the participant did choose to set new goals, incrementing the value from 8000 to 9000 points on Friday night and from 9000 to 10000 points on Saturday. On the topic of setting goals for physical activity, the participant had this to say:

“I think what it did was it gave me a goal. That really encouraged me to go up to and to meet that goal. So when I

sat down at the end of the night and I saw that I hadn't reached the goal, I would [start] waving my arms and legs, getting a little bit of exercise before I went up to the goal.”

10.2.10 Self-monitoring

In an effort not to bias the participant’s use of self-monitoring, the researchers did not explain how the NEAT Meter and TV Meter worked when introducing *Vit0*. When asked after the study to explain the functional behavior of these interface elements, the participant was nevertheless able to provide an accurate description. This fact stands as evidence that the participant did attempt to understand some of the interface elements, which may in turn have affected his behavioral outcome.

10.2.11 Proximal Feedback

The self-monitoring objectives are enabled through the use of feedback that provide real-time and historical data about the user’s behavior. As noted in the discussion of physical activity in Section 10.1.3, sensor data and video observation indicate that the participant used the graphing NEAT Meter to explore the sensors’ response to his activity. In the post-study interview, he expressed a fair amount of enthusiasm for this use of technology, and mentioned that he used the NEAT summary screen up to 3 times each day.

Question: [Follow-up] “Describe some of the ways in which you used the graphing bar display on the NEAT summary page.”

Answer: “Well, I would turn it on to look and see when I exercised ... I'd shake my arms ... you know how I used it ... just moving around a lot.”

It is likely that the novelty of real-time movement feedback increased the use of this feature to levels that are not sustainable for the long term. Nevertheless, the participant’s response does support further investigation of how real-time feedback might be used to promote long-term increases in physical activity.

10.2.12 Operant conditioning

When asked about *Vito's* behavior when turning off the television, the participant made no mention of the auditory stimulus that was presented. Further prompting about sounds emitted by the PDA also did not elicit mention of this signal. Although it is true that conditioned associations can be very subtle and out of conscious awareness of an individual, there is no evidence at the present time that the “whoosh” sound had an impact on the participant’s behavior.

10.2.13 Positive reinforcement

Using operant conditioning to reinforce target behaviors with visual displays was apparently a more salient approach for the user in this case study:

Question: [Follow-up] “How many times did the PDA present a reward screen for something you had done?”

Answer: “You mean how many NEAT points you’d gotten? Well, let’s see – there was one for the NEAT points... ‘This kind of exercise is good for you, keep it up.’ There was another one that just kind of congratulated me for, you know, the amount of movement that I had done ... I think I got those 4 or 5 times.”

Question: “How did you respond?”

Answer: “Well, I saw that there are points to be accumulated and then shook my arms and watched the points go up. When I saw the goal for the NEAT points I just moved until I got there.”

Judging from this sequence, the use of rewards, feedback, and goal setting appears to form a viable constellation of strategies for motivating short-term gains in physical activity. For sustained change over a longer term, some variation in the implementation of the strategies may be necessary, but the basic approach holds promise.

10.8.14 Variable reinforcement

The use of variable reinforcement in *VITo* is intended to prolong the user's curiosity about how and when the device will offer rewards by reducing the predictability with which they are delivered. Due to the short duration of this study, no conclusions can be drawn about the effectiveness of this approach, but the goal-orientation exhibited by the user serves as evidence of his expectation that the device will deliver rewards—a prerequisite to effective use of variable reinforcement.

10.2.15 Shaping

During the course of operation, all of the parameters and thresholds that *VITo* uses to reason about NEAT points automatically adapted in service of increasing the users' activity levels. For the evaluation system, the adjustments were one-way fixed intervals. To optimally promote long-term behavior change, a more flexible approach should be taken to respect variation in the users' stages of change.

In the short term of this case study, *VITo* successfully increased the amount of movement necessary to complete puzzles in the NEAT Arcade (Section 7.5). At the start of the study, 72 NEAT Points were required to resolve each game. By the end of the study, that number had risen to 90. Through the course of post-study inquiry, the participant made no indication that he was aware of this change.

10.2.16 Clicker training

Section 10.1.3 presents some of the data produced by the clicker training procedure. When asked about this strategy in post-study conversation, the participant revealed awareness of the general goal it was intended to shape:

Question: [Follow-up] “Why do you think the PDA produced those sounds?”

Answer: “I think it was reminding me to move my arms.”

In spite of the fact that *VITo* presented these stimuli at moments when the he was watching TV, working, or otherwise not focusing on the PDA, the participant expressed no annoyance with this interface element. Review of video footage from the participant's stay at the *PlaceLab* revealed that at times he made apparently deliberate movements in order to receive the reward at the end of a click sequence. On other occasions, however, he made no apparent gestures; in some cases, this was probably because the device was out of earshot.

10.2.17 Intrinsic motivation

The participant's response to NEAT Games mirrored his reaction to the other features that respond to bodily movement, including a strong reception to its novelty:

Question: "How would you describe the NEAT games?"

Answer: "Well, I really liked them ... You move your arms and legs and you get to see the picture. Sometimes there was a question that you had to shake to answer.... I think if we had those NEAT games on the PDA screen and had to shake to earn those, I think that would be very interesting."

The NEAT games were, in fact, designed to be novel and provocative, so the user's response to some extent validates this objective. Over the course of his stay, the participant played 27 NEAT games, most of which were on the last two days of the study. Five of the games were initiated by the system during commercial breaks while he was watching television. The remainder were launched on demand using the *VITo* interface. Table 10-6 shows the distribution of the games played.

	# Played	# Aborted
Question Game	9	
Music Game	6	2
Pixel Game	4	
Zoom Game	8	1

Table 10-6: Frequency of NEAT Games
Number of times participant played each game. Where

applicable, the number of times the participant failed to complete (aborted) the game is listed.

Of note is the fact that the participant aborted 2 (33%) of the six Music Games presented. There are several possible explanations for this, the most likely being that the stimuli used are typically identifiable before the game is completed, thus prematurely satisfying the curiosity that motivated the game.

Overall, the goal of producing an intrinsically motivating game experience appears to be supported by the user's behavior. Video review revealed the participant frequently engaging in very rapid movements in an apparent effort to solve the puzzles rapidly—seeking immediate gratification. At times the participant was also observed narrating the games and guessing out loud what the resolution was.

10.2.18 Consistency

The user in the *Vito* case study evaluation was exposed to the viewing commitment sequence (Figures 8-5) eleven times as shown in Table 10-7

Date	Day	Time	Committed Duration	Actual Duration	Difference
1-Aug-2005	Mon.	9:05:16 PM	30	8	- 22
		10:59:55 PM	60	45	- 15
2-Aug-2005	Tue.	8:11:07 PM	20	5	- 15
		10:02:55 PM	30	7	- 23
3-Aug-2005	Wed.	8:09:57 PM	30	110	+ 80
		8:40:02 PM	30		
		9:12:59 PM	30		
		9:44:32 PM	30		
4-Aug-2005	Thu.	7:31:46 PM	30	11	- 19
5-Aug-2005	Fri.	5:59:20 PM	30	60	+30
		6:31:28 PM	30		

Table 10-7: Pre-commitment viewing times

The participant showed a strongly stereotyped response to the Commitment prompt, suggesting that it did not inspire a substantial amount of reflection. When asked about this

after the study, the participant's comments reflected a decision-making process that was more general than specific to each viewing session:

Question: "Describe an example of your reasoning in deciding what to answer [to the Commitment Prompt]"

Answer: "Well, I put in about 30 minutes only because I don't remember having the TV on longer than that. There was one where I exceeded the time. So 30 minutes for the most part. At the beginning I said 60 minutes, and that's how long I think I watched and then I decided to turn it off. From that point forward I did 30 minutes. It's hard to say when you don't know how long you're going to watch TV."

Based on these data, the participant was exposed to the Reminder screen (Figure 8-6) five times during the study. Three of these occurred on Wednesday, when the participant was watching a movie on television and chose to extend his viewing. The final two prompts occurred on Friday. The latter of these coincided with the user's completion of his viewing session, and automatically turned off the television. About this the participant responded:

Question: "What was your reaction when the TV turned off by itself?"

Answer: "I think I had already finished watching and was doing something else, so I didn't bother turning it back on."

