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Promoting Pro-environmental Behaviour: a tale of two systems

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ABSTRACT
Sustainability is becoming increasingly important in our everyday lives. We no longer see it as solely the responsibility of governments or large corporations, but we are asking ourselves how we as individuals can contribute to the well-being and maintenance of the world we live in. This paper explores the use of mobile persuasive technology to promote pro-environmental behaviour in the home. We have designed, implemented, deployed and evaluated two mobile systems in two different domains, in two different countries. The novelty in this research is that the theoretical outcomes from two different but related studies are analysed together. From this we have discovered eight overarching persuaders to sustainable domestic resource consumption. The fact that these concepts are common to both studies strengthens the generalisability of our findings. The contribution of this paper to HCI is a set of eight key concepts to consider when designing mobile persuasive technology to promote pro-environmental behaviour.

Author Keywords
Sustainability; persuasive technology; mobile computing; electricity consumption; water conservation; households.

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

INTRODUCTION
In recent years, human computer interaction research has responded to the significant increase in people's awareness and interest in sustainability and environmental impact of natural resource use on a personal and domestic level (Froehlich, 2009). People are keen to act in a sustainable way (DiSalvo et al., 2010), and yet they find it difficult to know exactly what to do. This is because they are often unaware of their own, or their household's consumption of finite resources such as water, gas or electricity since detailed patterns of consumption or guidance on "smart" consumption have not been readily available. Water meters and electricity meters are placed out of site to the average consumer, sometimes locked away in cupboards or hidden at the end of the garden. And even when we do look at them, as everyday consumers, the dials and the numbers make little sense to us. The only real metric we have on these resources is when the bill comes, and whether or not we find the amount acceptable or reasonable. Typically, electricity bills report limited or irrelevant information and this kind of feedback is insufficient for energy management (Darby, 2006). *How much is a kilowatt-hour, and how many should I be using?* Sometimes we ask friends and neighbours what they are paying, to get some comparative measures, but even when we decide we are paying too much compared to our neighbours, how can we know how and where to cut down? This kind of ambiguity prevents people from successfully reducing the amount of electricity they use in the home (Darby, 2006; Fischer, 2008), or optimising domestic garden watering habits for water conservation (Nansen, 2012).

In this paper we report on the design, development, deployment and evaluation of two mobile systems that address these challenges from the perspective of persuasive technology as introduced by Fogg (2003). That is, systems "designed to change attitudes or behaviour through persuasion and social influence, but not through coercion". The two systems are: the Smart Garden Watering Advisor (*Water Advisor*), deployed in Melbourne, Australia (Pathmanathan et al., 2011); and the *Power Advisor*, deployed in Aalborg, Denmark (Kjeldskov et al., 2012). Both were evaluated with a total of 10 consumers for three weeks of continuous use.

What is novel here, is that the theoretical outcomes from the analyses of these two systems being used in longitudinal field studies were then combined and analysed. What we gained from this approach is a set of eight overarching concepts that can persuade people to adopt pro-environmental behaviour and can be used in designing mobile applications that promote sustainable behaviour in everyday domestic situations.

In this paper, we present related work on experimental systems for sustainability in both the water conservation and electricity conservation domains. We also present research on behavioural change of people in home settings and the design of persuasive technology. This is followed by two sections detailing the systems' design. The longitudinal field study section presents our method. This is followed by a findings and discussion section, including implications for design. Finally we conclude by reiterating the contribution of this paper and listing our eight overarching persuaders to promoting pro-environmental behaviour.

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RELATED WORK

In this section we will briefly introduce related work that has been done in the water conservation area, in the power conservation area, and in the area of creating persuasive technologies.

Reducing domestic water usage

Several studies have been conducted in the area of changing people's water-use behaviour in private households (Arroyo et al., 2005; Kappel & Grechenig, 2009; Kuznetsov & Paulos, 2010; Pearce et al., 2008). Arroyo et al. (2005) present numerous persuasive techniques to increase awareness of water conservation in the kitchen, specifically around the kitchen sink. Their system WaterBot motivates people to turn off the tap when they are not using the water. "Show me" developed by Kappel & Grechenig (2009) and UpStream developed by Kuznetsov & Paulos (2010) are both physical installations designed to help people conserve water when showering. Both give information about current water usage so that people can reduce this. The SmartGarden watering online application (Pearce et al., 2009) is an internet-based application to support gardeners' reasoning about water demand and water supply for their gardens.

Reducing domestic electricity usage

There are several studies into people's energy consumption, and ways to promote household energy conservation (Kirman et al., 2010; Schultz et al., 2007; Weiss et al., 2009; Yann et al., 2010).

