Embedding Behavior Modification Strategies into a Consumer Electronic Device: A Case Study

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Abstract. Ubiquitous computing technologies create new opportunities for preventive healthcare researchers to deploy behavior modification strategies outside of clinical settings. In this paper, we describe how strategies for motivating behavior change might be embedded within usage patterns of a typical electronic device. This interaction model differs substantially from prior approaches to behavioral modification such as CD-ROMs: sensor-enabled technology can drive interventions that are timelier, tailored, subtle, and even fun. To explore these ideas, we developed a prototype system named *ViTo*. On one level, *ViTo* functions as a universal remote control for a home entertainment system. The interface of this device, however, is designed in such a way that it may unobtrusively promote a reduction in the user's television viewing while encouraging an increase in the frequency and quantity of non-sedentary activities. The design of *ViTo* demonstrates how a variety of behavioral science strategies for motivating behavior change can be carefully woven into the operation of a common consumer electronic device. Results of an exploratory evaluation of a single participant using the system in an instrumented home facility are presented.

1 Introduction

The average American watches over 4 hours of television each day [1]. As time spent in sedentary media consumption increases, the amount physical activity one incurs typically decreases. This is an unsettling fact of life for many Americans, 50% of whom feel they presently watch too much television and would like to reduce their viewing [2]. Meanwhile, rates of obesity have increased markedly in recent decades, and millions of Americans report engaging in weight-control efforts on a regular basis [3]. Few people, however, actually succeed in altering their long-term health outlook, in spite of accumulating evidence of the positive correlation between sedentary behavior and obesity [4] as well as lifestyle-related medical disorders such as Type 2 diabetes [5]. Similar trends are being reported in other industrialized countries.

Successfully reducing the time spent in television viewing over the long term could produce meaningful gains in an individual's overall health, especially if this activity is replaced with less sedentary alternatives. However, television habits are notoriously difficult to modify, often exhibiting the resilience of chemically based addictions [6]. 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 [7].

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 essential problem is that television viewing is instantaneously rewarding while exercise is instantaneously aversive. Intervention in this area has proved challenging in the past because successful behavior modification depends on delivery of motivational strategies at the precise place and time the behavior occurs. Advances in sensor-enabled mobile computing technologies will now facilitate the creation of applications that can intervene at critical moments throughout the day. As an exploration of how ubiquitous computing devices might enable novel approaches to improving lifestyle behaviors, we describe a case study with two interrelated objectives: (1) pilot the use of a novel technology to preempt or disrupt the stimulus-reward cycle of TV watching and (2) pilot the use of the same novel technology to decrease the costs of physical activity, while providing immediate positive reinforcement.

1.1 Technology-enabled behavioral modification strategies

This project builds upon prior work relevant to the motivation of lifestyle change. Knowledge campaigns (e.g. [8]) and clinical interventions (e.g. [9]) are the two most common approaches to the problem thus far. Other than websites and CD-ROMs, 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 and a token access system [10]. These systems use forced rationing or punishment often imposed by the parents, and therefore they are less likely to be adopted by adults.

Several technology-related projects have attempted to simultaneously address the problems of television viewing and inactivity by creating exercise-contingent TV activation systems. One such system, *Telecycle* (see [11]), 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. 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* [12], 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 [13].

Research into the use of technology to increase physical activity independent of television viewing is more extensive. The most pervasive use of technologies is for measuring amount of ambulation and providing open-loop feedback (e.g. [14]). 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. Preliminary research also suggests that more interactive just-in-time feedback such as that provided by the arcade game *Dance Dance Revolution* may be successful in producing short-term motivation for physical activity among otherwise sedentary children [15].

Another type of technology intervention proposes to motivate physical activity by mimicking the type of advice (and affect) used by a human personal trainer [16]. When delivered on a mobile computing device, such an interface may help users sustain an ongoing activity regimen. For individuals who do not already exercise regularly, new interventions might consider ways to lower the startup costs by focusing on small increases in physical activity that accumulate over time, rather than more intense and therefore intimidating regimens. Research suggests that simple body movements such as standing up, talking, and fidgeting—behaviors related to non-exercise activity thermogenesis (NEAT) [17]—may account for energy expenditures of over 300 kcal per day in obese individuals [18]. The intervention described in this paper builds on this finding by rewarding small activity increases in addition to intense or sustained exercise.