Vitō's other main application of the consistency principle, the use of a quality rating scale for media and activities will require a more substantial ratings database before its behavior change potential can be fully explored. During the *Vitō* case study, the participant was occasionally prompted to rate media content. A total of seven ratings were elicited, 3 for television programs, and four for music selections. In the post-study interview, the participant was asked to describe his reasoning process for these ratings (based on a scale of 1-5 with 5 being the highest):

Question: “Explain what you were thinking when you rated the following programs.”

Answer: [Cruel Intentions: 3] “I had seen it before, but liked it.”

[Fear Factor: 3] “I’m pretty neutral about that. I watch it, but ‘3’ is about right.”

[Antiques Roadshow: 1] “I wasn't expecting a whole lot from that, but it's interesting to watch.”

10.2.19 Normative influence

The use of normative influence to bias the participant’s use of the To Do List application produced the following results:

Activity	Explanation
(e.g.) Call Mom	Keeping in touch with family members helps strengthen your social network.
(e.g.) Do 15 jumping jacks	Jumping jacks are a great way to get your whole body moving.
Make orange juice	Freshly squeezed orange juice tastes great and is great for you
Relax and breathe	Breathing helps you to relax
Work on curriculum	This will relieve you of your stress to get this task done, and free up your weekend

Table 10-8: To Do Activities

The first two items were seeded by the researcher as sample activities. The remaining three activities were entered by the user using PC-based application.

The goal of this strategy was to encourage activities that reflect objectives of improved health and well-being. Based on these responses, it appears to have been successful. Nevertheless, caution should be exercised in drawing this conclusion, as there would have been very little cost to the participant if he wanted to please the researchers with his

responses. Furthermore, the fact that the participant did not use the To Do List interface during the second half of the study suggests his initial motivation may have been influenced by novelty and curiosity.

10.2.20 Optimal timing

The way in which the timing of several strategies played out during the pilot study has been referenced in the preceding discussions. What follows are several additional observations about the effectiveness of delivering just-in-time behavior change techniques.

Onset of commercial breaks. Due to the challenges of manually flagging commercial breaks (for example, at times the participant watched stations not available of the remote TV), only 5 of the possible commercial segments were replaced with NEAT games. On four of these occasions, the participant completed the games, thereby engaging in physical activity that might otherwise have not. The current implementation of the *ViTo* system did not allow the user to manually start NEAT games while watching TV, so it remains unclear whether the user found NEAT games sufficiently valuable to proactively launch them as alternatives to watching commercials or channel surfing. When asked to describe his usual reaction to television commercials, the participant responded with the following:

Question: “When at home, what do you typically do when a commercial comes on TV?”

Answer: “I’ll watch it if I am not doing anything else.”

Data from the *PlaceLab* video record, however, did not unilaterally confirm this report. For two of four randomly sampled commercial breaks during his stay, the participant was observed switching between channels until the desired program resumed. This observation lends support to the hypothesis that consistently initiated NEAT Games or other “distracter” content may reduce channel surfing during commercial breaks.

One question during the interview was left open-ended to allow the participant to comment about aspects of the NEAT games that might be considered annoying (such as interruption

of television viewing by automatic activation). His response did not reference the activation, but rather a failure of the researchers to adequately tailor the games to his interests:

Question: “What, if anything, did you not like about the NEAT games?”

Answer: “Um, I can’t say that there was nothing I didn’t like about it. I guess it seemed like most of the pictures were from Nebraska ... but uh ... ”

Turning off TV. Television viewers are likely to be disposed to turn off the television if they have another activity to transition into. For the present study, only statistical feedback was presented at the offset of the viewing experience. However, proactively delivered suggestions at this time might also prove efficacious, as on several occasions the participant was observed transitioning into other activities enabled by the PDA including listening to music (Tuesday, 10:10pm) and playing NEAT Games (Friday, 7:00pm).

11. Discussion

The results of this study remain open to interpretation. There is clear evidence that the participant responded strongly and positively to certain aspects of the system design, such as *value integration*, *ease of use*, and *reduction*. His responses to specific persuasive elements such as *goal setting*, *self-monitoring*, and *proximal feedback* likewise show a willingness to tolerate or even value more proactive behavior change strategies.

Reaction to some of the more abstract strategies employed by *ViTo*—for example *intrinsic motivation*, *consistency*, and *normative influence*—cannot be easily measured using observational and self-report techniques. Where possible, evidence relevant to the participant’s response to these strategies is presented, with the understanding that the evaluation described in this work only begins to address the myriad questions surrounding the design and use of persuasive technologies.

The case study evaluation featured in this research has inherent advantages as well as limitations. Although the small size and relatively short duration of this study will limit what conclusions can be drawn from the data, it is hoped that the results of the present study will provoke further interest in the deployment and evaluation of persuasive behavior change devices. A discussion of the some of the considerations readers should bear in mind when evaluating this work follows.

The rich observational records that were produced using the *PlaceLab* facility enabled detailed review of the participant's use of the technology. At the same time, the awareness that his actions were being recorded may have influenced the participant's behavior in ways that would not represent his use of the device under other conditions. During the post-study interview, the participant expressed his reaction to the study environment as follows:

Question: "In what ways did the awareness that your stay was being recorded impact your behavior in the *PlaceLab*?"

Answer: "I think, well, everybody goes through this. You know you have cameras and I guess maybe it just takes ... maybe a day or so to, you know, take in and then once you get settled and then you forget about that and then you enjoy your stay. Um, I really think that's about it. I was quite comfortable there."

The participant repeatedly expressed great pleasure about living in the research environment, which itself may have influenced his behavior. As noted earlier, certain aspects of living in a new home environment may have had an impact on his activities, such as the lack of a DVD movie collection. It is for this reason that a baseline data collection period is useful, in that it provides an environmentally controlled within-subject point of comparison for behavior change outcomes.

The participant's enthusiasm for living in the *PlaceLab* may be a further possible confounder, in that he may have exhibited approval seeking behavior in order to increase his chances for participation in future studies. After the conclusion of the study, feedback was elicited to determine if the results of the analysis may have been biased to confirm the researcher's hypotheses:

Question: "If you were going to tell a friend about this study, how would you describe it?"

Answer: “Actually I had one person who seemed sort of interested ... It's a very nice place. I 'd show them pictures show them the technology, because, you know, it sounds pretty interesting.”

Question: “What do you think [the researcher] was expecting you would do with the PDA?”

Answer: Just to use it and get to know a little bit about my interests, what music I like, what shows I like to watch.

The participant's responses suggest that his primary impression of the study was to better understand how people live day-to-day, and that the experimental remote control device was intended for data collection about media preferences. This conclusion is further supported by remarks expressed by the participant on several outgoing phone calls in which he described the experience of living in the *PlaceLab*: “They've got a PDA here that works like a remote control for the TV and music ... so they can tell what I'm watching.”

Nevertheless, caution should be exercised in reviewing the results of this evaluation, as any single-user study can offer only anecdotal evidence of how a new technology might be received. Many of the behaviors exhibited (e.g. “air drumming” for NEAT Games) are likely to be idiosyncratic and not generalizable. Further, certain aspects of the participant's personality may also have disposed him to react in ways that would not represent mainstream response. For example, the participant showed an overall high level of interest in and comfort with technology, and may therefore have experimented more with the device and had greater tolerance for unexpected behaviors than a less technologically oriented user.

While the *caveats* above should temper reaction to this study, it is hoped that readers will identify those areas that hold promise for further research, and will use this knowledge to deepen and refine the design of persuasive technologies for the promotion of health and well-being.

12. Future Work

Based on initial evaluation and user feedback, *ViTo* represents a step forward toward the goal of producing a proactive technology that unobtrusively encourages lifestyle change. To maximize the behavior change potential of this device, further work will be necessary. Future design work shall focus on extending the range and flexibility of the persuasive strategies it employs. Short-term objectives include supporting multiple viewers in a single environment, as well as improving the ease with which users can customize *ViTo* to suit their needs and preferences. More distant objectives include the implementation of networked user groups to enable powerful socially-based persuasive techniques.