Shultz et al. (2007) conducted a study promoting household energy conservation through normative messages. In this study, 290 households were divided into two groups. One group received messages containing descriptive-norm-only messages (e.g. how much energy they had used that week), the other half received descriptive-plus-injunction information (e.g. the amount of energy used with a smiley face denoting whether this was above (☹) or below (☺) the average in the community). Those households with the injunctive messages displayed more pro-environmental behaviour.

With focus on the principles of attracting attention and raising awareness about electricity conservation, Yann et al. (2010) explored the requirements of an always-on feedback electricity consumption system. The outcome from the study was a three-stage approach to supporting electricity conservation routines: raise awareness, inform complex changes, and maintain sustainable routines. A design implication from this study was that raising awareness could be achieved with detailed electricity consumption information, including information about past electricity consumption patterns. Weiss et al. (2009) also reported this finding, and recommended showing information to people about their electricity consumption history to raise their awareness about how they use electricity.

Behavioural change and persuasive technology

To motivate behavioural change in users, Kirman et al. (2010) conducted a study exploring several ways of using persuasive technology based on empirical findings from behavioural science. Working from the stance that many technology products rely too much on positive reinforcement, they found that one way to effect positive change in people is to make use of negative messages and sad smileys to promote change. The outcomes of these studies is a set of recommendations for the kinds of interventions and messages that have a positive impact on people's use of electricity and their motivation to conserve it.

Projects that try to persuade people with technology to become more conscious about reducing environmental impact are sometimes called 'Eco-feedback' technology (Froehlich et al., 2010). In their research study Froehlich et al. conducted a comparative study of 89 papers from environmental psychology and 44 papers from HCI literature to make a summary of key motivational techniques that HCI-designers must be aware of if they want to promote pro-environmental behaviour. One of their most important issues was the way in which information could be used to persuade people to make this change, "Information must be easy to understand, trusted, attract attention and is remembered" (Froehlich et al.). Fogg (2003, 2009) predicted that mobile devices would be the dominant platform for persuasion. He claimed that mobile platforms could motivate people to achieve their own personal goals. According to Fogg (2009), "Mobile technology can layer information into our moment-by-moment lives in a way that changes our behaviour."

This led us to believe that mobile persuasive technology could be used to enhance the quality of today's communities by motivating people to use resources such as water and electricity more wisely and more sustainably. Mobile phones are pervasive and commonly used as an integral part of our daily life, regardless of whether we are at home, work, play or travelling. Mobile applications can gather and report current and localised information that is relevant to us, and our goals, in this context. As Fogg (2009) says, "Information provided by computing technology will be more persuasive if it is tailored to the individual's needs, interests, personality, usage context or other factors relevant to the individual". Therefore we argue that there is great potential in exploring how mobile technology can be used to motivate people to change their current consumption patterns in the home towards more pro-environmental behaviour.

RESEARCH DESIGN

Two research studies were conducted six months apart: a water conservation study in Melbourne, Australia in November 2010, and an electricity consumption study in Aalborg, Denmark in April 2011.

The primary goal of the water conservation study (using *Water Advisor*) was to explore the role of mobile devices as a tool to support people in their watering practices in their home gardens. A secondary goal was to explore the role that the actual source of information given by such a system plays in persuading people to be more conscious about their water usage.

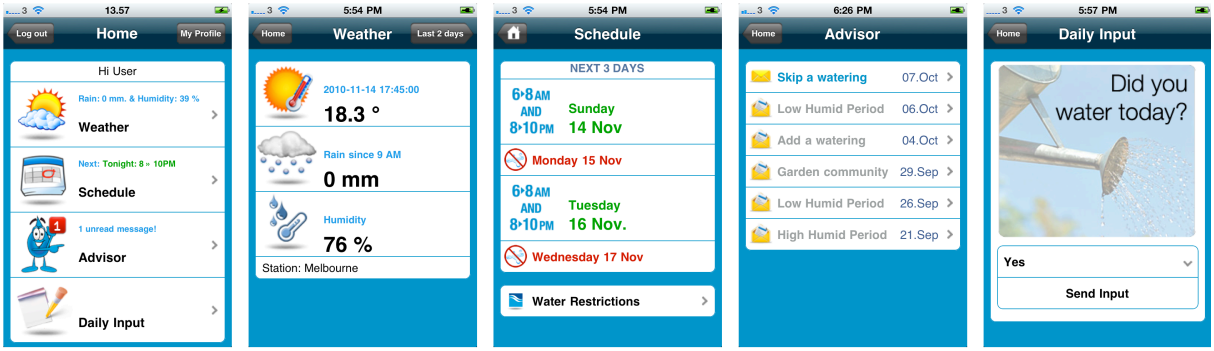

Figure 1. Water Advisor, home screen and menu screens

The primary goal of the electricity consumption study (using *Power Advisor*) was to explore whether a tailored mobile application could raise people's awareness of power consumption in their households. A secondary goal was to explore what role the actual source of information plays in persuading people to change their environmental behaviour.