1.2 The opportunity: just-in-time interactions

The technological intervention we present relies on the same behavioral tendencies that have been proven effective in unmediated communication: that people respond best to information that is timely, tailored to their situation, often subtle, and easy to process [19]. Inexpensive sensors and mobile computing devices provide a platform that enables the achievement of these objectives through the design of an interface that draws upon behavioral science principles such as suggestion, goal setting, self-monitoring and conditioning. To provide further design insight into how these strategies might be embedded into consumer technologies, we have developed a prototype system to address the growing problem of television watching and physical inactivity.

1.3 Case study overview

The physical embodiment of this intervention is a multifunction handheld device called *ViTo*. This device, prototyped 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 a 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.

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 exploratory 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 study will also be used to prepare for possible longitudinal testing of similar behavior change devices. The two-phase experimental design allowed assessment of user reaction to a non-persuasive PDA-based remote control as well as the complete *ViTo* system. The two main goals of this exercise were: (1) to demonstrate that ubiquitous computing technologies could measure changes in participant behavior between conditions and (2) to engage user feedback in evaluating the overall design of the device.

2 Challenges

The development of technologies that promote behavior change is inevitably subject to preconceptions of what a "persuasive" technology is and how it will behave. *ViTo* would be considered an *autogenous* technology, one that individuals might choose to adopt in an effort to change their own attitudes or behaviors [11]. Achieving this requires overcoming design challenges similar to those proposed for persuasive technologies to motivate healthy aging [19]: to provide a user experience that is rewarding enough for users to engage in regularly over an extended period of time. Toward this end, we sought to produce a prototype that shows how a consumer device might provide feedback that may motivate change while avoiding coercion and not relying on extrinsic justification.

2.1 Grabbing attention without grabbing time

Prior work on behavior change interventions reveals a tendency for these to be either (1) resource-intensive, often requiring extensive support staff, or (2) time-intensive, requiring the user to stop everyday activity to focus on relevant tasks. Most controlled clinical studies fall into the former category, and CD-ROM or web-based tools generally fall into the latter. For both approaches, the participant must stop what he or she would otherwise be doing to "receive" the intervention. The most promising CD-ROMs are engaging with game-like elements, but few are well suited for busy adults who find it difficult to repeatedly identify blocks of time during which they can focus on non-essential computer software.

The challenge of grabbing attention without grabbing time is addressed in the current project by embedding the intervention into an activity the target user population is certain to engage in: watching television. Although it may appear counterintuitive at first, the television remote control itself is an ideal platform upon which to develop this behavioral intervention. Ninety-four percent of all U.S. homes already contain at least one television with a remote control [10]. The remote control has become a central component of the TV viewing experience, and it is partly responsible for the increase in sedentary behavior associated with television viewing. The remote control has led to an increase in channel-surfing behavior, which frequently leads to extended and unplanned viewing [20].

ViTo is designed to modify the user's approach to program selection without interfering with the desire to do so remotely. A discussion of the techniques used to accomplish this objective is presented in Section 4. Additional strategies designed to promote physical activity are deployed not only during viewing, but whenever the user interacts with the device in other operational modes. Unlike interventions proposed in prior work, the device never requests exclusive interaction for more than a few seconds.

2.2 Sustaining the interaction over time

If a behavior change application is to have a meaningful impact, its outcome should be sustainable over the course of years. The design of *ViTo* as a multifunction device serves to add value that might encourage long-term adoption. With extended use, however, comes the risk of annoyance. To counter this possibility, content that may be viewed as paternalistic or authoritarian was rejected in favor of strategies that promote intrinsic motivation and self-reflection. Wherever possible, elements of fun, reward, and novelty are used to induce positive affect rather than feelings of guilt.

Overexposure to even the most innocuous of strategies creates further risk for discontinuation. Brevity of interaction sequences along with a time-out period between presentations serves to prevent excessive exposure to *ViTo*'s persuasive elements. Because natural usage patterns are likely to vary over time, the behavior change strategies use by *ViTo* are intended to be effective even if the user only occasionally interacts with the device.

2.3 Avoiding the pitfall of coercion

A review of websites, software, and technologies for behavior modification suggests a tendency for designers to succumb to the temptation of using coercion for motivation. In some cases, the result is a technology that prevents an activity such as watching television. In other examples, the user experience approximates the feeling of a medical professional mildly scolding the user for less-than-optimal compliance. More ominously, some systems use threats and fear appeals in an effort to motivate users to change lifestyle behaviors such as diet and exercise.

Particularly for preventive healthcare technologies aimed at users without immediate medical concerns, the likelihood that users with tolerate coercive devices for long is questionable. For this reason, the option to produce a device that nags, punishes, or otherwise inconveniences the user was expressly avoided in the design of *ViTo*.

