There's a Monster in my Kitchen: Using Aversive Feedback to Motivate Behaviour Change

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Abstract
In this paper we argue that "persuasive technologies," developed to motivate behaviour change in users, have so far failed to exploit the established body of empirical research within behavioural science. We propose that persuasive technologies may benefit from both adapting to individual preferences, and a constructive use of *aversive*, in addition to appetitive, feedback. We detail an example application that demonstrates how this approach can be incorporated into an application designed to train users to adopt more environmentally friendly behaviours in their domestic kitchens.

Keywords
Negative reinforcement, behavioural psychology, environmental awareness, connected kitchens, persuasive technology.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. J.4. Social and Behavioural Sciences: Psychology

General Terms
Design, Theory, Human Factors

Introduction

In this paper we present an intentionally provocative position that the field of persuasive technologies is systemically ignorant of 80 years worth of advances and discoveries of the behavioural sciences. Our intention is to provoke discussion and reflection around the objectives and motivations of ongoing research in the field of persuasive technology.

Much attention has recently been given to the role of technology such as mobile phones, the Internet, computer games and social networking sites in helping stimulate behaviour change in users. For instance, technology-based behavioural interventions have been developed in the fields of diet and exercise [1,2,3,4,6] chronic disease management [14,17] HIV prevention [25] and energy consumption [19,15] among others. Although these technologies are designed with the specific aim of effecting change in user behaviour, very few have implemented empirically established methods for doing so [25]. Indeed, very little of the published work on persuasive technology gives any specific insights into the processes involved in behaviour change, nor specific examples on how to apply these processes.

In this paper, we describe how applications can benefit from some useful aspects of traditional behavioural interventions, including adaptation to individual users and the increased use of aversive, as well as appetitive stimuli. We will then discuss how these processes can be incorporated into the design phase of a persuasive technology application for energy consumption.

Understanding Behavioural Interventions

Behavioural psychology is the scientific study of learning [5]. It is, by definition, practical and pragmatic, as it presumes that all behaviour is determined by interactions with and feedback from the organisms' surrounding environment [22]. Successful behaviour is maintained, while unsuccessful behaviour is not. For example, we will learn to slam the washing machine door shut if that is the only way the machine will power up. Mental constructs such as states of mind, feelings, personalities and so on are rejected as explanatory tools for behaviour as they cannot be directly manipulated.

Crucially, behavioural psychology suggests that because behaviour is determined by the environment, it can be changed readily by analysis and manipulation of that environment (see [20] for an excellent introduction to behavioural interventions; [7] for an in-depth analysis). For this reason, we suggest that behavioural psychology is the ideal framework within which to design persuasive technologies. Indeed, disregarding almost 80 years of empirical findings in this field on predicting and controlling behaviour would seem inefficient. The vocabulary of behavioural psychology has been developed to describe the processes whereby environmental variables can be manipulated to bring about change in behaviour. As we will use this vocabulary for clarity from now on, we will first briefly provide a definition of four useful terms:-

Operant Conditioning describes the process whereby the consequences of behaviour feed back to the organism and change the probability that the behaviour that produced them will occur again [21]. Positive reinforcement, negative reinforcement and punishment are all particular instances of operant conditioning.

Positive Reinforcement describes a situation where the presentation of a stimulus as a consequence of an instance of behaviour makes that behaviour more likely to occur in that context in future. For example, in the case of the faulty washing machine, the machine working properly may increase the probability of slamming the door shut in future. If this is the case, the machine powering on has functioned as a *reinforcer*; it has reinforced the behaviour of slamming the door shut (i.e. increased the probability of it happening again).

Negative Reinforcement describes a situation where the removal of an existing stimulus as a consequence of an instance of behaviour makes that behaviour more likely to occur in that context in future. For example, learning to close a door in order to prevent a cold draught. In this case, the removal of an ongoing aversive stimulus (a draught) has functioned as a "reinforcer"; it has reinforced the behaviour of closing the door (i.e. increased the probability of it happening again).

