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ENCOURAGING ENVIRONMENTALLY CONSCIOUS BEHAVIOUR THROUGH PRODUCT DESIGN: THE PRINCIPLE OF DISCRETIZATION

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ABSTRACT

Lead user methods were applied to develop product design principles that encourage environmentally conscious behaviours in individuals. Old Order Mennonites (OOMs) were chosen as lead users because of their low resource consumption lifestyles. Ethnographic analysis revealed that discretizing resource consumption facilitates and encourages conservation behaviours in OOMs. An experimental study demonstrated the effectiveness of discretization in reducing water consumption. We postulate several distinct ways in which discretization encourages conservation behaviours. We conclude with insights on how discretization can be integrated into the design of modern products to encourage environmentally conscious behaviour in the general population.

1. INTRODUCTION

1.1. Environmentally Conscious Behaviour

Encouraging environmentally conscious behaviours, particularly the conservation of energy and materials, is an interesting and complex problem. The benefits of conservation are clear. Whether motivated by desires to reduce climate change or dependence on foreign sources of energy, successful reductions in domestic energy and materials use can have significant effect. For example, in 2008, United States households were responsible for 1,220 million metric tonnes of carbon dioxide emissions, which accounted for roughly 21% of total U.S. emissions (EIA 2009). Therefore, even small reductions in each household's energy and material usage can have a large effect on the overall energy emissions of a nation.

The field of Environmentally Significant Behaviour (ESB) was established by behavioural psychologists and ecologists to study peoples' motivations for performing environmentally conscious actions. Stern (2000) defined these behaviours as those that reduce the material and energy impact of human activities on the biosphere. These can range from public actions, such as involvement in environmental organizations (*environmental activism*), to changes in the personal use and disposal of products (*private-sphere environmentalism*). Abrahamse et al. (2005) have examined many approaches to encourage environmentally conscious behaviour. Our aim is to determine new ways to encourage private sphere environmental behaviours by applying *lead user methods*.

1.2. Lead User Methods

Lead User Theory was initially articulated by Eric von Hippel (1986) as a way for product manufacturers to predict the needs of their users in the future. Von Hippel defined lead users as those who experienced needs well in advance of the mainstream population. These users could range from single individuals to entire corporations. For example, in the rapidly changing semiconductor industry, niche firms that use leading edge manufacturing processes and require extreme levels of precision could be considered lead users. On the other hand, individuals who use technologies well before their mainstream adoption, e.g., networked bulletin boards in the 1980's, could also be classed as lead users. Von Hippel's theory posited that the problems faced by these users could be used to forecast mainstream users' needs. In addition, solutions that lead users themselves devise also yield valuable insights.

Hannukainen & Hölttä-Otto (2006) expanded the definition of lead users to include those who perform tasks in a more limited capacity than the mainstream, namely disabled persons. Studying how blind and deaf users interacted with products such as cellular phones led to product features relevant to mainstream users that are *situationally disabled*, e.g., searching for a phone in the dark, or trying to communicate in a loud environment. Lin & Seepersad (2007) demonstrated that even temporary limitations in product interaction, e.g., imitating visual impairment using dark glasses, or dexterity impairment using gloves or mitts, can lead to useful insights about latent user needs. Noting the potential of this approach, we decided to apply lead user methods to identify ways to motivate individuals to engage in environmentally conscious behaviour. First, we sought to identify a group of people in which conservation behaviours were already practiced.

2. THE OLD ORDER MENNONITES

We identified the community of Old Order Mennonites as lead users in energy and material consumption because of their culturally enforced limitations on the use of such resources.

2.1. Background

Mennonites are an Anabaptist sect that emerged during the Protest Reformation in 16th century Europe. To escape persecution, Mennonites travelled around Europe and eventually to other parts of the world, including North America. Mennonite groups are united by shared beliefs in baptism in adulthood, pacifism, and a strict separation of church and state (Agarwala 2001). In dress, belief and other practices, they share many similarities with the Amish and the Hutterites.

Mennonites are relatively heterogeneous in their energy and material consumption habits (Peters 1987). Some have lifestyles very similar to the mainstream: they live in cities, drive cars and use electrical appliances and electronic devices. Others, such as the Dave Martin Mennonites, have no electricity in their homes, grow almost all of their food and only travel by horse and carriage (Gingrich 2002).