2.4 Avoiding reliance on extrinsic justification

The optimal outcome of any behavioral intervention is change that persists even if the technology is removed. Relying too heavily on extrinsic justification such as rewards and incentives may result in dependency that can lead to a falloff in progress if the incentives are removed. Although *ViTo* offers some rewards, this strategy is used in conjunction with many others to promote the more sustainable goal of increased self-awareness of activity patterns.

The use of an undesirable behavior as an incentive (e.g. rewarding exercise with access to television) is a particularly perilous form of extrinsic justification. Restricting the behavior and then framing it as a reward may increase the individual's motivation to engage in the activity, and will most likely lead to an increase in the behavior once the intervention is removed. Because of this possibility, *ViTo* is designed to reduce television viewing without restricting it or treating TV as a reward.

3 Case Study: *ViTo*

Our solution to the challenges of sustainable behavior modification is a device that exploits real-time feedback and game-style interaction to promote physical activity in a low cost, low impact manner. In this project, the intervention is conceived as a "universal" remote control that would seamlessly replace the user's existing devices. *ViTo,* shown in Figure 1, 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.

The implementation of the *ViTo* prototype system is illustrated in Figure 2. The system was assembled primarily from readily available consumer hardware. Custom devices were used for infrared control of the home theatre system and for collection of bodily movement data [21]. A standard laptop computer was provided for management of a music library and a to-do task list. All other user interaction was conducted on the handheld PDA. Wireless communication between the PDA and a central server enabled seamless response from the system components.

All of the capabilities enabled by this device are accessed using a graphical user interface (GUI) on the PDA's touch-sensitive display (see Figure 1). The graphical elements have been designed to accommodate finger input; no stylus is necessary. Some standard remote control functions (e.g., power, volume up/down, and mute) have been assigned to hardware buttons on the PDA faceplate. Unlike most high-end screen-based remote controls, the goal is not to provide a touch screen surrogate for standard buttons, but to provide a content-based interface similar to that of a portable MP3 player.

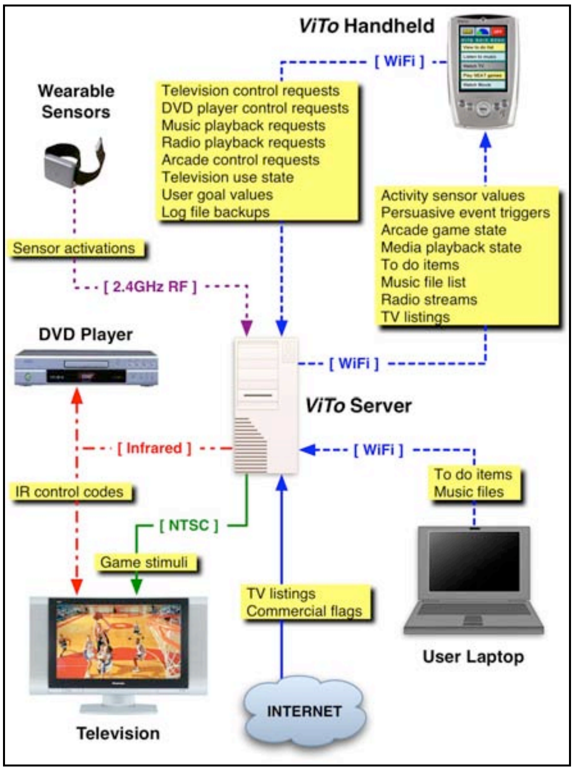

Fig. 1. *ViTo* handheld interface **Fig. 2.** *ViTo* system configuration.

The *Main Menu* selection grid featured in Figure 1 is the typical entry point of the user interface. Users can select among five main activities as indicated by labels (A) through (E). Each of these options initiates an interface sequence relevant to the selection. The principal display screens for these activities are shown in Figure 3, with corresponding labels (A) through (E). For media-related activities (A, B, C), the main interface screen features a selection grid representing all of the media content available at the current time. By default, content is sorted alphabetically by name, 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 available content, the *ViTo* server coordinates the appropriate response from the home theatre system. A separate display mode shown in Figure 3(F) allows control of a standard DVD video player.

Figure 3(D) shows a To-Do list screen that lets the user review a task list that is managed using a calendar-style application on a laptop computer. Figure 3(E) depicts the handheld interface that allows the user to start and stop “NEAT Games,” a collection of simple puzzles that use physical activity as their input. Each puzzle begins with the presentation of provocative but incomplete information on the TV screen. As the user activates wearable movement sensors, he or she is rewarded with more information until a threshold is reached and the final answer is delivered. Sample game templates are shown in Figure 4.