Further work on evaluating *ViTo* in ecologically valid settings will be necessary to determine its long-term effectiveness as a persuasive technology. Appendix J describes a within-subjects longitudinal study design that can be used to statistically assess the impact of *ViTo* over time. This study proposes to deploy 10 portable *ViTo* systems in users' own homes for a period of 6-12 months, with the eventual goal of determining whether the short-term behavior change outcomes observed in the current study are sustainable. Using an A-B-A (pre-test, intervention, post-test) experimental design, this study aims to demonstrate if changes in mean daily viewing duration and activity levels are observed over the course of months, and whether those changes persists after the device is removed.

13. Conclusions

This work describes the design and evaluation of a technological system that helps users manage aspects of their lives for which few technological aids presently exist. Television viewing and physical activity, the so-called *lifestyle behaviors* targeted by *ViTo*, contribute substantially to an individual's long-term health and wellbeing.

In combining aspects of ubiquitous computing, context-aware computing, and persuasive technology, this research undertakes a novel approach to the problem of lifestyle change. Successful demonstration of *ViTo* as a tool for behavior modification would have strong implications for the future of proactive healthcare.

The intervention measures from the case study evaluation described in this document are suggestive, lending support to the possibility the *ViTo* can indeed succeed in helping individuals lead more active lives. It is hoped that researchers in the field of public health will find value in using a tool such as *ViTo* to study the wide scale deployment of proactive health technologies. Although it may be years before *ViTo's* impact on an individual's long-term health can be fully evaluated, short term changes in the user's quality of life may alone justify the cost and effort involved in developing a robust mass-produced version for large scale deployment.

Appendix A: Design Process

The final *ViTo* device was product of an extensive iterative design and prototyping process. Early stage conceptualization arose through discussions with groups and individuals from a wide variety of professional backgrounds. A series of brainstorming sessions, including morphological forced connections [60] and provocative questioning [61], were conducted to generate novel approaches for simultaneously reducing television viewing and increasing physical activity.

The goal of developing a persuasive user interface that is grounded in behavioral science was serviced by the collection of over fifty behavior change principles that might be applied to the interface design. Individual methods were evaluated as potential strategies to be used in the final prototype. As the interface began taking shape, its design direction was formulated according to input from a series of paper prototyping sessions [62] to determine the optimal interaction sequence and display properties. The objective of this iterative design process was to enhance the ease-of-use without compromising the persuasive intent of the device. Primary usability considerations were to make the messages and graphics displayed on the device as clear and understandable as possible in order minimize the chance that users make errors in responding to it. Samples of the paper prototype screens are shown in Figure A-1.

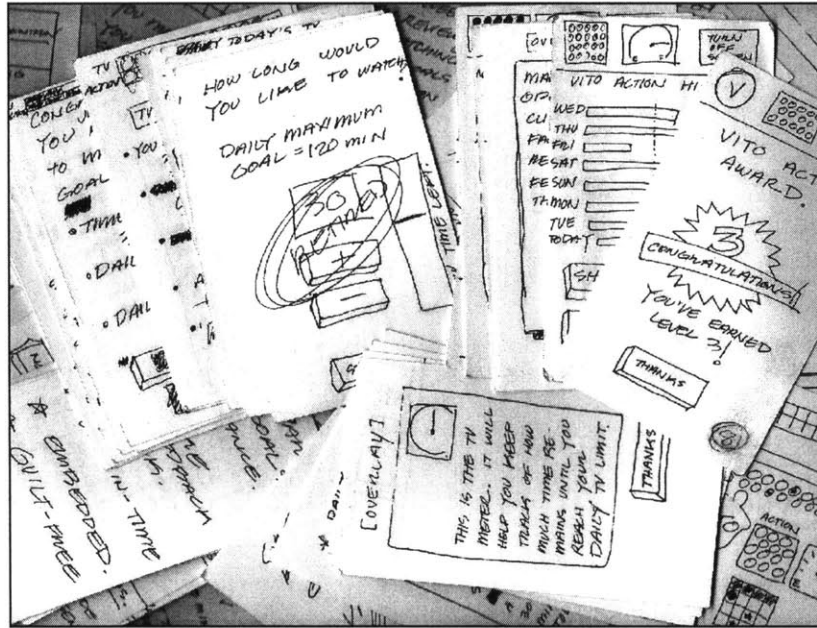


Figure A-1: Paper prototype samples

A series of low-fidelity mock-ups were used to generate the *ViTo* user interface.

After the preliminary user experience was defined using low fidelity prototypes, rough engineering diagrams were produced to guide construction of the interactive prototype. During the process of prototype development, potential users of this technology were routinely involved in evaluating the usability of the interface. Typical evaluation sessions occurred under naturalistic conditions in a mock-up living room located within a university research laboratory. Behaviors of interest included user expectations of how the device would behave, and these were elicited during “think aloud” sessions. Test subjects of various levels of technological comfort were encouraged to explore the technology on their own without detailed instruction, so that the consequences of any unexpected interactions would be exposed.

Appendix B: Server Applets

Five main server applications perform back-end operations that drive the *ViTo* user experience. Figures B-1 through B-5 show screen shots of the user interface for these applications.

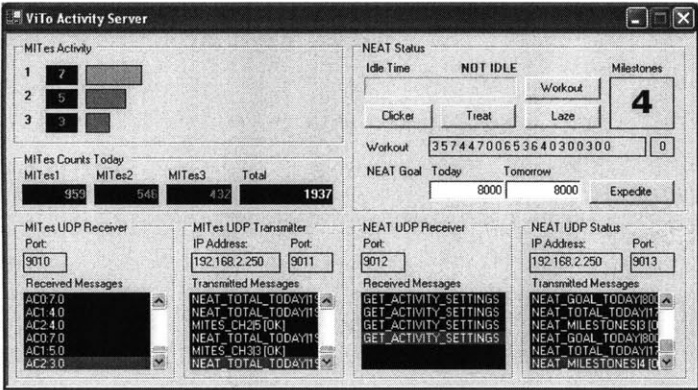


Figure B-1: Activity Server

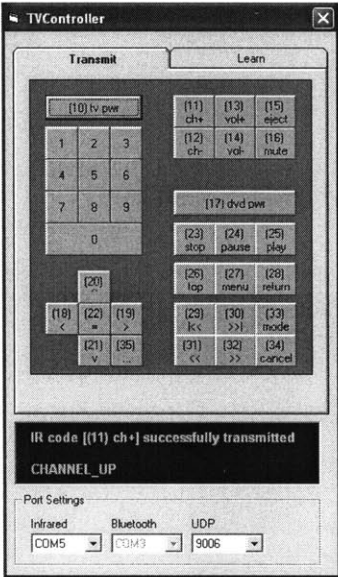


Figure B-2: TV Controller

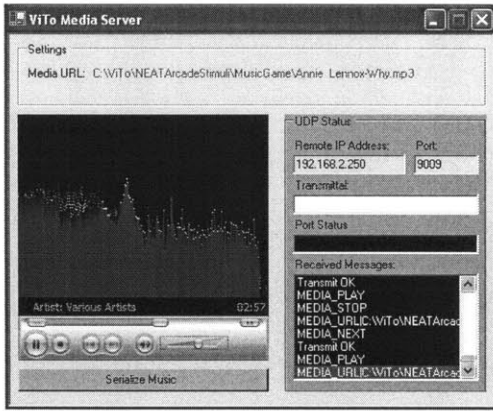


Figure B-3: Media Server

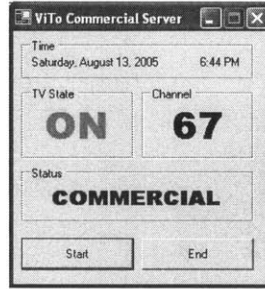


Figure B-4: Commercial Server



Figure B-5: Arcade Server

Appendix C: System Implementation

Hardware

The *Vito* Handheld used in this project is a Dell Axim Model X3 PDA running Microsoft Pocket PC 2003 operating system, version 4.20.1081 (Build 13100). This device includes an IEEE 802.11b wireless network adapter that is used to communicate with the other system components via an Agere Systems AP-2000 wireless access point connected to a Dell PowerConnect 5224 Internet switch. All network communication between devices is implemented over TCP/IP.