The method used in both studies is a modification of the approach used by Pearce et al. (2009) in their SmartGarden Watering research. For our studies, two prototype systems were designed, developed and deployed, six months apart, each with 10 participants in a longitudinal field study for a total of three weeks continual use. The collection of information included responses to messages sent via the system during the study. Six messages were sent to *Water Advisor* participants and nine messages to *Power Advisor* participants. There were also pre-use interviews focused on exploring and understanding the participant's current knowledge about their water/electricity use, their use of IT-devices in their daily life, and an introduction to the prototype device. Post-use interviews focussed on how the prototype presented information to the participants, and their reflections on the different information sources they had been introduced to during the three week study.

The following two sections detail the design features of each of the systems that were deployed.

System 1: The Water Advisor

The *Water Advisor* is a system that aims to support gardeners in their efforts at water conservation when watering their garden. We are not going to give full details of the design of the system here, they can be found in Pathmanathan et al. (2011). Rather we will give a quick overview of the system design to support understanding of our findings and discussions in later sections.

Previous work in this area had not explored the role that the actual source of information plays in persuading people to change their behaviour. This study aimed at bridging the gap between mobile persuasion and the use of different sources of information to achieve behavioural change. It did this by persuading gardeners to use water more wisely using tailored information technology. By implementing three different information sources, i.e. weather information, an expert's advice, and community information, it was able to explore how gardeners understand information delivered by a system and what information influences them to conserve water. This system ran on both mobile devices and desktop computers. The system was tested on both platforms to explore which platform was most preferred.

The *Water Advisor* explores whether gardeners find a mobile system supportive by giving them helpful information about watering their garden, as well as exploring the impact that different sources of information have on their decisions to water their garden today, or to skip a day from their regular watering schedule. We also wanted to explore their trust in the information given, and how that affected them acting upon that advice.

The menus

The *Water Advisor* system was designed with a main menu on the home screen, and four sub-menus: Weather, Schedule, Advisor and Daily Input (see figure 1).

The Weather option provides information about the local weather using current information from the weather station that the user lives closest to. This is real-time, localised data. It gives specific information about the current temperature, latest rainfall and humidity. It also provides the last two days minimum/maximum temperature, total rainfall, evaporation and average humidity.

The Schedule option gives information to the user about their current watering schedule for the next three days. The watering schedule is regulated through user's settings and complies with actual water restrictions in that area (Melbourne Water, 2011). Users are provided with information about the level and mode (i.e. hand, manual or automatic watering) of current water restrictions.

The Advisor inbox presents an overview of the incoming messages from the system. Unread messages are clearly identifiable. Clicking on a message opens it up in a display window. These messages can be sent from three different information sources. These are Weather, Expert's Choice or Garden Community. The weather messages are scientific weather information from the local Bureau of Meteorology. The information provided in the weather messages is scientifically objective and accurate. The Expert's Choice messages provide advice

from an expert system. The expert system measures scientific weather data and combines it with information from a knowledge base advising users to either skip a watering day, add a watering day or follow their regular watering schedule. The Garden Community messages provide information about what other gardeners are planning to do, or already doing in their gardens.

The Daily Input option is where the user is able to feed information into the system such as whether they have been watering that day or not. The information is sent to the expert system to be used in the Expert's Choice messages.

Incoming Messages

During the three weeks of the case study, the participants received six different messages in their Advisor inbox from the three different information sources. They were advised on whether to add an extra watering day or to skip a day compared to their regular schedule. Every time a message was sent to the Advisor inbox, participants received a SMS on their mobile phone. This method was suggested by Fogg and Allen (2009) as having a great potential to trigger a proposed behaviour.

The first three messages sent to the gardeners presented information from one type of information source, respectively, Weather, Expert's Choice and Garden Community. The last three messages were mixed messages, each with two different sources of information combined. Figure 2 (left) shows a Weather only message, while figure 2 (right) shows a combined Weather and Garden Community message.