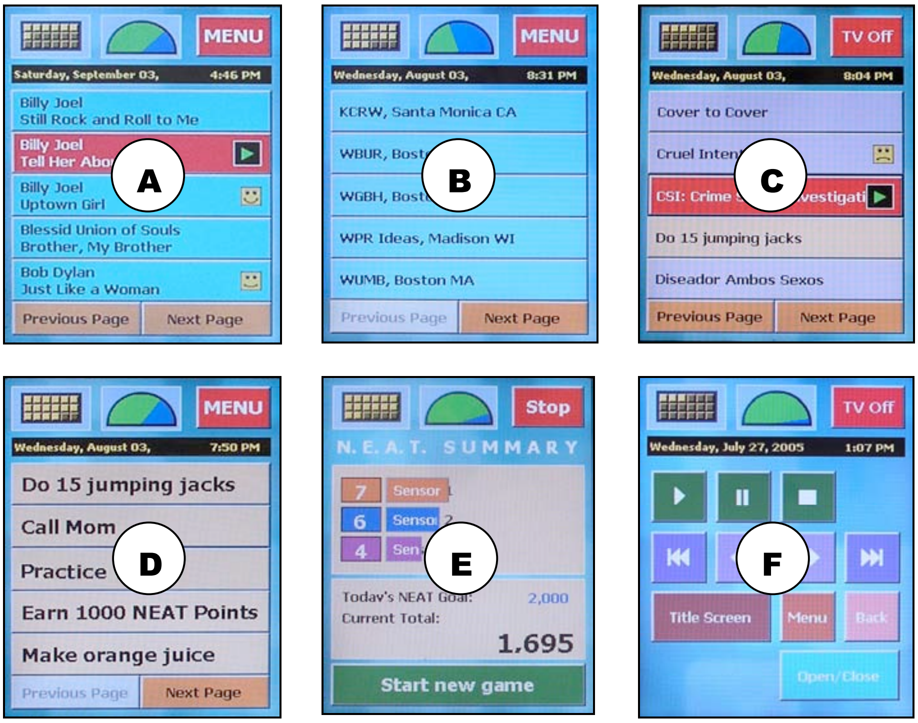

Fig. 3. Sample interface screens for activities enabled by *ViTo*: (A) Listen to Music, (B) Listen to Radio, (C) Watch TV, (D) View To Do List, (E) Play NEAT Games, and (F) Watch DVD

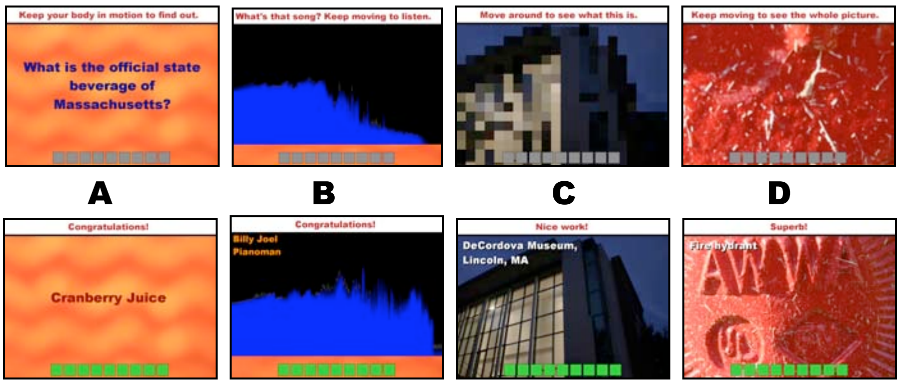

Fig. 4. NEAT Games stimuli as presented on the TV display. (A) Trivia Quiz, (B) Name That Song, (C) Pixellated Photos, and (D) Picture Zoom. As the user engages in physical activity, more information about the initial stimulus [top row] becomes available. The array of squares on each screen indicates progress toward final resolution [bottom row]

4 Behavior Modification Strategies

The *ViTo* case study was designed to investigate the viability of integrating behavior change strategies into everyday technologies like consumer electronics. Most of the strategies are derived from basic research on learning and decision-making. In the behavioral sciences, these phenomena (e.g. suggestibility, goal-setting, and operant conditioning) have been well studied and empirically supported. In creating *ViTo*, we sought to apply these same principles to the design of a motivational user interface. Similar interface elements could be adapted for use in other persuasive technologies.