The *Vito* Server is a Dell Optiplex GX-270 personal computer (PC) running Microsoft Windows XP Professional operating system. This machine is connected via GigaBit Ethernet to the Dell switch. Sensing of bodily movement is enabled using MIT Environmental Sensor (MITes) technology [63]. A USB MITes receiver listens for wireless transmission packets broadcast from 3 battery-powered wearable acceleration sensors. Control of the television and home theatre system in this configuration is enabled by a USB-based Tira v1.1 infrared transceiver from Home Electronics, Inc.

The user laptop in the prototype system is a Toshiba Satellite A25-S307 running Microsoft Windows XP Home Edition Version 2002. The television is a Panasonic TC-32LH1 32" diagonal LCD TV. The combination DVD player and home theatre audio system is also by Panasonic, model SA-HT1000.

Software

All software running on the PDA, server, and laptop was coded using the C# programming language within the Microsoft Visual Studio .NET 2003 Development Environment, version 7.1.3088. The *Vito* Handheld user application is deployed as a single executable assembly for Microsoft .NET Compact Framework v1.0 SP2.

Appendix D: NEAT Arcade Stimuli

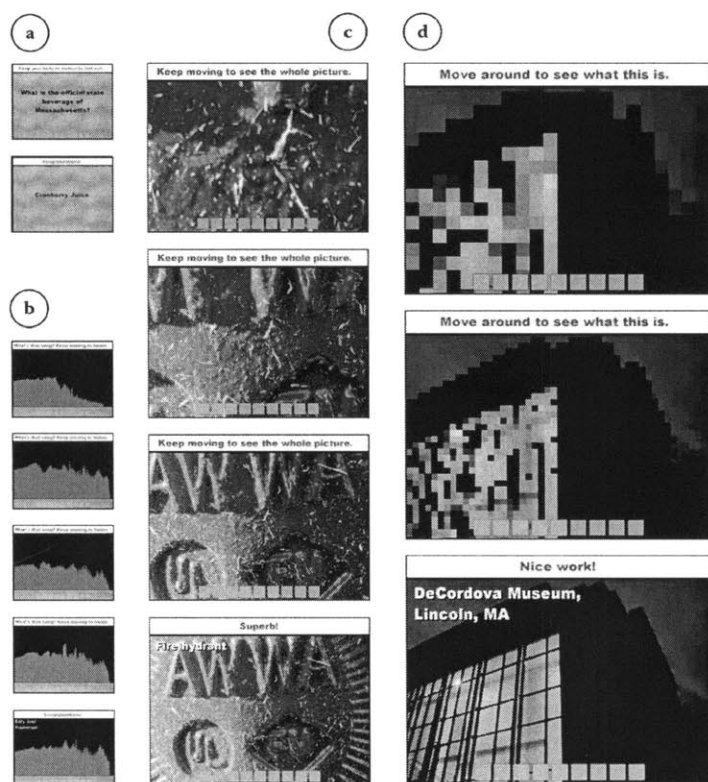


Figure D-1: Sample NEAT Arcade stimuli

As movement is detected, game play advances until all nine green squares are illuminated. Images show games at various stages: (a) Trivia game, (b) Music game, (c) Zoom game, and (d) Pixel game.

Appendix E: Recruitment Materials

Teach MIT Researchers about Your Everyday Life



Ever get the feeling that today's technologies and homes are not designed for you and the way you live? Help MIT researchers design better technologies and homes (with fewer frustrations!) by sharing your everyday experiences.

Live in a comfortable one-bedroom apartment for 10 days. Researchers will capture your activities and experiences and apply lessons learned to developing technologies for better health and living.


For more information, contact Jason at placelab-volunteers@mit.edu or (617) 452-5679

PlaceLab AN MIT + TIAX INITIATIVE

Figure E-1: Recruitment Flyer

Appendix F: IRB Application

[TEXT BEGINS ON NEXT PAGE]

	Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects	Application # (assigned by COUHES)	
		Date	11/04/03

APPLICATION FOR APPROVAL TO USE HUMANS AS EXPERIMENTAL SUBJECTS (STANDARD FORM)

Please answer every question. Positive answers should be amplified with details. You may mark N/A where the question does not pertain to your application. Any incomplete application will be rejected and returned for completion. A completed CHECKLIST FOR STANDARD APPLICATION FORM must accompany this application.

I. BASIC INFORMATION

1. Title of Study	
Recognizing Activities of Daily Living Using Computational Sensor Technology	
2. Principal Investigator	
Name: Stephen Intille	Building and Room #: NE18-4FL
Title: Research Scientist	Email: intille@mit.edu
Department: Architecture	Phone: 617-452-2346
3. Associated Investigator(s)	
Name: See attachment	Email:
Title:	Phone:
Affiliation:	
4. Collaborating Institutions. <i>If you are collaborating with another institution(s) then you must obtain approval from that institution's institutional review board, and forward copies of the approval to COUHES)</i>	
5. Location of Research. <i>If at MIT please indicate where on campus. If you plan to use the facilities of the Clinical Research Center you will need to obtain the approval of the CRC Advisory Committee. You may use this form for simultaneous submission to the CRC Advisory Committee.</i>	
This research will take place in an off-campus residential condominium owned by MIT collaborator, TIAX, LLC. The facility, known as the "PlaceLab," is located at the following address:	
6. Funding. <i>If the research is funded by an outside sponsor, please enclose one copy of the research proposal with your application. A draft of the research proposal is acceptable.</i>	
Source:	Contract or Grant Title:
Contract or Grant #:	OSP #:
7. Human Subjects Training. <i>All study personnel MUST take and pass a training course on human subjects research. MIT has a web-based course that can be accessed from the main menu of the COUHES web site. COUHES may accept proof of training from some other institutions. List the names of all study personnel and indicate if they have taken a human subjects training course.</i>	
Intille (yes), Beaudin (yes), Kaushik (yes), Kukla (yes), Larson (yes), Mungui Tapia (yes), Nawyn (yes)	

APPLICATION FOR APPROVAL TO USE HUMANS AS EXPERIMENTAL SUBJECTS
(STANDARD FORM) – revised 7/23/2003

8. Anticipated Dates of Research	
Start Date: 01/05/04	Completion Date: 12/30/04

II. STUDY INFORMATION

1. Purpose of Study. *Please provide a concise statement of the background, nature and reasons for the proposed study. Use non-technical language that can be understood by non-scientist members of COUHES.*

Home-based computing devices that automatically identify a user's activities from sensor inputs could provide context-relevant information to a user. New applications for education, entertainment, and preventive healthcare might then be possible. The goal of this exploratory study is to collect sensor data and user activity information using audio and video recording, temperature and humidity sensors, water and electricity meters, object movement sensors, position tracking sensors, and handheld computer input devices. The research environment will be outfitted with the above technologies to allow data collection on human subjects as they perform daily activities. Sensor data and audio/video information will be recorded unobtrusively on a continual basis as the subjects inhabit the research apartment. A handheld computer may be used at times to prompt subjects about the behavioral intent of their activities.

Data collected from this study will be used to develop algorithms that can automatically determine what the user is doing from sensor input. Information gathered from audio/video recordings and handheld computer input will be used to train pattern recognition systems to classify user activities. This study will help researchers determine which sensors are most critical for detecting everyday home activities deemed important for specific types of tasks.

2. Study Protocol. *For biomedical, engineering and related research, please provide an outline of the actual experiments to be performed. Where applicable, provide a detailed description of the experimental devices or procedures to be used, detailed information on the exact dosages of drugs or chemicals to be used, total quantity of blood samples to be used, and descriptions of special diets.*

For applications in the social sciences, management and other non-biomedical disciplines please provide a detailed description of your proposed study. Where applicable, include copies of any questionnaires or standardized tests you plan to incorporate into your study. If your study involves interviews please submit an outline indicating the types of questions you will include.

You should provide sufficient information for effective review by non-scientist members of COUHES. Define all abbreviations and use simple words. Unless justification is provided this part of the application must not exceed 3 pages.

Attaching sections of a grant application is not an acceptable substitute.

