NEAT-o-Games: Ubiquitous Activity-based Gaming

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Abstract
The role of Non-Exercise Activity Thermogenesis (NEAT) has become a key component of obesity research, prevention, and treatment. This paper describes research that aims to suppress the obesity epidemic by infusing NEAT in the sedentary lifestyle of an average person. The method combines unobtrusive physiologic sensing and novel Human-Computer Interaction (HCI) technologies. It supports a strong motivational framework based on ubiquitous computer gaming, appealing enough to likely change the behavior of 'couch potatoes' on their own volition. This novel generation of computer games (NEAT-o-games) is fueled by activity data recorded by small wearable sensors. Data from the sensors are logged wirelessly to a Personal Digital Assistant/Cell Phone (PDA), which acts as the central computing unit of the system. Algorithmic software processes these data and computes the energy expenditure of the user in real-time. The paper presents a prototype implementation of NEAT-o-games and initial evaluation results.

Keywords
Computer game, energy expenditure, ubiquitous computing

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

The importance of obesity to world health is without question. There are 1 billion people in the world who are overweight and 300 million with obesity. Recent work suggests that this is driven by a reduction in energy expenditure, rather than a rise in energy intake. In Britain where obesity has doubled since the 1980's, energy intake appears to have decreased.

Non-Exercise Activity Thermogenesis (NEAT) is the energy expenditure of all physical activities other than volitional sporting-like exercise. NEAT is highly variable among individuals. NEAT in an agricultural job exceeds that for an office job by 1,500 kcal/day. Similarly, an evening of television watching expends 30 kcal whereas an evening of gardening and walking the dog expends 600 kcal. This marked variability in NEAT supports the notion that is fundamental in energy balance [7].

The ultimate goal of this research is to increase NEAT in the modern lifestyle. It leverages already ubiquitous gadgets (e.g., cell phones), unobtrusive metabolic measurement technology, and the entertainment appeal of computer gaming by developing a new breed of computer games catalyzed by human motion (NEAT-o-games).

Specifically, we collect physical activity data from small sensors worn by the user. The data collected from the activity sensors are logged via Bluetooth connections to a Personal Digital Assistant/Cell Phone (PDA), which acts as the central computing unit of the system. The data are processed through metabolic modeling software that computes the energy expenditure of the user in real-time. If the system projects energy expenditure below target levels, creative HCI mechanisms that promote NEAT intensify to prevent this from happening. The pillar of these mechanisms is NEAT-o-gaming. In a first variety of such games, avatars are competing against each other propelled by the physical activity data of real and virtual users participating in networked buddy lists.

Relevant Work

Recently, a stream of publications on ubiquitous Human-Computer Interaction (HCI) for battling obesity has appeared. Toscos et al. [10] have developed a cell phone application that helps motivate teenage girls to exercise by exploring their social desire to stay connected with their peers. Consolvo et al. [4] have developed a mobile phone application for encouraging activity by sharing step count with friends. Lee et al. [6] developed PmEB, an application for mobile phones that allows users to monitor their caloric balance as part of weight management.

The behavioral (almost addictive) effect of computer gaming has also caught the attention of the HCI community. In a recent article, Clarke et al. [3] reported an exploratory interview-based study of computer gaming. They have found that aspects of gaming most salient to gamers were those perceived to be most behaviorally relevant to goal attainment. Brown [2] identifies the role that video games play in the sedentary lifestyle of youth. At the same time, since video games are such a draw to young people (and people in general) he recommends the use of video games for healthful influence, not just for entertainment. For example, he suggests that dietetics professionals may add interactive, educational games to their ever growing repertoire of dietetics knowledge, skills, and patient/client education.

The cultural phenomenon created by the Dance-Dance Revolution (DDR) gaming has been studied by Hoysniemi [5]. The results showed that playing DDR had a positive effect on the social life and physical health of players. A few researchers have also developed immersive fitness computer games [8] [9].

Although, our work is firmly embedded in the HCI framework suggested by the aforementioned publications, it is also quite distinct in many ways. Overall, researchers have started identifying the potential role that ubiquitous devices, like cell phones, can play in an HCI framework for battling obesity. Some have even tried to integrate ubiquitous sensing. However, integration is still weak and monitoring of energy expenditure relies in large part on user input. Also, the incentive scheme is based largely on warning and encouraging messaging. The effect of such messaging alone on people with behavioral problems is iffy. By contrast, our system is highly integrated and automated and most important, it is highly motivating.

Methodology

We use a tri-axle accelerometer to measure physical activity. The form factor of the sensor is similar to a mobile phone and is attached to the waist of the user. It communicates with a PDA through a Bluetooth connection (**figure 1**). Measurements are recorded every second and are correlates of the energy expended by the user due to motion at the time. These expenditure data are being used in novel computer games that require physical activity. We are developing a new generation of ubiquitous games where characters are being moved by activity data logged in by body-worn sensors (NEAT-o-games).

In this paper, we report the first NEAT-o-game that can be played either between many people participating in a buddy list or between a single person and multiple computer-generated opponents. Every user is represented in the game as an avatar that runs around a circuit. Each avatar's motion is controlled by the accelerometer data logged in from the waist sensor of the user. The most physically active user is ahead in the race. Data communication between the users' PDAs participating in this competitive race is effected either through cellular broadband or Wi-Fi. Players in the game are notified periodically of their standing and a winner is proclaimed every day.

figure 1. User wears activity sensor at his waist and holds a Palm Treo PDA at his palm. The devices are indexed in the right panel, where the form factors are evident.