Tables 1, 2, and 3 list the strategies employed with definitions relevant to technological intervention in the left-hand column. Where possible, the definitions used are similar to those in [11]. Specific examples of how the strategies were deployed in *ViTo* are listed in the right-hand column. Table 1 presents *user experience strategies* that are leveraged in an effort to create a satisfying and rewarding user experience, with the goal of promoting adoption and sustained use of the device. Table 2 shows a layer of persuasive content involving *activity transition strategies* designed to promote less sedentary alternatives to watching television. Table 3 presents a set of *proactive interface strategies* that encourage specific steps toward behavior change. These represent the most visible layer of persuasive elements.

Table 1. User experience strategies for behavior modification

Strategy	Example
Value integration. Delivering persuasive strategies within an application that otherwise provides value to the user increases the likelihood of adoption.	*ViTo* is a multifunction device that enables multimedia control of a home theatre system while delivering persuasive content in a way that is not disruptive to the other activities.
Reduction. Reducing the complexity of a task increases the likelihood that it will be performed.	(1) *ViTo* serves as a single alternative to multiple home theatre remote controls, likely increasing the chance that users with chose this device. (2) *ViTo* reduces the barriers to increased physical activity by encouraging small incremental changes rather than large lifestyle alterations.
Convenience. Small mobile devices can accompany the user throughout their day-to-day lives, increasing opportunities for delivery of behavior change strategies.	*ViTo* can be deployed on a handheld PDA or mobile phone, capitalizing on the fact that users are likely to already use such a devices on a regular basis.
Ease of use. Technologies that are easy to use are more likely to be adopted over a long term.	A participative design and testing process served to eliminate irritating behaviors that might otherwise prompt the user to discontinue using *ViTo*.
Intrinsic motivation. Incorporating elements of challenge, curiosity, and control into an activity can help sustain the user's interest [22].	*ViTo*'s NEAT Games were designed to reflect 5 features of intrinsically motivating activities: goals, uncertainty, feedback, self-esteem, and relevance. Other games more tailored to the user's interests could be substituted.

Table 2. Activity transition strategies for behavior modification

Strategy	Example
Suggestion. People can be biased toward a specific course of action through even very subtle prompts and cues.	*ViTo* extracts alternative activities from the Music, Radio, and To Do Menus, and systematically seeds these suggestions into the TV program listings.
Encouraging incompatible behavior. Engaging an individual in activities that inhibit an unwanted behavior can be effective in deterring the target behavior.	(1) *ViTo* gently promotes listening to music, playing games, and day-to-day chores as incompatible alternatives to sitting around and watching TV. (2) NEAT Games are started automatically when commercials begin in order to reduce exposure to program teasers and discourage channel surfing.
Disrupting habitual behavior. Bad habits can be eliminated if the conditions that enable them are removed or avoided.	(1) *ViTo* discourages habitual clicking on Watch TV by randomizing the order of Main Menu items. (2) *ViTo* disrupts habitual viewing practices such as channel surfing through the replacement of standard control buttons (i.e., channel-up and channel-down) with on-device program listings.

Table 3. Proactive interface strategies for behavior modification

Strategy	Example
Goal setting. Setting concrete, achievable goals promotes behavior change by orienting the individual toward a definable outcome.	*ViTo* prompts users to specify daily physical activity goals in terms of sensor movement counts called "NEAT Points" and daily TV viewing goals in terms of maximum minutes to watch. Timely reminders are used to encourage continual progress toward long-term improvements (Figure 5).
Self-monitoring. People who are motivated to change their behavior can do so more effectively when they are able to evaluate progress toward outcome goals.	*ViTo* features graphical meters that provide quick and easy feedback about the user's progress toward daily physical activity and TV viewing goals (Figure 6).
Proximal feedback. Feedback that occurs during or immediately after an activity has the greatest impact on behavior change.	*ViTo* provides real-time activity graphing to give users feedback about how many NEAT Points they are earning as they move around (Figure 7).
Operant conditioning. Desirable behaviors can be increased in frequency and intensity by pairing them with rewarding stimuli.	*ViTo* recognizes the user's progress toward his or her goals, and immediately rewards milestone achievements with congratulatory displays and reinforcing sounds (Figure 8).
Shaping. Conditioning can be used to transform a pre-existing behavior into a more desirable one by rewarding successive approximations of the end goal.	*ViTo* gradually increases its reinforcement thresholds over time. Users must work slightly harder each time they want to earn the next reward.
Consistency. The desire to demonstrate consistency between what we say and do is a basic trait that can be used to help people adhere to their stated goals.	*ViTo* prompts the user to specify how long he or she wants to watch prior to turning on the TV. After that duration expires, a second prompt reminds the user of the time, and asks whether he or she wishes to continue watching (Figure 9).