This study proposes to investigate how sensor technologies installed in a home can be used by a computer to identify activities of daily living of occupants of the environment. A residential observation research facility that has been instrumented with multiple sensors technologies will be used to collect data from subjects under controlled conditions. Only one subject will inhabit the apartment as a resident at any given time. Subjects will move into this laboratory for a short stay, ranging from 1 day to several weeks, depending on the availability of both the subject and the research facility. The typical duration of participation is expected to be 2 consecutive weeks. The research laboratory, which is called the PlaceLab, is a 1-bedroom residential condominium in Cambridge, MA located on [REDACTED], a residential neighborhood. This facility is owned by MIT Dept. of Architecture partner TIAX, LLC. The interior of the facility is

currently under construction as of October 2003 and will be complete in January 2004. The unit will be outfitted with 300-400 data acquisition devices designed at MIT that will be integrated in or attached to doors, cabinets, drawers, appliances, sinks, toilets, showers, beds, light switches, and furniture such as chairs and tables. These devices will record the times when the objects they are attached to are moved. Many of the sensors will be embedded into the cabinetry that is built into the unit. Each room will also contain air quality sensors to measure carbon dioxide, carbon monoxide, temperature, and humidity. Further, cameras and microphones will be built into every room in the environment. In addition to built-in sensors, a handheld computer may be used in the study to prompt subjects who live in PlaceLab for information about the activities they are performing (using multiple-choice questions).

Data from all the sensors and the handheld computer are stored to a disk stored in a locked room on the PlaceLab facility. At the end of the data collection phase, data deemed sensitive by the subject will be deleted. The audio and video recordings of subject activities will be annotated by researchers with labels of a subject's everyday activities (e.g. "cooking," "reading," "socializing," "napping"). These labels will be correlated in time with the sensor readings and used to train and test machine learning algorithms that attempt to identify the subject activity automatically using sensor readings.

Our protocol is as follows:

- 1) Recruit subjects using posters placed at adult community centers in the Boston-Metropolitan area and messages sent to mailing lists for older adults, such as the AARP list. See attachment for recruitment text.
- 2) Contact potential subjects by telephone and conduct a brief screening interview with interested persons. Attempt to establish appropriateness for participation in this study (see exclusion/inclusion criteria). Address any questions or concerns the potential subjects might have.

Sample questions to ask potential subjects:

- a. How old are you?
- b. What do you do for living?
- c. Are you presently a student or staff member at MIT?
- d. Do you live in the Greater Boston area?
- e. Do you live independently?
- f. How many hours a day do you spend at home?
- g. Do you have pets?
- h. Would you be available and willing to live alone in the PlaceLab environment for a period of one day to two months? How long would you be willing to spend?
- i. Would you be willing to spend most of your time inside the PlaceLab during the period of the experiment?
- j. Would you be willing to participate in an experiment in which audio and video recordings of your activities will be made?
- k. Would you be willing to carry a handheld computer while you lived in the PlaceLab and respond to frequent prompts (i.e. beeps) requesting you to answer

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multiple-choice questions about your activities?

l. Do you suffer from any medical conditions that might limit your ability to participate in this research?

m. How did you hear about this study?

3) Identify persons eligible and likely to participate. Invite prospective subjects to visit the PlaceLab. Conduct a guided tour of the facility and explain the camera, microphone, and sensor configurations. Answer any questions the subject may have about the facility or the study. Explain informed consent procedures, and provide consent forms for the potential subject to read and understand fully. Request that the subject return the form by mail if he or she is willing and able to participate.

4) Work with the subject in determining and scheduling a mutually convenient period of time during which he or she will use the PlaceLab research apartment as his or her primary residence. Lengths of stays would vary from 1 day to several weeks, depending upon the subject's desires and the needs of researchers.

5) Ask subject to provide a list of the people (with contact information) they are likely to invite to visit the PlaceLab during their participation in this study. Contact potential guests and explain the procedure for demonstrating informed consent and the reasons it is important. Provide consent forms to potential guests, and request that guests complete and return these forms before they visit the PlaceLab.

6) Conduct an orientation session with each new subject on the first day of his or her participation in this study. Introduce the subjects to the features and amenities of the PlaceLab, as well as to emergency procedures. Show subjects the locations of all audio and video recording devices in the apartment and the type of data that will be collected. Explain how the subject should fill out and submit a data recording logbook for use in indicating times for which they wish recordings to be deleted or disguised. Provide training and instructions on using a handheld computer for labeling activities of daily living. Explain the procedure for inviting guests into the PlaceLab, including the necessity of gaining informed consent from visitors.

7) Help subjects move into the PlaceLab research apartment on the day scheduled for the beginning of their participation in this study. Answer any questions they may have at this time. The home will be professionally cleaned before the subject's arrival. Bedding and household supplies will be provided, but the subject will be encouraged to bring small personal items and other items to make the PlaceLab feel as comfortable as possible. Food items will not be provided and must be brought by the subject.

8) Subjects begin living in the PlaceLab. The PlaceLab sensor infrastructure will begin saving sensor data continually to a computer disk in a secure location in the PlaceLab residence. This data will not be viewed by the researchers until they indicate to the subject that the data will be retrieved from the apartment. The data will never be accessible via the Internet. Researchers will ensure that subjects understand that no real-time monitoring of their behavior will occur.

9) Instruct subjects to carry a handheld computer at all times in a pocket or in a pouch provided by the researchers. This device will occasionally prompt subjects with an audible signal when a response is requested. The device will signal on a schedule predetermined by the researchers, and it may prompt up to 40 times a day. Responses will involve labeling activities using a series of multiple-choice responses. The device will not beep during the subject's regular sleeping hours. Researchers will teach the subject

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how this device is operated and how to recharge it before going to sleep at night. Sample questions to asked by the handheld computer are:

- a. Please select your current activity from the following list: [multiple-choice responses will be listed].
- b. What were you doing at the beep? Select from a multiple-choice list that includes activities such as preparing lunch, watching television, getting ready for work, sleeping.
- c. You indicated that your last activity was exercise. How much time did you spend on this last activity?
- d. Are you going to sleep? If so, please remember to turn off this device and recharge it in its docking station.

10) Provide subjects with wearable sensors in the form of wrist- or ankle-bands containing wireless sensors that will be used to determine movement and/or position within the PlaceLab. Demonstrate how the bands should be worn and how they should be cared for. Inform subjects that wearable sensors should not be used while sleeping or bathing.

11) Prior to entering the PlaceLab, subjects will be asked to spend the majority of their time inside the PlaceLab so that everyday activities such as preparation and consumption of meals is observed by the sensors. Objects commonly found in a home will be present, such as equipment for entertainment, cleaning, cooking, communications, eating, and sleeping.

12) At the end of their first day in the study, contact participants and elicit feedback about their experience thus far. Address any questions or concerns they may have about their experience in the PlaceLab.

13) On the final day of a subject's participation in this study, conduct an exit interview and elicit answers to questions about their experience of living in the PlaceLab. Sample exit interview questions:

- a. Describe your experience of living in the PlaceLab research apartment.
- b. How was the experience similar or different to living in your own home?
- c. How did the presence of recording equipment affect your behavior in the PlaceLab?
- d. Did you feel that the cameras, microphones, or sensors where invading your privacy at home? Please specify why and what you think could be improved to avoid this problem.
- e. Did you feel annoyed, stressed or experienced any discomfort because of prompting by the handheld computer?
- f. Did you find the recording logbook procedure a convenient way to exercise control over the data recording procedure? Could it be improved?
- g. In the future, if the sensing and recording devices were widely available, would you be willing to live in a home in which they had been permanently installed if they helped you to stay healthy?

14) After completion of the exit interview, debrief subjects as to the intent of this study, and explain how the data collected will be used in the publication of this research. Remind subjects that no identifiable audio/video clip will be used in any publication or presentation that they have not explicitly approved.