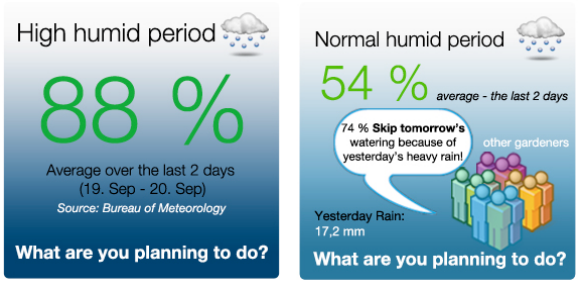

Figure 2. Messages sent to the Advisor inbox, (left) from Weather, (right) from Weather and Community Gardners combined.

Further details on the design and the technical specifications of the system can be found in Pathmanathan et al. (2011).

System 2: The Power Advisor

The *Power Advisor* mobile system is designed to explore whether users find the system supportive, by providing them with helpful information about their power consumption. Mobile persuasive technology theories were used in the design of the prototype which was deployed to explore: the role that the actual source of information plays in conserving energy; how much users trust this information; and also whether a system like this makes them more aware of their power usage.

To get access to participants' actual electricity usage, an automatic meter reader (AMR), designed by a Danish utility company, Modstrøm, was installed in the households of participants. These AMRs take a picture of the meter readouts every hour and send that picture through to Modstrøms server where it is accessed by the *Power Advisor* system. We will give a quick overview of the system design in this paper, additional technical details can be found in Kjeldskov et al. (2012).

Three different information sources, i.e. an expert's advice, the community, and personal power consumption, are used in the system to enable us to explore householder's understanding of information about electricity consumption and what kind of information influences them to conserve it.

The Menus

The *Power Advisor* has a home screen with a main menu with four sub-menu options: My Consumption, Enok's Guide, Inbox and Tip Of The Day.

The My Consumption option provides personal information about the user's electricity consumption. Existing research (Fogg, 2003; Weiss et al., 2009) suggests that self-monitoring can lead to changed or adjusted behaviour as consumers become more aware of their own behaviour and actions. Therefore, under the menu item My Consumption, the *Power Advisor* provides self-monitoring through personalized information about the user's power consumption through four different views (see Figure 3). These views comprise: the total household power usage for the last week compared to the average consumption in Northern Denmark with a gauge showing low, average or high, and a smiley to reinforce the assessment (as suggested by Shultz et al. (2007)); the last 24 hours power usage on a graph; the household's consumption per day for the past week compared to the previous week; and the last picture taken by the AMR of the household power meters.

Figure 3. Information given in My Consumption: (left) comparison with the community, (middle) last 24 hours, (right) past week compared with previous week.

Enok's Guide provides general information and advice to the user about power consumption in the household. The advice provided is about lighting, domestic whitegoods, IT and home office settings and the indoor climate. This advice comes from the Danish Energy Saving Trust (DEST, 2011). It has been shown that people tend to increase their energy consumption knowledge by simply viewing a list of advice (Shiraishi et al., 2009).

The Inbox shows incoming messages in the system. Unread messages are clearly identifiable. This operates in the same way as the Advisor inbox, in the *Water Advisor*, and also uses three different information sources to create the messages. The different sources of message explored in this study were: Expert's Advice, Community and Personal Power Consumption. Expert's Advice messages provide users with information and advice about power consumption. An expert system measures the user's power consumption, combines it with information from the knowledge database of DEST (2011) and provides information about whether to change their power consumption behaviour. An animated Eskimo named Enok is used to represent the expert, as he was being used by DEST in their TV advertising during the study period. The Community message consists of information about what other users are planning or already doing in their households. For example, whether the majority of households achieved their goal to reduce their electrical consumption that week, and how this household is doing compared to the community. Personal Power Consumption messages give information about the user's own personal power consumption. It gives objective and detailed information about their electricity consumption. The information in these messages comes in a variety of forms, from smileys to graphs and bars.

The Tip Of the Day menu shows random daily advice about power consumption. The advice is retrieved from the same pool of tips as used by Enok's Guide.

Incoming Messages

During the three weeks of the case study, the participants in this study received nine different messages containing information from three different sources. Each participant received three messages about their personal power consumption (see figure 4), three messages about the community and three messages from the expert. There were no mixed source messages used in this study.

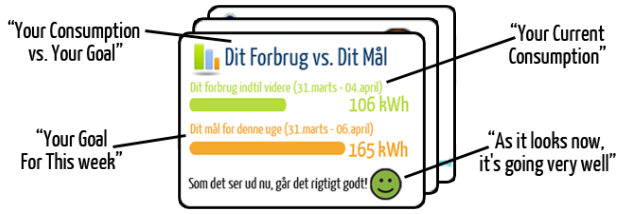

Figure 4. Example Personal Power Consumption message.