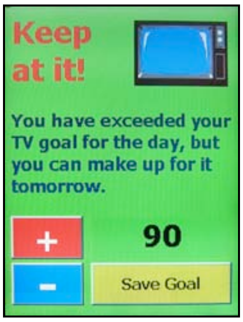

Fig. 5. Sample screen showing proactive elicitation of television viewing goals

Fig. 6. Graphical meters depict status of (A) NEAT goals and (B) TV goals

Fig. 7. Graphing bars show activity of 3 wearable motion sensors in real-time

Fig. 8. Sample reward screen delivered for an extended period of movement

Fig. 9. Users are prompted to demonstrate consistency between how much TV they say they are going to watch, and how much they do

5. Exploratory Evaluation

For a device such as *ViTo* with clear outcome objectives, the overall effectiveness of the intervention—sustained change over time—would provide a valuable measure for evaluating the system's usefulness. Establishing the true ecological validity of this result, however, would require deployments in real homes for a period of years.

A long-term, wide-scale study is an ultimate goal of this work. Before such an effort can be justified, more evidence in support of project's viability is needed. To begin acquiring pilot data, an exploratory study of *ViTo* was conducted with four main objectives: (1) to stress-test the system in a live-in home setting for 1-2 weeks, (2) to collect a naturalistic dataset on which to conduct preliminary analyses, (3) to learn more about how a layperson—not a researcher—will react to the device, and (4) to determine what further study and improvements are warranted.

For this evaluation, a *ViTo* prototype system tailored for an individual who ordinarily lives and watches TV alone was deployed in a specially instrumented research apartment called the *PlaceLab*. This apartment is a live-in laboratory designed for the study of home-based activities located in a typical condominium in a residential neighborhood [23]. One participant, a 33-year-old male elementary school teacher who had responded to a recruitment flyer in an ice cream parlor, was selected to live in the *PlaceLab* for a total of 14 days. He was compensated $25 per day for his time according to the following schedule:

- 7 days in the *PlaceLab* for baseline data collection with a non-persuasive remote control
- 12 days at his permanent home while other work occurred at the *PlaceLab*
- 7 days in the *PlaceLab* for intervention data collection with the *ViTo* persuasive remote control

The participant was informed that he would be involved in research about everyday activities, and that data would be recorded from built-in and wearable sensors. A researcher explained that some technologies in the *PlaceLab* were experimental, including the remote control for the television and home theatre system. The device used during the baseline study was specifically designed to resemble *ViTo* but did not deploy persuasive strategies. For the intervention phase, the participant was issued the complete *ViTo* system, and was informed that the device had been improved during his absence. The participant was not instructed that this was a study of behavior changes related to television viewing and physical activity.

Although a technology like *ViTo* would ultimately be targeted at users with an expressed desire to change their lifestyle, this evaluation was intended to gauge the overall reaction of a user who was not intrinsically motivated to modify his behavior.

6 Results

Because each *PlaceLab* stay began and ended midday, the first and last half days of each study were excluded from the final analysis. Each experimental phase therefore yielded 6 days of data (Monday through Saturday). The content of this discussion is based on this dataset as well as *PlaceLab* audio/video recordings and an extensive post-study interview conducted by a researcher who was not a developer of *ViTo*. At the time of this interview, the participant had not yet been told the intent of the study. Because data were being collected for several other experiments, it would not necessarily have been obvious that the remote was the major focus of the study, a fact that was confirmed by the participant following the debriefing. The researcher who conducted the interview had previously interacted with the participant and summarized his temperament as "upbeat, high-energy, and accommodating [with a] strong affinity for new technologies." As is typical in the case of small-*n* research designs, individual personality traits of the participant and situational factors will limit the extent to which general conclusions can be drawn from this study.

Most of the discussion to follow pertains to the participant's use of the *ViTo* system during the intervention phase. The baseline stage was used to provide a point of comparison for interpretation of the participant's behaviors. During baseline, the participant watched an average of 133 minutes of television per day, a finding that was roughly consistent with his self-reported averages of 2 hours of television per day and 2-3 DVD movies per week. Use of the stereo system averaged 54 minutes per day, an amount that was consistent with self-reported averages of 1 hour per day at home.

Television use during the intervention phase was found to be significantly lower than baseline at an average of 41 minutes per day ($p < 0.05$; $F(1,11) = 8.79$). Use of the stereo system increased to 65 minutes per day, although this was not significant. Because there are many factors other than *ViTo* that may have influenced participant behavior, these statistical results should not be interpreted too strongly.