15) Inform participants of the opportunities for participation in follow-up studies. Ask

whether they wish to be contacted about such opportunities.
3. Drugs and Devices. <i>If the study involves the administration of an investigational drug that is not approved by the Food and Drug Administration (FDA) for the use outlined in the protocol, then the principal investigator (or sponsor) must obtain an Investigational New Drug (IND) number from the FDA. If the study involves the use of an approved drug in an unapproved way the investigator (or sponsor) must submit an application for an IND number. Please attach a copy of the IND approval (new drug), or application (new use).</i> <i>If the study involves the use of an investigational medical device and COUHES determines the device poses significant risk to human subjects, the investigator (or sponsor) must obtain an Investigational Device and Equipment (IDE) number from the FDA.</i>
Will drugs or biological agents requiring an IND be used? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>
<i>If yes, please provide details:</i>
Will an investigational medical device be used? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>
<i>If yes, please provide details:</i>
4. Radiation <i>If the study uses radiation or radioactive materials it may also have to be approved by the Committee on Radiation Exposure to Human Subjects (COREHS). COUHES will determine if you need COREHS approval.</i>
Will radiation or radioactive materials be used? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>
<i>If yes, please provide details:</i>
5. Diets
Will special diets be used? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>
<i>If yes, please provide details:</i>

III. HUMAN SUBJECTS

I. Subjects	
A. Estimated number: 10 Residents, 10 Guests	B. Age(s): 18+
C. Inclusion/exclusion criteria	
<p>i. What are the criteria for inclusion or exclusion?</p> <ul style="list-style-type: none"> - Single adults with no living companion or dependents. - No chronic medical conditions or disabilities. - Must be available to live in the PlaceLab environment for a period of one day to two months. - Subjects must be living alone during the period of the experiment. - Subjects must spend most of their time in the PlaceLab alone during the period of the experiment. - Subjects must consent to participate in an experiment wherein audio and video recordings of their activities will be made. - Subjects must maintain a primary residence in the Greater Boston metropolitan area. - Current students and staff of the Massachusetts Institute of Technology will be excluded from participation. <p>ii. Are any inclusion or exclusion criteria based on age, gender, or race/ethnic origin? <i>If so, please explain and justify</i> Subjects must be at least 18 years of age.</p>	
D. Please explain the inclusion of any vulnerable population (e.g. children, cognitively impaired persons, non-English speakers, MIT students), and why that population is being studied.	

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Not Applicable. Vulnerable populations will not be studied.
2. Subject recruitment <i>Identification and recruitment of subjects must be ethically and legally acceptable and free of coercion. Describe below what methods will be used to identify and recruit subjects</i>
Subjects will be recruited using posters placed at adult community centers in the Boston-Metropolitan area and messages sent to mailing lists for older adults, such as the AARP list. See attachment for recruitment text.
Please attach a copy of any advertisements/ notices and letters to potential subjects
3. Subject compensation <i>Payment must be reasonable in relation to the time and trouble associated with participating in the study. It cannot constitute an undue inducement to participate</i>
Describe all plans to pay subjects in cash or other form of payment (i.e. gift certificate)
Subjects will be recruited as volunteers with the option to be paid. The investigators will present this option neutrally and free of bias. Those subjects selecting the payment option will be compensated \$25 for each day they live in the PlaceLab. Subjects will be required to acknowledge their decision on the informed consent document. Subjects withdrawing from the study will be paid only for those days spent in the facility. Payment will be issued in the form of a check from the Massachusetts Institute of Technology.
Will subjects be reimbursed for travel and expenses?
Travel and personal living expenses (e.g., food, toiletries) will not be reimbursed. Expenses for household supplies (e.g., laundry detergent, paper towels) will be reimbursed up to \$50 when submitted to the investigators with a receipt of purchase. Payment for reimbursement will be issued by MIT in the form of a check.
4. Potential risks. <i>A risk is a potential harm that a reasonable person would consider important in deciding whether to participate in research. Risks can be categorized as physical, psychological, sociological, economic and legal, and include pain, stress, invasion of privacy, embarrassment or exposure of sensitive or confidential data. All potential risks and discomforts must be minimized to the greatest extent possible by using e.g. appropriate monitoring, safety devices and withdrawal of a subject if there is evidence of a specific adverse event.</i>
What are the risks / discomforts associated with each intervention or procedure in the study?
Potential psychological risks or discomforts associated with this study pertain to the density and ubiquity of the data collection devices. During the course of this study, subjects might at times feel uncomfortable about having their behavior recorded. Some subjects may feel pressured to "perform" for the researchers and might become self-conscious about their activities within the PlaceLab. Psychological stress may result from the belief that the investigators will be passing judgment on the behaviors exhibited.
Subjects may feel that their right to privacy is being invaded by the presence of audio and video recording devices. As a result, some subjects may feel inhibited in their ability to conduct themselves freely in the PlaceLab. Subjects might also feel uncomfortable about the possibility that their data may be publicized in an inappropriate or embarrassing way.
What procedures will be in place to prevent / minimize potential risks or discomfort?
During all stages of the research project, the investigators will inform participants that any data collected in this study will be subject to stringent security procedures, and that personal identifiers will not be associated with their data in any way. All participants

must sign an informed consent agreement indicating that they understand and agree to these conditions. All research personnel involved in this study must have passed the MIT training course on Research Involving Human Subjects. Additional training on procedures for handling data and maintaining subject confidentiality will be conducted by the investigators.

In order to reduce anxiety about recorded audio and video materials, the investigators will conduct an orientation session during which the potential subject will be shown the locations of all sensors, cameras, and microphones within the PlaceLab facility, and also how the video recording can be blocked. At this time, the investigators will also explain the procedures in which the audio and video footage will be used, including sample footage and data. Procedures for selectively deleting or disguising recorded data will be demonstrated at this time. Subjects entering the study must sign an informed consent document indicating that they understand and agree to the procedures for recording and use of audiovisual material.

Data collected during the study, including those derived from audio and video recordings, will be stored confidentially on a secure, password-encrypted computer at MIT. Data with identifying information will never be made available on the internet. Research publications based on these data will not include any personal information that might reveal the identity of the participants. Unless special consent is obtained from a subject for a specific video segment, photographic content including images of the subjects will be reproduced with all identifying features visually obscured by blurring.

Any concerns the subjects may have about the use and confidentiality of the recordings should be communicated to the investigators, who shall address these concerns specifically. Subjects will be given the phone number to the research team and will be instructed to contact the investigators at any time during the study if they wish to discontinue recording or to terminate their participation in the study.

5. Potential benefits

What potential benefits may subjects receive from participating in the study?

The subject will have the opportunity to ask the researchers about new technology for enhancing the living environment and to learn about new home-based sensor technologies.

What potential benefits can society expect from the study?

A system that can recognize typical domestic activities would be an enabling technology that could be used to improve existing electronic devices and create new types of human-computer user experiences for entertainment, proactive health care, education, and energy conservation. The study will help researchers determine which sensors are most critical for detecting everyday home activities deemed important for specific types of tasks.

6. Data collection, storage, and confidentiality

How will data be collected?

Activities in the research environment will be detected by electronic sensors that respond to object movement, device activation, and changes within the ambient environment. Data from these sensors will be acquired on a continual basis and stored in a time-stamped format on a secure computer. Data generated by the subject via answers to questions

prompted on a handheld computer will also be stored.

Is there audio or videotaping? YES NO *Explain the procedures you plan to follow.*

Subjects will be informed of the audio and video recording procedures before consenting to participate in this study. Each subject will be required to sign an informed consent document that describes the recording procedure. In this study, up to 30 active video cameras and microphones will be integrated into cabinetry within the residential environment. These devices will be capable of recording activity occurring anywhere within the space. Prior to entering this study, all subjects will be shown the location of all the recording devices, and must indicate that fact on the audiovisual consent form. During the course of the study, they will be able to block video recording from individual cameras using paper shields provided by the investigators. Participants in this study maintain the right to selectively delete or blur any recorded footage before it is viewed by members of the research team. A diary will be provided for subjects to indicate the times of recording they wish to delete or blur, and a member of the investigation team will do so at the conclusion of the subject's stay in the PlaceLab.

Audio and video recordings of subject behavior shall be produced and stored in digital format on a single secure computer. Audio and video recordings will be annotated by researchers after the conclusion of data collection. The annotation data will be used to help train activity recognition algorithms.

Will data be associated with personal identifiers or will it be coded?

Personal identifiers **Coded** *Explain the procedures you plan to follow.*

Each subject will be assigned a numeric identification code that will be used to catalog the data collected. Subject identities will not be associated with their data in any way.

Where will the data be stored and how will it be secured?

Data will be stored initially on a secure computer at the PlaceLab site. After data collection is completed for each subject, the contents of this computer will be transferred to and permanently stored at MIT in a single, secure location.

What will happen to the data when the study is completed?

Data, including annotated video and audio footage, will be used by the investigators to generate a report on the study and to make suggestions for future work. Identities of the participants will not be used in the analysis process. Data without identifying information may also be used by collaborating researchers outside MIT who are interested in activity recognition.