TWO LONGITUDINAL FIELD STUDIES

Both prototypes were deployed for a total of three weeks continual use with 10 different households. The objective in both cases was to explore how people used the prototype, their preferences for messages from the different information sources, and how effectively those messages promoted pro-environmental behaviour.

Study 1: Water Advisor Field Study

Participants

The participants in this study were recruited through a gardening course held at the Burnley Campus of the University of Melbourne, Australia, and through a Danish society in Melbourne. All participants lived in the greater metropolitan area of Melbourne. Each participant had to meet the following basic set of requirements to be selected for participation. They had to have a garden, a Smartphone or personal computer that allowed them to browse the Internet, and a mobile phone for receiving SMS messages. Participants varied in age, from 25 – 57 years. Their garden knowledge also varied, with four novice gardeners, four intermediate gardeners and two experts. Five of the participants had Smartphones; the other five used personal computers.

Participants were asked to use the *Water Advisor* at least once a day for the normal "Daily Input" data entry, which typically only took a couple of minutes to do. They were also asked to check their mobile phones for SMS messages to prompt them to check the systems Advisor inbox and respond to new messages. They could use the *Water Advisor* system whenever they wanted to, throughout the day.

Method and data collection

The pre-interview started with a tour of the participant's garden, and a discussion about their garden and watering systems to "break the ice". This was followed by a semi-structured interview to obtain a general understanding of the participant's garden knowledge and current gardening practice. Participants were also asked about their current use of IT-devices and their current sources of information about appropriate gardening. They were then introduced to the *Water Advisor* prototype system and given a simple user's manual. They also received a regular watering schedule for the study period.

The study was conducted during spring, and for consistency, each participant received a potted pea plant seedling to look after during the case study period.

During the study, participants had to respond to six incoming messages in the system. The system was monitored remotely for any technical problems. Also, every time a participant used the *Water Advisor* and entered information about their watering practice, or responded to a message in the Advisor inbox, the answer was saved in a system database.

After the three-week case study period had ended, a second semi-structured interview was conducted to investigate how the participants responded to the different information sources of the incoming messages, in terms of likeability, credibility, and usefulness.

The post-interview started with questions about using a mobile device as a supportive tool in their gardening practice. Then the three different sources of information used in the messages were discussed, followed by general questions exploring the benefits of the *Water Advisor*. Those participants using mobile phones were asked to reflect on using a mobile device to influence their watering patterns. Personal computer users were asked to reflect on how using the PC worked for them, which brought up discussions on the disconnect between sitting at the PC for advice and doing work in the garden.

Data analysis

Data from interviews and questionnaires were analysed using the Grounded Theory approach (Strauss & Corbin, 1990). There were 20 audio recordings of the 10 pre- and post-interviews, comprising approximately 9 hours of recording. These were transcribed and analysed.

In the *Water Advisor* study, Open Coding was used to discover in total 273 different properties, which were subsequently categorised into 72 phenomena. Using Axial Coding, relations between the different phenomena resulted in 12 categories, which were then split into four main themes.

Study 2: Power Advisor Field Study

Participants

The participants in this study were recruited through the utility company, Modstrøm, using their customer database to locate customers living in Northern Denmark. The basic requirements for participants included having a Smartphone/Tablet that allowed them to browse the Internet and a mobile phone to receive SMS notifications of incoming messages to the Power Advisor system. The AMR was installed in the house of all participants to allow access to power-meter information.

Participants were asked to use the Power Advisor at least once a day to get a view of their current power consumption. This took at most 1-2 minutes to do. Like the Water Advisor study, participants were also asked to check for SMS messages, to prompt them to respond to messages in the system (a total of nine). They were also encouraged to use the system whenever they wanted.

There was a good diversity in age and household size in the study, with participants ranging in age from 24-59 years, with household sizes from 1-5 people.

Method and data collection

In this study, the pre-interview included a tour of the house and a talk about electrical appliances to "break the ice". The semi-structured interview covered general understanding of the participant's power-consumption knowledge and current use of electrical appliances. Like the Water Advisor study, participants were given information about the system and the three information sources.

This system was also monitored remotely and logged all use and responses by participants.

The post-interview was conducted in exactly the same way as the Water Advisor post-interview, with the same questions about the incoming messages, the use of mobile devices as a supportive tool in the household, and the benefits of the system.

Data analysis

Data from interviews and questionnaires were again analysed using the Grounded Theory approach (Strauss & Corbin, 1990). There was approximately 12 hours of audio recording from the interviews with participants. This was transcribed, and Open Coding was used to discover a total of 601 different properties, which subsequently categorised into 22 different phenomena. By using Axial Coding, relations between the different phenomena were categorised to 12 categories and then split among three main themes.