User Interface

The guiding principles for the design of the game interface can be synopsized as follows:

- Simple – This is a game on the go, and it is supposed to take place amidst other activities (e.g., walking).
- Informative – The user should be able to get at a glance all that he/she needs to know.
- Discreet – This game runs mostly in the background and does not interfere with normal tasks.
- Motivating – The game supports a behavioral framework and facilitates motivation.
- Elegant – This is a PDA application, one of the most competitive software domains. Users are increasingly getting used to high quality mobile applications and anything clumsy by comparison will be a "turn-off."

Two sample screens are shown in **figure 2**.

figure 2. The left screen shows a two-player NEAT-o-race. In this, the two avatars race around the track and overall standing is shown on the left. The rate of animation is based on the level of user physical activity. The right screen shows a congratulatory screen for an individual who is doing well. It shows graphically in a dial the relative activity lead and a pleased action figure.

Typically, the user runs the NEAT-o-game in the background while doing other tasks. A rallying screen pops-up to alert a user who is lagging behind the competition. It shows graphically in a dial the relative activity lag and a frustrated action figure. If the user is far ahead of the competition, then a congratulatory screen pops-up. The first action figure developed is a caricature of Arnold Schwarzenegger, as he is an ex-athlete turned politician and for this reason not only well-known but also semantically relevant. In future versions of the game the user will choose from a roster of action figures.

Experimental Design and Results

We ran an initial evaluation with 4 users. The study aimed to assess the robustness and usability of the system as well as obtain a first indicator of its behavioral impact. The users lived a mostly sedentary lifestyle, they were in their twenties and thirties, and on average they were overweight (BMI=26, WHO I classification). All users were PDA savvy. Each user completed three sessions on different days. Sessions were scheduled post-lunch or pre-dinner times when people often take walks or watch television.

In session 1, each user was given a system (PDA and waist activity sensor) with the NEAT-o-game software disabled. The system simply recorded his activity and sent the data to a lab data server automatically. In session 2, the user was allowed to play the NEAT-o-game, but only against a computer generated avatar, which was programmed to have an average activity level. In session 3, the user played the NEAT-o-game against a human opponent. Users played this in pairs. Each user was equipped with a system (PDA and a waist activity sensor) and selected each other to play

the game through the user buddy list. Each system was communicating the data recorded by its sensor to the competitor's system through the cellular broadband. At the end of the session a winner was declared.

Each session lasted 45 minutes and completed at a different day, but at consistent times. For the two-user session, the two users were up to 15 miles apart. Every user completed pre- and post-study questionnaires based on the SUS usability instrument [1] .

As shown in **figure 3**, addition of the computerized avatar greatly increased activity versus baseline. Moreover, activity increased further with the human opponent. All user activity was generated simply by walking in or around their offices and homes.

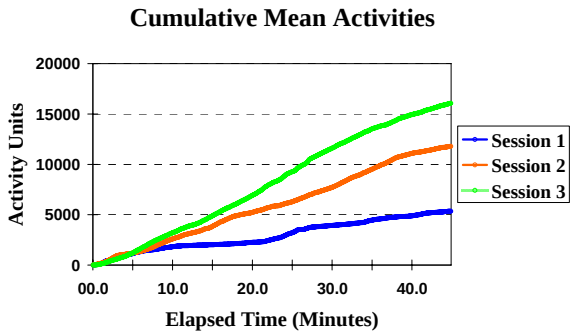

figure 3. Comparison of cumulative (integral) energy expenditure averaged across 4 pilot users. The bottom line represents no motivation. The middle line represents playing against the computer avatar. The top line represents playing against another human user.

The post-session questionnaire focused on general usability questions, such as complexity and intuitiveness using a 5-point Likert scale as well as open ended questions. Based on a Kruskal-Wallis test there was no significant difference among the 4 users ($p=0.8649$), so results were combined. Scores for most questions were positive (i.e., 3.25 - 4). The only question with a negative response was whether the system could be used without any technical support (mean 2). However, this difference was not statistically significant. The open-ended questions revealed that the users loved the idea of NEAT-o-gaming, felt it would be helpful in a weight-loss program, and wanted more.

Conclusions

This prototype demonstrates both the feasibility and acceptability of the NEAT-o-games concept. Initial experiments with a small user set confirmed the robustness of the system operation even when users who played the game were physically miles apart. It also gave a first confirmation of the basic hypothesis: typical sedentary users enthusiastically embraced the game and played it with zest, much the same way one would expect them to play most other competitive computer games. Of course, due to the nature of the game, the side effect was higher physical activity. Feedback from the users was uniformly positive.

This paper presents a new paradigm to attack the behavioral aspect of the current obesity epidemic. It introduces a new generation of ubiquitous games (NEAT-o-games) where characters compete based on energy counts recorded by accelerometer sensors, which they wear along side their ubiquitous cell phones. Typically, games are considered short duration diversions from everyday life. NEAT-o-games are unlike other games, because they may potentially run for hours, days, or for life. They are meant to become part

of people's everyday routines. The system is highly automated and integrated, which makes it least-interfering with the user's daily tasks.

This is work in progress and much remains to be done. The user set is small and statistically significant conclusions cannot be drawn at this time. However, there are some clear indicative trends and experiments are ongoing with a user pool including up to 30 individuals. Also, the appeal of the game over time has not been tested. True, users are enthusiastic the first time they get their hands on it and quit watching the 6 o'clock news in favor of a neighborhood walk. But, would this be the case after 30 days of use? Eventual fatigue is expected to take over, which we plan on addressing by increasing the variety of NEAT-o-games. Finally, several issues remain to be worked out for the system to become truly practical. The major obstacle is energy consumption, which we plan on addressing with energy scavenging. Currently, the sensor battery drains after about 2.5 hours of continuous use. The goal is to extend the autonomy of the system throughout the waking hours of the users.

More information about this project, including dynamic content (e.g., videos) can be found at http://www.cpl.uh.edu/html/localuser/ocgi/.

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