Punishment describes a situation where the presentation of a stimulus as a consequence of an instance of behaviour makes that behaviour less likely to occur in that context in future. For example, dangerous fouls in a sporting match may result in the presentation of a fine or temporary ban, therefore reducing the probability of it happening again.

The Role of Aversive Stimuli in Persuasive Technology

Most Persuasive Technology applications aim to effect behaviour change simply through offering simple rewards to users. It is rare to find an application that takes advantage of the full capabilities of operant conditioning, despite the fact that a combination of positive reinforcement, negative reinforcement and punishment is a fundamental aspect of how behaviour is learned and maintained in the natural environment [22]. For example, in an office a person will work hard in order to achieve a salary and the approval of colleagues (positive reinforcement). However, that person's performance is also maintained by the aversive stimuli that they are avoiding such as peer disproval, suspension, termination of employment (forms of punishment) and poverty (working to escape poverty is an example of negative reinforcement), which will be delivered if the person does not work hard.

One significant problem with designing behaviour change programs that offer only rewards is that when a reward is not obtained, there is no meaningful feedback delivered to the user at all. It is difficult to evaluate what a person learns from a complete lack of feedback upon failure to meet targets. Additionally, when feedback is not presented, the control over what the person learns is taken out of the hands of the program designer and can lead to the development of problematic "folk theories" (see [8,9,17] for a discussion of how such folk theories can impact energy consumption). We suggest that Persuasive Technologies may benefit from the delivery of aversive stimuli when a user does not meet behavioural targets, as this will increase the overall frequency of feedback delivered to users and, consequently, the control of the intervention over the users behaviour.

Interestingly, computer games typically consist of a complex system in which decisions are made and meaningful feedback is delivered in a timely fashion. Games are a perfect example of how technology can exploit a combination of positive reinforcement, negative reinforcement and punishment in order to maintain the motivation and engagement of users. For example the basic act of accumulating points and advancement through levels are forms of positive reinforcement. Negative reinforcement is manifest in some games by the ubiquitous requirement for players to re-start from the beginning of a level or stage when they die or fail a mission (not wanting to waste time replaying the easy parts of the same level over-and-over is a powerful motivator). Some games implement punishment systems; for example, where role-playing games penalise players an amount of gained experience points or inventory items when a character dies. We suggest that technology designed to bring about behaviour change in users would benefit from careful and deliberate implementations of similarly sophisticated systems of reinforcement.

Adapting to Individual Users

The task of changing a person's behaviour appears to be a task in delivering appropriate feedback when a target behaviour is detected. However, the problem with designing interventions for large numbers of people is that there are very few, if any, stimuli that are universally reinforcing or universally punishing to all people, since these definitions are dependent on each persons individual history. The same stimulus can function as a reinforcer for one person and a punisher for another. For example, some people find listening to classical music to be the highlight of their week, while many find it boring. Delicacies such as Caviar, Kokoretsi (Organ meat), Oysters and Marmite are often seen as repulsive to different palates. To continue the example of having to re-play a failed level in a game, some players will be motivated by this situation to perform better, while many other players will abandon the game entirely due to frustration.

When behavioural psychologists create a behaviour change program, the first step is often to evaluate which stimuli the student/patient will work for and which stimuli they find aversive. One child may do their class-work diligently in exchange for gold stars, while another may work harder to avoid being put on pencil-sharpening duty. The process of reacting to the impact of a delivered reinforcer ensures that the rewards provided by the program are ones that the learner is motivated to obtain.

Persuasive Technologies typically do not evaluate which stimuli, or types of stimuli, a person will work for, and which stimuli they find aversive. Instead of evaluating what works for the individual, designers tend to presume that they know what will work on average for a group of individuals. We argue that technology designed to effect behaviour change in users should attempt to continuously evaluate the effectiveness of the feedback they provide in order to provide feedback that is optimally effective for an individual. For example, if a technology is designed to generate energy-related behaviour change through the display of a cartoon polar bear and its habitat (e.g. [10]), some participants may find it entertaining to try and harm the polar bear, thereby using unnecessary amounts of energy and contradicting the goals of the project. Systems designed to adapt to users' behaviour could, 1) recognise that the deteriorating state of the polar bear and its environment is predicting increased energy consumption and; 2) take appropriate action, such as to reverse the contingency, whereby the only way to worsen the polar bear's environment is through reduction in energy consumption.