FINDINGS AND DISCUSSION

The two research studies have made independent contributions in the form of several interesting findings towards designing persuasive mobile technologies to raise awareness in a specific domain, i.e. water or electricity conservation. But of most interest to this paper are those findings that are common to both studies. This facilitates drawing conclusions across the two studies about which themes are the most important and should be key influences when designing systems that persuade people to pro-environmental behaviour in the home.

The model in figure 5 illustrates our key findings from both studies. The circle on the left hand side represents findings from the *Water Advisor* study, the circle on the right hand side, findings from the Power Advisor study. The intersection area between the two circles contains those concepts that were shared across both studies.

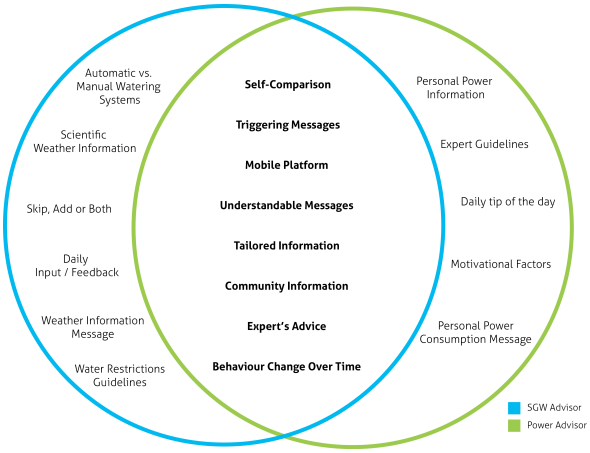

Figure 5. Findings from Water Advisor and Power Advisor longitudinal field studies.

These findings, common to both studies, represent our eight key concepts to consider when designing mobile persuasive technology to promote pro-environmental behaviour. They are: Self-Comparison, Triggering Messages, Mobile Platform, Understandable Messages, Tailored Information, Community Information, Expert's Advice, and Behaviour Change Over Time. We will discuss these findings and implications for design later in this section. First we give a description of the findings unique to each of the studies, Study 1 and Study 2.

Findings unique to Study 1

Generally, results for the *Water Advisor* study show that gardeners found the prototype to be a supportive tool to use in their gardening practice. They perceived the provided sources of information as useful. They also mentioned that their own judgement had a greater impact on them than the three provided information sources. Furthermore, the results also indicated that gardeners wanted more tailored and contextualised information to

be persuaded to more actively conserve water. Gardeners found the messages containing different sources of information as very credible and asked that more messages be like this because it created greater trust in the information, giving them greater motivation to become pro-environmental.

The four main themes revealed in this study are: participant's own judgements, misunderstanding of messages, more tailored information and mixed sources of information. The six unique categories, shown in figure 5 are: Automatic vs. Manual Watering Systems, Scientific Weather Information, Skip, Add or Both, Daily Input/Feedback, Weather Information Message, Water Restriction Guidelines. Both the themes and categories specific to the *Water Advisor* study are described in more detail in Pathmanathan et al. (2011).

Findings unique to Study 2

Results for the *Power Advisor* show that the residents using the system found it a supportive tool to use in their households. The participants indicated that by using the system over a longer time span they had a greater opportunity to change their behaviour. They found the information sources in the system credible. The most important information source, which had the greatest impact on the behaviour of the participants, was the information about their personal power consumption. The community information and the expert's advice information messages were only found credible as long as they were combined with information about their personal power consumption. The results also indicated that the motivational factors such as saving money for buying a specific product or saving money to donate to charity could be used to persuade residents to become more aware of their power consumption.

The three main themes revealed in the second study were: self-comparison, motivational factors and possibility to change behaviour. The five unique categories, shown in figure 5 are: Personal Power Information, Expert Guidelines, Daily Tip of the Day, Motivational Factors, Personal Power Consumption Message. These themes and categories specific to the *Power Advisor* study are described in more detail in Kjeldskov et al. (2012).

Of particular interest to this paper are those eight categories that sit in the intersection of the two studies (the intersection of the two circles in Figure 5). These contribute to new knowledge about what the important factors affecting our pro-environmental behaviours in the domestic context are.

Themes common to both Study 1 and Study 2

The findings suggest that the eight important concepts promoting pro-environmental behaviour in a persuasive mobile technology are: Self-Comparison, Triggering Messages, Mobile Platform, Understandable Messages, Tailored Information, Community Information, Expert's Advice, and Behaviour Change Over Time. We will now take each of these concepts in turn and discuss the design implication of each.