In sections 6.1, 6.2, and 6.3 we now discuss user reaction to the individual persuasive strategies described in Tables 1, 2, and 3 respectively. Where possible, feedback elicited during the post-study interview is used to help explain observed phenomena.

6.1 Reaction to user experience strategies

ViTo is intended first and foremost a tool that enables and simplifies certain daily activities in the home. This objective was serviced through the strategies in Table 1.

Value integration. Based on post-study interview responses, it appears the goal of providing a valuable convergent device was successful: "I just like the fact that it gives you the choice of what TV shows are on. And you can go right to a song that you like without having to swap CDs." The participant provided no indication that any of the persuasive content interfered with his enjoyment of the device.

Reduction. Although the participant was provided with the standard TV and home theatre remote controls to use if he found *ViTo* annoying or lacking control capabilities, he did not use these during the intervention phase. When prompted to explain, he responded, "I didn't use them … I liked using the PDA … I liked having the shows listed, plus the music and NEAT stuff."

Convenience. The participant did not currently own or use a mobile phone in his daily life, but reported finding potential in convergence of traditional mobile computing devices: "[*ViTo*] could maybe act as a portable phone, so if the phone rings you can use the PDA to pick up." During the intervention phase, he also expressed interest in using the device to track physical activity outside of the home.

Ease of use. To assess the learning curve for this device, a researcher observed the participant during a 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 noted – that the user misjudged how long to hold down the volume control buttons to reach the desired level.

Intrinsic motivation. The NEAT games were designed to appeal to a user's desire for a novel interactive experience. Over the course of his stay, the participant completed 27 puzzles, many of which he launched on demand using the *ViTo* Main Menu. Overall, the goal of producing an intrinsically motivating game experience appears to be supported. Video review revealed the participant frequently engaging in very rapid movements in an apparent effort to solve the puzzles quickly. This behavior suggests a desire for immediate gratification, a typical response to intrinsically motivating activities.

6.2 Reaction to activity transition strategies

Engaging the user in activities other than watching television was a key objective in this work. The strategies in Table 2 were intended to address this challenge.

Suggestion. When interacting with *ViTo*, the participant was repeatedly exposed to activities as alternatives to watching TV. During the interview, he indicated there were two occasions when he had planned to watch TV but changed his mind: "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." While watching television, the participant also twice clicked on music tracks that were interspersed among TV program listings. After the selected songs ended, *ViTo* delivered a prompt asking if he would like to stop watching television and start listening to music. On one occasion he responded affirmatively and continued listening to music for about 14 minutes.

Encouraging incompatible behavior. Listening to music or radio is used as a distracter in part because it meets the user's motivation to watch TV—seeking relaxation—but is less likely to promote extended sedentary behavior because it is not linked to a single location. In fact, video review revealed that the participant would move around and occasionally "dance" while listening to music.

The just-in-time encouragement of alternative activities during commercial breaks responds to the fact that television programming is itself persuasively designed to engage the viewer for extended periods. To lesson the possibility that the viewer will be seduced into watching additional programs by network advertisements, *ViTo* can replace commercials with NEAT Games. A remotely operated "Wizard of Oz" simulation was used to flag the onset and offset of TV commercials. Due to practical challenges of remotely flagging these breaks, only five of the possible commercial segments were replaced with NEAT Games. On four of these occasions, the participant completed the games. Although it is not known whether this had an effect on the duration of viewing, it is clear that the games promoted physical activity that might not otherwise have occurred.

Interrupting habitual behavior. The first application of this principle, re-ordering main menu items, was assessed indirectly during the interview: when asked to recall the options in the list, he successfully named each one, but made no indication that he noticed the change in order.

The second interruption strategy was intended to discourage channel surfing. When asked whether he would rather use channel up/down buttons or program titles to select what to watch, the participant responded as follows: “I think it’s a lot easier to use titles ... you know what's on without looking at all the channels.” In contrast to on-TV program matrices, *ViTo* only lists content for the present time, thereby discouraging spontaneous decisions to watch more programming in the coming hour.

Based on data collected from the baseline and intervention phases of the case study, it appears that the effect for the reduction of channel surfing was robust. For this analysis, channel surfing is operationally defined as the number of TV channels displayed per minute of television watched. A significant ($p < 0.01$; $F_{(1,11)} = 14.03$) difference in channel surfing was found between baseline (1.91 channels/min.) and intervention (0.29 channels/min.). Although this result should be viewed cautiously given a sample size of one, it does support the hypothesis that channel surfing behavior will be reduced through the use of content-based program selection

6.3 Reaction to proactive interface strategies

The target user population for a *ViTo*-like system is expected to be individuals with a preexisting desire to reduce their television viewing while increasing their physical activity. The strategies listed in Table 3 were selected with this population in mind.