Thus, we argue that any technology designed to change the behaviour of users would benefit from delivering feedback consistently, whether the user reaches behavioural goals or not; and should also be able to monitor the effectiveness of each stimulus delivered and adapt, so that the most effective strategy is used for each user. However, from an application designer's perspective we realise this is a very broad statement and is, perhaps, easier said than done. In order to make our argument more relevant to the HCI community, the next section describes a complete concept application, "Nag-baztag", as an example of a persuasive technology designed explicitly to use the mixed approach to motivating behaviour change we have proposed in this paper.

Nag-Baztag

Nag-baztag is conceived as a device for helping users become more environmentally friendly in their kitchens. Domestic energy usage has been recognised as a key contributor to global climate change [16]. In addition, domestic energy consumption has increased 30% since the 1970's. Clearly, this behaviour trend is not sustainable, with the use of voluntary or potentially enforced interventions likely to become a reality.

Kitchens are perhaps one of the most resource hungry rooms in the average household, being a focal point for using large amounts of power, gas and water through daily activity. Therefore, changes in behaviour around the use of appliances and resources in the kitchen can have an effect on the environmental impact of the entire household, and help reverse the trend of increasing carbon emissions. The complexity and misconceptions around green issues make them an ideal topic for which to develop technologies that aim to interpret and alter ongoing behaviour.

The Nag-baztag is an Internet connected agent that is able to monitor power usage on a per-appliance basis, and able to track water and gas usage through networked metering devices. The application is embodied in the form of a physical agent, here represented by a "Nabaztag" rabbit device[1]. The Nabaztag is a wirelessly connected rabbit that acts as the human-facing interface to the system, and is set up in the kitchen itself. Previous work has demonstrated the effectiveness of using such embodied agents for giving evaluative feedback to users [24]. All of the technology, including the Nabaztag and the various meters that form the technical infrastructure for the concept, are currently either available off-the-shelf or otherwise easily constructed. Indeed, previous studies have demonstrated how meters for measuring gas, electricity and water consumption can be linked together in a single display [11].

Enabling Technology

"Smart meters" have become a very common tool for monitoring energy usage in residential situations. The