Self-Comparison

The results from the *Water Advisor* study showed that participants' own judgement had a greater impact on them than the provided sources of information in the system when they had to make a decision whether to follow the information contained in the messages or not. The *Power Advisor* showed a similar result. Participants mentioned that no matter which type of message they received during the study period, they always compared this to their own situation and to the information displaying their own consumption.

Implications for design: It is important to have a focus on the user's own situation when trying to persuade the users to become more aware of the environment and their use of resources. This issue supports the finding by Yann et al. (2010) that raising awareness of the individual has great potential in adjusting user's behaviour and reducing consumption. This is achieved by providing personal information about the user's own consumption.

Triggering Messages

In the *Water Advisor* study, the majority of participants requested that information be pushed to them by the system. In particular, they indicated that the incoming SMS messages were an excellent way to trigger them to act and did make them check incoming messages in the Advisor inbox of the system.

The same thing was found in the *Power Advisor* study. Participants mentioned that the SMS messages were a good triggering technique to raise awareness of their power consumption.

Implications for design: Using triggering messages reminds the user to be focussed on their environmental behaviour and can help persuade the user to act toward a proposed direction. Froehlich (2009) raised the same point in his list of ten design dimensions of feedback technology in a pro-environmental domain. By using prompting messages there is a possibility to raise awareness in the user and trigger change in behaviour, if the messages are in the right place at the right time. That is, the messages should be delivered by a system that is easy to hand on a daily basis.

Mobile Platform

In the *Water Advisor* study, half of the participants used the system on a mobile device and the other half on a desktop personal computer. Nevertheless, nine out of the ten participants said that they would prefer the system on a mobile platform. This was because they found the information received on the mobile device (for half this was only SMS reminders) much handier and easier to react to than information delivered on a PC platform. This was especially important in the context of gardening, and having information to hand while they were doing the watering.

In the *Power Advisor* study, all participants used the system on a mobile device, from Smartphones to tablet PCs. The same question about the preferred platform was asked, and the majority of participants said they would rather use the system on a Smartphone, irrespective of the

platform they used in the study, because of the flexibility to receive SMS messages on the same device as the system. The ability to check incoming messages in the system Inbox was then handy, quick and easy.

Implications for design: We can argue that the platform the system runs on should be a mobile device, preferably a Smartphone, to create the biggest opportunity to persuade users. This is confirmed in a study by Petersen et al. (2009). A key to encouraging people to engage with their consumption of natural resources is to make it truly portable, available at any time, and easy to use. By taking advantage of the Smartphone form factor it is possible to create a compelling experience for the users, increasing the opportunities to influence their behaviour.

Understandable Messages

Some of the participants in the *Water Advisor* study expressed difficulty in understanding some of the incoming information messages, which could lead to misinterpretation of that message. An important issue of concern is designing the messages so that they are easy to understand, increasing the persuasive influence of the system.

In designing the *Power Advisor* system we were able to respond to some of the communication issues raised in the *Water Advisor* study interviews. For that reason, during the *Power Advisor* study, the participants received different messages with smileys to simply and quickly communicate approval or disapproval of the amount of power the individual household had consumed. The majority of participants said that the smileys were easy to understand and interpret. Another method used to provide participants with understandable information was by providing positive and negative reinforcement messages to them using the Inbox. The participants mentioned that these messages were easy to understand because it was clearly described if they were a "good" or a "bad" consumer.

Implications for design: Using smileys combined with positive and negative reinforcement messages can avoid misinterpretation of the messages provided by the system, that are designed to persuade users to alter their behaviour in a proposed direction. However, the positive and negative messages should not be used all the time, and only in the right places. The message should contain both positive and negative comments. Participants said that if they only received messages that praised them, they would be likely to stop trying to improve. This finding is supported by the work of Helen et al. (2010) and Kirman et al. (2010).

Tailored Information

In the *Water Advisor* study, results showed that participants required more tailored information in the messages they received. They claimed that messages with more tailored information might have persuaded them to pay more attention to incoming messages. If users processed messages more thoroughly, accepted the information in them, and believed in outcomes, they would be more open for persuasion.

This lesson learned from the *Water Advisor* study allowed us to create a stronger focus on using tailored information in the *Power Advisor* study. By providing personalised information about the participant's own consumption, (e.g., a direct link to the output from their AMR), the system was able to achieve this tailoring. Participants expressed that the personalised information about their own consumption made them think more actively about this, and gave the system much higher credibility. They expressed that tailored information was more influential than general information from sources such as brochures, or television campaigns.