Can data acquired in the study affect a subject's relationship with other individuals (e.g. employee-supervisor, patient-physician, student-teacher, family relationships)?

No. Data will not be released to any of these groups.

7. Deception *Investigators must not exclude information from a subject that a reasonable person would want to know in deciding whether to participate in a study.*

Will information about the research purpose and design be withheld from subjects?

YES NO *If so, explain and justify.*

8. Adverse effects. *Serious or unexpected adverse reactions or injuries must be reported to COUHES within 48 hours. Other adverse events should be reported within 10 working days.*

What follow-up efforts will be made to detect any harm to subjects and how will COUHES be kept informed?

Subjects will be given the phone number to the research team and will be instructed to

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contact the researchers with any questions or concerns about the study at any time during or after their participation in it.

9. Informed consent. Documented informed consent must be obtained from all participants in studies that involve human subjects. You must use the templates available on the COUHES web-site to prepare these forms. Draft informed consent forms must be returned with this application. Under certain circumstances COUHES may waive the requirement for informed consent.

Attach informed consent forms with this application.

10. The HIPAA Privacy Rule. If your study involves disclosing identifiable health information about a subject outside of M.I.T., then you must conform to the HIPAA Privacy Rule and complete the questions below. Please refer to the HIPAA section, and to the definitions of protected health information, de-identified data and limited data set on the COUHES web-site.

Do you plan to use or disclose identifiable health information outside M.I.T.?
 YES NO

If YES, then the subject must complete an Authorization for Release of Protected Health Information Form. Please attach a copy of this draft form. You must use the template available on the COUHES web-site.

Alternatively, COUHES may grant a Waiver of Authorization if the disclosure meets criteria outlined on the COUHES web-site.

Are you requesting a Waiver of Authorization?
 YES NO

If YES, explain and justify.

Will the health information you plan to use or disclose be de-identified?
 YES NO

Will you be using or disclosing a limited data set?
 YES NO

If YES, then COUHES will send you a formal data use agreement that you must complete in order for your application to be approved

IV. INVESTIGATOR'S ASSURANCE

I certify the information provided in this application is complete and correct

I understand that I have ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects, and strict adherence to any stipulations imposed by COUHES

I agree to comply with all MIT policies, as well all federal, state and local laws on the protection of human subjects in research, including:

- ensuring all study personnel satisfactorily complete human subjects training
- performing the study according to the approved protocol
- implementing no changes in the approved study without COUHES approval
- obtaining informed consent from subjects using only the currently approved consent form

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- protecting identifiable health information in accord with the HIPAA Privacy Rule
- promptly reporting significant or untoward adverse effects

Signature of Principal Investigator _____ Date _____

Print Full Name and Title _____

Signature of Department Head _____ Date _____

Print Full Name and Title _____

Please return a signed hard copy of this application to the COUHES office at E32-335

Please also return additional copies, either by email or regular mail, in accord with the instructions on the COUHES web-site.

Appendix G: Pre-Study Questionnaire

Background

Name	
Street Address	
City	
State	
Zip Code	
Daytime Phone	
Evening Phone	
Email address	

Date of Birth	
Occupation	
Employer	
MIT Affiliation	

Please describe your household makeup, specifically the number of people you live with.

How much time do you spend outside your home on a typical weekday?

Are you willing and able to be away from home for 10-20 consecutive days?

Are you willing to have your activities at the *PlaceLab* recorded with video and audio devices as well as environmental sensors?

Activities

What types of small tasks/chores can you complete within a very short period of time (90 seconds or less)? In other words, if you had 90 seconds while waiting for some other task to be completed, how would you most effectively use that time? If applicable, please list the time of day during which you would most likely complete each activity.

Activity	Time of Day
(Example) Unload Dishwasher	Evening
(Example) Do 30 sit-ups	Any time

In the sections below, you are asked to estimate how much time you spend in various activities. Your answers will be approximate. Please respond to the best of your ability and provide any necessary clarification in the space for comments.

Music

On average, how many hours per day do you spend listening to music from the radio, CDs or other recorded sources?

- Less than 1 hour
- 1-2 hours
- 2-3 hours
- 3-4 hours
- 4-8 hours
- More than 8 hours

How do you usually listen to music?

- On the radio
- On the Internet
- On a stereo
- On a portable music player
- On your computer (from music files on the hard drive)
- Other...

When do you mainly listen to music?

- While at home
- While at work
- While commuting (e.g. in the car)
- During some other activity outside the house (e.g. jogging)
- Not Applicable

What kinds of music do you like to listen to (check all that apply)

- | | |
|------------------------------------|-----------------------------------|
| <input type="checkbox"/> Classical | <input type="checkbox"/> Pop |
| <input type="checkbox"/> Country | <input type="checkbox"/> Rock |
| <input type="checkbox"/> Gospel | <input type="checkbox"/> Reggae |
| <input type="checkbox"/> Jazz | <input type="checkbox"/> R&B |
| <input type="checkbox"/> Oldies | <input type="checkbox"/> Other... |

In the space below, please list up to 5 of your favorite music albums.

Artist name	Album title

Radio

On average, how many hours per day do you spend listening to “talk” radio programming, such as news and commentary? (Do not include music listening)

- Less than 1 hour
- 1-2 hours
- 2-3 hours
- 3-4 hours
- 4-8 hours
- More than 8 hours

When do you usually listen to talk radio programming?

- While at home
- While at work
- While commuting (e.g. in the car)
- During some other activity outside the house (e.g. jogging)
- Not applicable

Listed below are some popular radio programs please respond based on your experience with these programs.

Program	Network	Do you listen to this show?	Rate this program (1 = lowest, 5 = best)
Morning Edition	NPR	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
All Things Considered	NPR	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
This American Life	PRI	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
As It Happens	CBC	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Car Talk	NPR	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5

Television

On average, how many hours per day do you spend watching television?

- Less than 1 hour
- 1-2 hours
- 2-3 hours
- 3-4 hours
- 4-8 hours
- More than 8 hours

How many televisions do you have in your home?

- 0
- 1
- 2
- 3
- 4 or more

Which of the following do you have in your home? (Check all that apply?)

- VCR
- DVD player
- Digital Video Recorder
- Home theater system

How many DVD or other recorded movies do you watch during a typical week?

- 0
- 1
- 2
- 3
- 4 or more

During an average week, how many times do you go to the cinema to watch movies?

- 0
- 1
- 2
- 3 or more

What television programs do you watch regularly? In each row please list the program, the network it plays on, the duration of the program and the time and day(s) it airs (specify "daily" if you watch the program every day).

Program	Network	Start Time	Duration	Day
(Example) Friends	NBC	8:00 pm	30 min.	Thursday
(Example) Nightly News	ABC	6:00 pm	30 min.	Daily

Below are some popular television programs. Please indicate whether you watch the program and how you would rate it on a scale from 1 to 5.

Program	Network	Do you watch this program?	Rate this program (1 = lowest, 5 = best)
Desperate Housewives	ABC	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
American Idol	FOX	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
CSI	CBS	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Survivor	CBS	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Grey's Anatomy	ABC	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Lost	ABC	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
60 Minutes	CBS	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Without A Trace	CBS	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
House	FOX	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Apprentice	NBC	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Sometimes	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5

Appendix H: Post-Study Interview

In order to elicit the participant's feedback on his experience using the *Vito* system, a researcher familiar with the project (but not one of the principal investigators) was recruited to conduct an interview with the participant 3 days after the conclusion of the study. This interview was based loosely on the following questionnaire, which was designed to gather responses with minimal bias.

- You have remarked that your experience in this study was an enjoyable one. Could you expand upon the aspects of living in the *PlaceLab* that you found appealing?
- Tell me about the aspects of your experience that you found inconvenient or dissatisfactory.
- In what ways did the awareness that your stay was being recorded impact your behavior in the *PlaceLab*?
- Tell me about your experience of having recording devices in your apartment for the portable kit study
- How many times did you visit your home apartment during your stay at the *PlaceLab*?
- For what reasons?