[1] See http://www.violet.net for more about the Nabaztag device

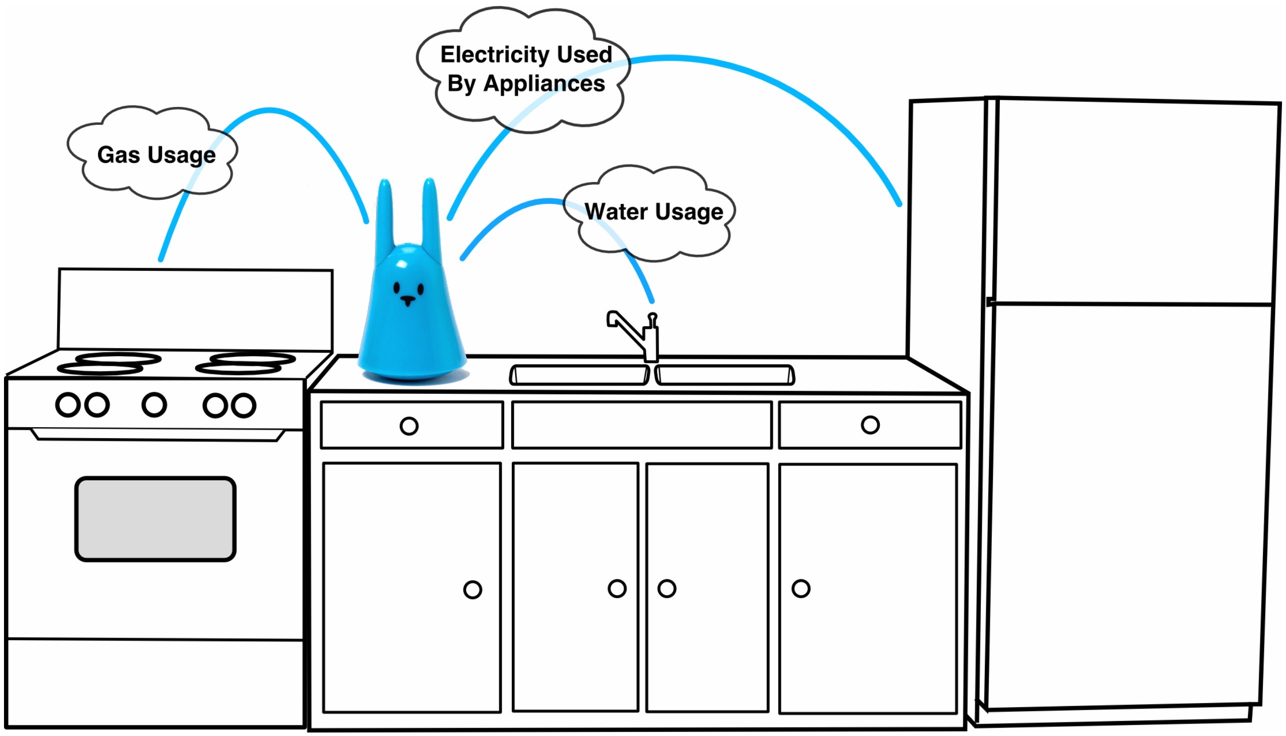

Figure 1 – The system collects usage data from wireless meters connected to water pipes, gas pipes in addition to electricity usage from meters connected to sockets used by individual kitchen appliances.

UK government has recently begun plans to have smart meters for gas and electricity installed in every home by 2020 [23]. Typically they either connect directly to the mains electricity supply, or at the point where an appliance is connected to a power socket. In addition, a flow meter can easily be attached to a kitchen sink to collect information on water usage. All of these devices are able to provide rich information on current and historical usage data for each appliance and household. More advanced versions, such as those employed in our current concept, are able to transmit usage data in a semantic format via a wireless network to be analysed on a computer or on the web (e.g. "Holmes" software for Wattson meters[2]). The reporting capabilities of all these devices form the input for the system to measure a person's energy usage patterns in a very finely detailed manner.

In addition to the rich input provided to the system in order to calculate energy usage behaviours, the system also has the capability to exert effects on this connected kitchen in a limited fashion. Each point where an appliance is plugged into a socket has a simple electrical relay system that allows power to the socket to be switched on or off based on instructions from the software itself.

Changing Behaviours

With the technology described above, the system is able to monitor the energy usage patterns of the user. The objective is to change these behaviours in a positive way – reducing consumption of power, gas and water and therefore reducing both the cost of these resources for the user and the environmental impact of their kitchen activities generally.

By analysing patterns of usage in the kitchen, the system is able to identify certain environmentally detrimental behaviours that should be targets for improvement. The system has a variety of tools based on operant conditioning techniques that can be used to attempt to effect positive behaviour change in the user.