Implications for design: From the two research studies we can see that tailored information delivered to users is more effective than generic information. It has a greater possibility to persuade users and change their behaviour. This supports Fogg's (2003) principle of information being more persuasive if it is tailored to the individual's needs, interests, personality or usage context.

Community Information

Findings from the *Water Advisor* project showed that the participants had different views on the information coming from the community. Some of the participants judged the messages about the community as useful in making decisions on what they planned to do in their garden. Other participants wanted more tailored information about the community to be able to compare it with their own situation. In either case, community information was of interest to them, and could potentially have an affect on their behaviour.

Some of these findings from the *Water Advisor* study were considered in designing the *Power Advisor* system. The participants were given detailed information on their own power consumption. They then used this to compare themselves with the community. The majority of participants felt the community information was very useful and easy to compare against their own consumption level. Despite the fact that it was not possible to compare their consumption on a household-by-household level, participants said that summary information about other residents in the community was a highly motivating factor for them.

Implications for design: From the two studies we can see that displaying information about what the community is doing can persuade users to change their behaviour. However, it is important to show information about the participant's own situation to give them the opportunity to measure this against the community information. This supports the findings in other studies that using community information for comparison persuades users to more pro-environmental behaviour (Froehlich, 2009; Froehlich et al., 2010; Shipworth, 2000).

Expert's Advice

Participants from the *Water Advisor* study found messages from the expert reinforced their confidence in what they were planning to do. They found the information trustworthy and even mentioned that more

information about the identity of the expert would have increased the credibility of that advice.

In the *Power Advisor* study an extra button with more information about the expert was added to counteract this issue. When discussing the different types of expert messages the participants received, the majority of participants said that messages containing their own personal electricity consumption linked to the tailored expert's advice was the most effective in persuading them to pro-environmental behaviour.

Implications for design: We can see that expert's advice is a good persuader of user behaviour, especially when it is linked to the user's own situation. This aligns with Fogg's (2003) idea of using suggestion-technology as a method to make users open to persuasion.

Behaviour Change Over Time

In the *Water Advisor* study, participants said that they found mixed messages with more than one source very interesting. It was easier for participants to interpret and understand these messages, and they found them more credible. Different information in one single message also had the opportunity to educate the participants to become more conscious about water conservation. The majority of participants saw the system as an educational tool and results showed that they tended to skip more watering days and added less watering days outside of their regular schedule over the three-week period of the study

In the *Power Advisor* study, participants received more messages with mixed sources of information. They responded that these messages raised their awareness and made them more conscious of their own power consumption. In discussions, they said that the system had the opportunity to change their behaviour but only if it was used over a longer time span.

Implications for design: A mobile application that keeps reminding people with small messages using different sources of information, comparing their own situation to the advice from an expert and to what their community is doing, can be a useful tool to raise awareness. If this system is then used over time, it becomes an even more powerful tool, so that it is not just making people aware but actually profoundly changing their behaviours to be more pro-environmental in their daily lives. This is in direct support to the Trans Theoretical Model (TTM) of Behaviour Change introduced by Prochaska and Velicia (1997), and applied to the energy conservation domain by Helen at al. (2010). This model shows that people need to go through different stages, from being aware to becoming aware that their behaviour is problematic, to taking action, changing their behaviour and then maintaining that. It takes time for mobile persuasive technology to promote a maintainable behaviour change toward pro-environmental behaviour.

CONCLUSION

What we have presented in this paper represents a unique opportunity to compare and analyse the empirical findings from two related research studies and draw key identifiers that span across not only two different systems, but also two different conservation domains and two different countries. The high degree of intersection in the qualitative findings from these two studies is noteworthy, and only serves to reinforce the general applicability of these concepts in promoting pro-environmental behaviour using mobile persuasive technology.

In conclusion, we offer a set of eight key concepts, empirically proven to persuade behaviour change to consider when designing mobile technology to promote pro-environmental behaviour:

Self-Comparison

- Give access to the user's own situation

Triggering Messages

- Push messages push the user in a proposed direction

Mobile Platform

- Smartphones are currently the most desired platform

Understanding Messages

- Use smileys and a combination of positive and negative reinforcement in messages

Tailored Information

- Tailored information is more persuasive

Community Information

- Use community information for comparison

Expert's Advice

- Use expert's advice for comparison

Behaviour Change Over Time

- Mobile persuasive technology needs to be used over time to change peoples behaviour

There is great potential in using applications on mobile devices to not only persuade citizens to act in a pro-environmental way, but to give them the tools and timely and tailored information that they need to make their own decisions about how they want to live their life and how much they want to contribute to a community effort of conserving of our natural resources.

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