- During a typical weekday at the *PlaceLab*, how many times did you leave the apartment aside from going to work?
- How many times did you visit the Franklin Place fitness room?
- Could you discuss your decision making process in selecting what items to bring to the *PlaceLab*?
- During your first week at the *PlaceLab*, on how many separate occasions did you listen to music?
- How many individual CDs did you use?
- How many separate occasions did you listen to the radio?
- What kind of broadcast service do you have at home?
- On average, how many DVD movies do you watch per week?
- Name 5 television programs that you watched during your second stay at the *PlaceLab*.
- Explain what you were thinking when you rated the following programs...
- Tell me about some of the differences between the remote control software you used during your first stay and your second stay.
- Indicate any ways in which your program selection process differed between stay one and stay two.
- Did the design of the remote control affect what you watched?
- Did the channel selection availability at the *PlaceLab* differ from the selection you have at home?
- In what ways did the channel lineup affect what programs you watched at the *PlaceLab*?
- When at home, what do you typically do when a commercial comes on TV?
- How many DVD movies did you watch during your first stay?
- How many DVD movies did you watch during your second stay?
- Describe an example of your reasoning in deciding what to answer when the remote control asked you how long you wanted to watch TV.
- Do you feel that you more often over-estimated or under-estimated the time you would spend watching?

- How many times did you encounter the red screen telling you that your had watched for the number of minutes specified?
- How many times did the TV turn off by itself?
- What was your reaction to that phenomenon?
- How many times did you fall asleep watching TV at the *PlaceLab*?
- When at home, how often do you fall asleep watching TV?
- What are some of the activities you do while watching TV?
- Tell me what happened on the PDA after you turned off the TV.
- There were two graphic images at the top of the PDA screen during your second stay. Can you describe them for me?
- You mentioned they changed - how did they change?
- How many times did you click on the NEAT Meter?
- What happened when you clicked on the NEAT Meter?
- Describe some of the ways in which you used the graphing bar display on the NEAT summary page?
- What activities generated the largest number of NEAT points?
- What was the maximum number of NEAT points you earned in one day?
- How many times did you click on the TV Meter?
- What happened when you clicked on the TV Meter?
- While you were at the *PlaceLab*, do recall any situations when you planned to watch TV but changed your mind?
- If so, what changed your mind, and what did you do instead?
- How many times did you play NEAT games on the TV?
- What kinds of movement did you do in order to advance the NEAT games?
- How many times did the NEAT games appear on the TV other than when you started them using the PDA?
- What situation?
- What, if anything, did you like about the NEAT games?
- What, if anything, did you not like about the NEAT games?

- How many times did the PDA present a reward screen for something you had done?
- What did it reward you for?
- How did you respond?
- What kinds of activities were rewarded?
- At any point did you find yourself purposefully trying to earn a reward from the PDA?
- At times, the PDA emitted clicking and chiming sounds. How many times did this happen?
- Why do you think the PDA produced those sounds?
- You used a *PlaceLab* laptop to enter activities into a To Do List application. Describe your thought process as you decided what to enter into this application.
- How many times did you click on individual To Do items on the PDA?
- What happened when you did this?
- How many times did the PDA ask you to decide which of two activities you find more rewarding?
- Describe how you responded to this question.
- How many times did you click on a music item in the PDA while watching TV?
- What happened when you did this?
- Describe some incidents where the PDA did not behave as you expected it to.
- How many times did you use the original remote control that came with the TV?
- How many times did you use the original remote control that came with the home theatre?
- In a TV remote control, would you rather use channel up/down buttons or program titles to select shows.
- What would you tell someone interested in purchasing a remote control like this?
- What would need to be improved to make this a viable commercial product?
- Who do you think would be a likely consumer of such a product?
- If you were going to tell a friend about the device, how would you describe it?
- What would tell a friend say about the sensors?

- If you were going to tell a friend about this study, how would you describe it?
- What do you think the purpose of this study was?
- What do you think [the researcher] was expecting you would do with the remote control device?
- What do you think [the researcher] will be surprised about when he reviews the video/data from your stay?

Appendix I: Participant Characteristics

Impressions from an associate researcher:

“Based on interactions before, during, and after the experiment, I would describe the participant as upbeat, high-energy, and accommodating.

“He spoke quickly and seemed to prefer rapid overviews when learning new information. When introduced to new appliances, technologies, or study procedures, he often immediately began interacting with the items without waiting for or reviewing verbal, written, or visual instructions. After a period of time with the technology or procedure, he did ask questions to clarify his understanding. For example, he initially overlooked descriptive details for the wearable sensors that were provided to him and assumed that they were capturing audio and biophysical data. He followed-up with questions to the researchers, however, after wearing the sensors for a day and trying describing what he knew about the sensors to co-workers.

“The participant expressed strong affinity for new technologies or gadgets. He made a point of showing us his “high-tech” camera-watch and describing his advanced home phone monitoring system. He readily expressed in interest in the “cool factor” of new technologies and seemed primarily interested in identifying what was cutting edge about the spaces and technologies of the PlaceLab. He did not seek many details about how technologies worked,

technology design motivations, or study goals, and seemed more interested in the bigger themes (contributing to a study to aid technology design) and personally pertinent information (how he could use *ViT0* for music selection). He enjoyed sharing what he learned with his friends and family, actually creating and narrating a personal video during his stay, in which he described the PlaceLab as clean, comfortable, with nice appliances, and equipped with a variety of monitoring devices so “everything you do” is recorded.

“The participant was accommodating when given study requirements and when study interaction (interviews, visits) were requested and on several occasions sought confirmation that his participation was meeting the needs of the study. However, acting as a camp counselor during the study period, and preparing for the school year as a teacher, he did put priority on his personal and professional tasks, asking that research visits be short, so he could attend to his daily routines.”

Appendix J: Longitudinal Study Design

To evaluate the long-term behavior change potential for this technology, a larger scale study of its use in natural home settings is proposed. As an extension to the case study evaluation described in Section 9, this research would yield at least 10 participants and intended to produce adequate statistical power to for quantitative examination of intervention effects.

A portable version of the *ViTo* system has been designed for deployment in the homes of volunteer participants. Similar to the system outlined in Section 6, this version features a laptop-based server and a portable MITes receiver that does not depend on the *PlaceLab* infrastructure. A connection to the Internet as well as a wireless network router must be available at installation sites, although this equipment may be provided by the researchers.

Data from this study will be collected for six months, in three experimental phases.

Phase One: Baseline (1 month)

In this phase a non-persuasive remote control device (Figure 6-1) will be used to measure baseline TV viewing behavior and physical activity levels of the participants. No feedback will be given and no persuasive strategies will be employed.

Phase Two: Intervention (4 months)

The *ViTo* interface will be introduced to the participants. Participants will be encouraged to explore the interface and to make use of the goal setting features if they wish. At the end of each month, measurements will be computed for activity and screen time. This will enable the assessment of behavior change over the course of the active intervention period.

Phase Three: Maintenance/Post-Test (1 month)

In this phase, the *ViTo* persuasive remote control will be replaced with the non-persuasive unit from the baseline phase. During this time activity levels and TV viewing will continue to be measured.

Hypotheses

- The use of *ViTo* is associated with a reduction in mean daily television viewing
- The use of *ViTo* is associated with an increase in mean daily physical activity
- Heavy television use is correlated with low physical activity levels during baseline
- Effects of intervention will be greater for individuals exhibiting heavy television use during baseline

Data analysis

The following main variables will be used in this analysis:

- Mean television viewing per day in minutes
- Mean TV session length in minutes
- Mean number of NEAT points per day

Six data points for each participant will be assessed: Baseline, Post-Test, and Intervention months 1, 2, 3, and 4. Repeated measures ANOVA will be used to investigate statistical differences in activity level and screen time over the course of the study. Primary outcome analysis will compare baseline and intervention data to evaluate the overall effectiveness of

the device. Further analysis will investigate behavior change across the study timeline using polynomial regression. Research questions to be addressed through this analysis are as follows:

- Are measures of behavior significantly different between baseline and post-test?
- At what phase do participant demonstrate optimal behavior change outcomes?
- What is the extent of change between time points? Is there measurable fall-off or increases over time?

Additionally, the subject pool will be subdivided into two groups according to levels of activity in the baseline phase. Classification of heavy television users and light television users will enable examination of the differential effect of $VIT\theta$ on groups with different baseline profiles:

- Do heavy versus light users show a different pattern of behavior change?
- Is $VIT\theta$ more useful for high screen users?

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