[2] http://www.diykyoto.com/uk/holmes/why-use-holmes

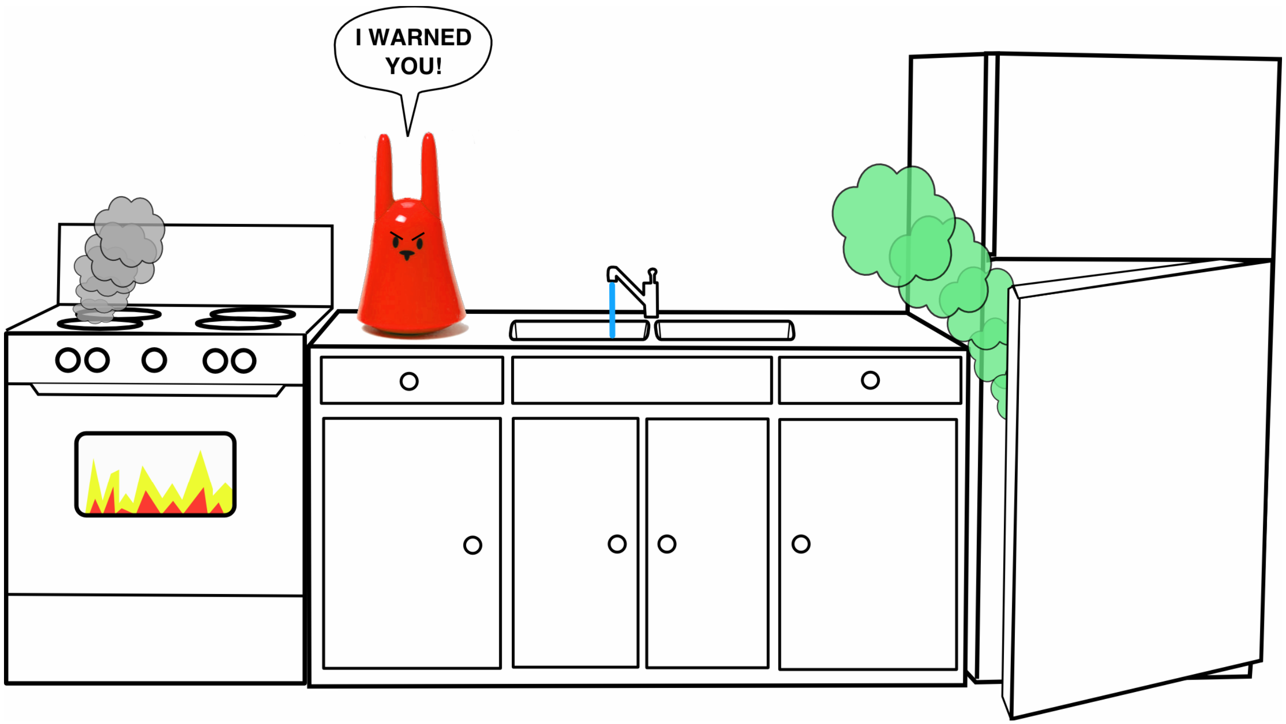

Figure 2 – Repeated poor behaviour can result in severe punishment as the agent has the capability to turn off power to appliances at will.

In a kitchen there are a wide variety of such environmentally detrimental behaviours, but this concept will focus on kettle usage for illustrative purposes. Boiling an electric kettle is an extremely inefficient use of energy, therefore should only be used when strictly necessary. When making a cup of tea for example, using the kettle is unavoidable. However it is important that energy isn't wasted by boiling more water than is necessary. If a kettle is boiled twice in a row without any water having been drawn through the kitchen tap, this is an indicator that the kettle was initially filled up with more water than necessary – and therefore this activity is identified as a negative behaviour to be addressed.

Positive Reinforcement - Nag-baztag can use positive reinforcement to teach the user to change their habit of filling the kettle with too much water. This can be done in any number of ways popular in PTs generally. For example, when the user only draws the correct amount of water, they can be rewarded with praise, or a virtual "gold star", or even just by letting them know how much money they have saved so far (this is in effect the same as accumulating points in a computer game).

Negative reinforcement – People will work to avoid an ongoing aversive stimulus. The aversive stimulus that people must work to avoid in the Nag-baztag application is the constant nagging by the Nabaztag device over the amount of energy and water being used. For example, if, when a user goes to make a cup of tea, the tap is used to draw more than a usual amount of water, the rabbit will complain, for example, that, "*You should not use too much water because it costs money and money does not grow on trees!"* When the electric kettle is switched on, the rabbit could remind the user "*Only boil the water you need, otherwise you are killing the planet!*" It is suggested that this nagging will constitute an aversive stimulus for most users (i.e., they will work to avoid it). Thus, whenever they want to make a cup of tea, that in the future they will be very careful to only use the correct amount of water (in which case the rabbit remains quiet, or occasionally provides positive reinforcement).