We focused on the Old Order Mennonites of Waterloo County, Ontario, Canada. The Old Order Mennonites (OOMs) of Waterloo County originated in Switzerland and migrated to Pennsylvania in the 17th and 18th centuries. After the American Revolution, they settled in Ontario (Burridge 1988). OOMs are more traditional and conservative than most Mennonite groups but also have limited interaction with newer technologies.

2.2. Energy and Material Use in OOM Societies

OOM communities have a unique relationship with electricity and electrical devices, and use materials differently from the mainstream. OOM households did not participate in the initial electrification of North America because connection to the electrical grid was seen as a loss of their separateness from mainstream society (Burridge 1988). Nevertheless, OOM communities slowly adopted the limited use of electrical appliances, e.g., heaters and refrigerators. Lacking electrical connections, these devices were powered by diesel generators or modified to run on kerosene and other fuels. Recently, younger generations of OOMs have begun to adopt electricity in their homes. OOM communities are also well known for reusing materials and living a spare lifestyle. A large proportion of their diet is derived from what they grow and raise on their own properties. OOM homes are also known for repeated reuse and refurbishment of domestic products. Clothes are handed down from older children to younger ones and old furniture is often repaired or rebuilt with scrap parts (Gingrich 2002).

2.3. Old Order Mennonites as Lead Users

The OOM's experience in living and performing daily tasks with limited use of materials and energy made them suitable lead users. By studying their lifestyle and practices, the problems they encountered and the solutions they developed, we hoped to find transferrable strategies for encouraging and facilitating resource conservation behaviours in mainstream populations. While OOMs live in a resource-limited environment due to culturally imposed restrictions, mainstream populations in developed countries may face resource limitations due to economic (rising energy costs) and social (increased environmental awareness) factors.

3. ETHNOGRAPHIC STUDY

3.1. Methods

The unique nature of OOM communities required significant preparatory work before we could interact with OOM families successfully. First, we reviewed available literature on the culture and customs of the OOMs. We consulted books on the history of the Mennonite movement, scholarly papers on Mennonite and Amish community lifestyles and their attitudes towards modern technologies, and anthropological studies of various Mennonite communities.

Next, unstructured interviews with three experts were conducted to determine how best to access OOM families who would be willing to share information about their lifestyles. The first expert was a furniture trader in Waterloo County who bought furniture from local OOM families and had interacted with the OOM community for many years. He showed examples of hand-built OOM furniture, highlighting the use of manual joints, nails instead of screws and simple staining and finishing techniques, illustrating some of the low-technology methods the OOMs employed to construct furniture. He also advised us to contact OOMs at the weekly farmer's market. Several visits to the local farmer's market were useful to learn more about the crafts and food of OOM communities, as well as observation of the vendors and quick interviews, but were unfruitful in helping us gain access to OOM homes.

The second expert was the coordinator of Creation Care at the Mennonite Central Committee of Ontario. The Mennonite Central Committee is an international Mennonite organization that carries out disaster relief, sustainable community development, and social justice programs across the world. The Creation Care program is a series of ongoing sustainability initiatives undertaken by the Ontario Mennonite Central Committee. The program coordinator provided information about their initiatives including a campaign to retrofit homes and farms with solar panels. We learned that the more modern Mennonite groups, with which the Mennonite Central Committee interacted, did not typically conserve resources any better than mainstream non-Mennonite populations.

The third expert was one of the curators of the Mennonite Visitor Centre in St. Jacobs, Ontario, an information centre that also hosts a museum of Mennonite history. The curator provided much information about the practices of local OOM populations, and arranged visits to local OOM family homes.

We visited two local OOM families, where we conducted half-hour semi-structured interviews followed by a tour of their homes. Semi-structured interviews were used to ensure that all relevant topics were covered, while leaving enough flexibility to follow leads based on unexpected responses (Bernard 2006). A list of guiding questions was constructed beforehand based on the aims of the inquiry and information from consulted textual sources and experts. The purpose of the interviews was to glean the material and energy needs faced by OOMs and to find examples of solutions they had developed to address those needs. Individuals were queried on the types of fuels they used and their purposes, their use of electrical appliances, their use of drinking and washing water, and their production and storage of food. We wanted to learn about the problems they encountered in meeting their material needs and the solutions to those problems they had developed. We also performed brief usability surveys of their kitchen appliances, electronic or otherwise. We were interested to see if they would have unique insights about common electrical appliances such as stoves and refrigerators because of their otherwise different lifestyle. As chores and responsibilities are highly segregated by gender in OOM communities, it was necessary to conduct interviews with both the eldest male and female members of the household. Notes were recorded by hand throughout. We were unable to use methods involving photography (such as photo diaries) as OOMs have cultural taboos against photography. Affinity clustering was carried out on the qualitative data collected.