Goal setting. During pre-study screening, the participant expressed interest in participating in exercise-related studies (as well as other study options). This inclination may explain his favorable response to the use of goal setting for physical activity. In *ViTo* the term “NEAT Point” was used as a unit of movement derived from simple accelerometer counts. Over the course of the study, the participant raised his daily NEAT Point goals from 8000 to 10000 per day, a 25% increase. When asked to discuss his use of NEAT goals, the participant explained, “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.”

Perhaps because he did not have a preexisting desire to change his TV habits, the participant did not respond as strongly to goal setting for television viewing. When asked to describe his use of daily TV goals, the participant reported that he didn’t set any: “I just didn’t anticipate watching that much.”

Self-monitoring. Consistent with the fact that he was not concerned about meeting his daily television goal, the participant indicated that he did not actively use the TV Meter (Figure 6(B)) to track his viewing duration. On the other hand, the participant reported that he used the NEAT Meter (Figure 6(A)) regularly to gauge his progress toward physical activity goals.

Proximal feedback. Clicking on the NEAT Meter from anywhere in the *ViTo* interface brings up a display offering real-time graphing of physical activity levels. Video review confirmed the participant’s report that on several occasions he used the NEAT Meter to understand how his movement affected NEAT Point totals as he moved around the apartment engaging in different kinds of physical activity. In the post-study interview, the participant expressed a fair amount of enthusiasm for the use of technology to monitor physical activity. Although it is possible that the novelty of real-time feedback increased the use of this feature to levels that are not sustainable for the long term, the participant's response does support further investigation of how activity feedback might be used to promote healthier living.

Operant conditioning. Reinforcing desirable behaviors is another strategy that may prove viable for long-term motivation. During the course of the evaluation, the participant was rewarded six times for engaging in sustained or vigorous activity. Two of these were delivered during NEAT Games and another when the user was interacting with the real-time activity graph, further supporting the notion that computational feedback can effectively motivate meaningful changes in behavior.

Shaping. Gradually increasing the amount of physical activity necessary to earn rewards may lead to large changes over time. For the short duration of this case study, the effect of shaping was probably negligible, as reward thresholds were incremented only 1% for each delivery. For use of NEAT Games, however, the impact of incremental shaping was more apparent. 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. In spite of this 25% increase in difficulty, the participant revealed in the interview that he was unaware of the change.

Consistency. For television viewing, the participant encountered a commitment prompt sequence (Figure 9) eleven times. Again consistent with his lack of interest in tracking viewing time, the user did not appear to use this feature in a reflective manner. Nine of eleven times he responded that he would watch for 30 minutes. Four times he watched substantially less than this, four times he watched substantially more. On one occasion the commitment sequence ended with a prompt to turn off the television that coincided with the user's completion of his viewing session. The participant had left the room, so the device automatically turned off the television after a timeout period of 3 minutes. About this the participant reponded: "I had already finished watching and was doing something else, so I didn't bother turning it back on."

7 Conclusions

The results of this exploratory study may raise more questions than answers. 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 related to physical activity—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* (e.g. suggestion, intrinsic motivation, and consistency) 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 study was undertaken with four goals. We successfully stress-tested the system in a real home setting for a week. We also collected a naturalistic dataset useful for preliminary analysis of the system, allowing evaluation of specific interactions in some depth. We gained additional insight into how a person might use a persuasive consumer electronic device. Finally, we used the experience to identify some issues that should be addressed before this system is tested longitudinally.

Among the most important design observations drawn from this work are the following: (1) Interventions based on consumer electronics may be particularly viable if the devices offer substantial improvement over competing technology—efforts focused on basic user experience will likely pay off in long-term adoption. (2) Designers should plan for long-term use and resist the temptation to impress users with an initial panoply of persuasive elements—strategies should be phased in over time so the user can react to them individually. (3) Most strategies will be initially received as novelty—user curiosity can be used to advantage by encouraging exploration of new features. (4) Not all users will react well to all strategies—interventions should adapt to the user's preferences; keep strategies that work, and phase out those that don't.

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.

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 outcome measures from the case study evaluation described in this document are suggestive, lending support to the possibility that *ViTo* might 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, and that researchers in ubiquitous computing and user interface design will begin to apply their expertise to create novel and high-impact behavior modification systems that are embedded into everyday life.

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