This will minimize the amount of nagging they will have to endure from that annoying rabbit, but will also reinforce the (positive) environmental behaviour of using kettles efficiently.

Punishing Lapses in Good Behaviour - When a user falls back into bad behaviour, or has lapses in concentration that cause major expenditures in terms of resources, it may be necessary for the system to apply a suitable punishment. Given the control the system has over the power supplied to the various appliances, these punishments have the possibility to be very harsh indeed.

For example, if a user leaves the tap slightly on by mistake when going to work, the rabbit can issue a set of graded punishments. In the first instance this may be simply a long nagging session when they return home, or constant reminders while at work via email, SMS (text) messages or even Twitter and Facebook about their poor water-usage behaviour.

On future occasions the rabbit may issue ultimatums – "*If you don't come home IN THE NEXT HOUR and turn the tap off, there will be consequences!"*, and from then on issue very real punishments. For example, it may never allow the user to use the kettle to boil water (by switching the appliance off at the socket whenever it is used), or perhaps on the third punishment, the rabbit may decide that the user has *gone too far*, and therefore while the user is at work it switches the power off to the freezer, allowing the perishable contents to defrost and spoil during a long hot summer day!

The fact that the punishments may not themselves be very environmentally friendly is beside the point – it was always the user's fault and the rabbit always has the classic excuse "*I warned you and you MADE me do it*!"

Adapting to users

The most important aspect of the system is its adaptability. It is key that the persuasive techniques used by the system depend entirely on what is effective for the individual using the system. For example, some people may find the constant nagging of the Nag-baztag to be entertaining. Other people may resent the punishments and stop using the system when it keeps preventing them from boiling the kettle (This is the same as a computer gamer quitting the game in frustration at having to re-play the same mission *again*).

Therefore, the system has to be reactive; monitoring activity and linking changes in behaviour with energy consumption over time, based on feedback delivered. If nagging leads to an increase in energy consumption (or even simply no decrease in consumption), then it will stop nagging and choose another feedback mechanism (e.g. perhaps rewards based on incremental changes). The combination of feedback mechanisms changes over time based on what strategies have been most successful.

Additionally, a single user with several different negative behaviours may respond to different feedback for each behaviour (e.g. nagging is effective for boiling the kettle, but rewards are more effective for keeping the thermostat low) and effectiveness may change over time. Therefore, persuasive systems in general must constantly re-evaluate users' responses to feedback and be highly adaptive, in order to maximise the effectiveness of the technology.

Discussion

In this paper we have argued that persuasive technologies rely too much on positive reinforcement, which is only one aspect of successful behaviour change programmes. We propose that technologies that attempt to change behaviours should take advantage of the full variety of operant conditioning techniques in order to maximise their effectiveness. In particular, we have highlighted that existing persuasive technology fails to take advantage of negative reinforcement and punishment as tools for effecting positive changes in behaviour and makes no attempt to adapt persuasive techniques to individual users.

We have introduced the Nag-baztag concept, which is an illustrative application for teaching positive, environmentally friendly, behaviours within a domestic kitchen environment. The unique and potentially controversial aspect of the application is that the learning is based on an adaptive approach, and this explicitly includes negative reinforcement and potential for punishment with real negative consequences.

The Nag-baztag concept is provided as a case study to illustrate clearly how the psychological concepts of operant conditioning can be genuinely applied to real purposes generally in the field of HCI applications, rather than simply dismissed as theoretical concerns. In fact we give direct examples of how computer game applications already use a wide range of different reinforcement techniques to increase engagement in the game, and how these same techniques can be used to motivate real change above and beyond simple engagement.

Indeed, this paper serves to demonstrate how the field of persuasive technologies need not be a "research island" and can take direct advantage of 80 years of research in behavioural science to make more effective and engaging applications.

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