3.2. Results

Many interesting conservation practices were observed in the OOM homes. Both homes visited resembled early 20th century farmhouses. Three generations of family members resided in the same home, with each family having up to six or eight children. The amount of space occupied by each member of the household was therefore much smaller than is common in the mainstream. The kitchen was the focal point of the house and a wood-burning stove in the kitchen was the central source of heat. Large windows around the house made indoor artificial lighting largely unnecessary in the daytime. They had fewer electrical devices, such as televisions or radios, in their homes and depended heavily on locally sourced renewable fuels such as firewood for cooking, space heating, and even heating water. During our visits that occurred in autumn, we observed that the indoor temperature in the OOM homes was noticeably lower than that in typical urban homes. The persons interviewed also wore heavier clothing indoors during the cooler months than is common in mainstream society. Clothes were washed by hand and dried either outside or around the wood stove in the kitchen. A kettle of boiling water on the wood stove was used to humidify the homes in the winter.

We observed other aspects of the OOM lifestyle that led to reduced resource consumption. Almost all the food in the households interviewed was either grown on their own land or a nearby farm, greatly reducing the energy required to transport produce. Over a year's worth of canned fruits, vegetables, meats, pickles and jams were stored in the basements. One home had an un-insulated kitchen pantry separated from the kitchen by a sealed door. In winter, the pantry windows would be opened, allowing it to serve as a cold room for food storage. Potatoes and root vegetables were stored in barrels filled with natural desiccants, e.g., sand, to prevent spoiling from moisture.

The homes visited had few consumer products and used reusable instead of disposable items wherever possible, thereby reducing waste production. One family had a kitchen table constructed entirely from parts of other pieces of furniture the family once owned. One family utilized large cisterns to collect rainwater that was then used to water garden plants and for some washing needs. The families were also well attuned to changes in daylight hours over the course of the year and adjusted their work schedules accordingly.

The information gathered from the OOMs was analyzed to determine the need each observed behaviour met, each behaviour's environmental significance, and how each need identified would be addressed in a modern technological context. Being lead users, there were some needs (such as long term food storage) OOMs had that do not exist significantly in modern societies. In addition, many solutions used by OOMs involved both demand reduction, e.g., wearing heavier clothing indoors in winter to reduce need for heating, and a solution on the supply side, e.g., firewood burning in the stove to provide additional heat. The main findings are listed in Table 1.

4. THE PRINCIPLE OF DISCRETIZATION

Qualitative analysis of the ethnographic data revealed unexpected commonalities in many of the behaviours exhibited by the OOMs interviewed. In many cases, a conservation behaviour had to do with the use of resources in discrete units. For example, the interviewed OOMs could immediately quantify the amount of hot water they used for bathing in numbers of buckets they needed to fill a bath. Additionally, having this understanding of their usage seemed to help OOMs better manage their consumption patterns. If they wished to conserve water, they could quantify the savings in terms of the reduction in the number of buckets they used. When additional family members arrived, they could measure the additional resource demand by the number of extra buckets of water required. There were multiple examples of the principle of the discretization found in our observation of OOMs (see Table 2).

Individuals in mainstream society would have more difficulty estimating the amount of water or energy they consume by comparison. Most consumers have difficulty ascertaining the energy and material requirements of particular tasks, and when presented with the information, have difficulty comprehending it. For example, at a University of Toronto student residence, the average water usage per student was calculated and presented to the students in numbers of litres. Nonetheless, the building manager felt that students did not understand the magnitude or how excessive it was.

Contrasting the discrete units of resources that the OOMs deal in, mainstream households obtain resources through direct water and electricity connections that enable continuous flows. We therefore hypothesized that the discretization of resources encouraged or enabled their conservation. To test this hypothesis, we designed an experiment that challenged subjects to conserve water in a washing task.

Table 1: Old Order Mennonite Solutions, Environmental Significance, and Modern Solutions to Needs.

Need	OOM Solution	Environmental Significance	Modern Solution
Space heating	Wood fired stove located in kitchen, the family spending time together in one room to increase ambient temperature, the wearing of heavier clothing during winter months, lower expectations for thermal comfort	All firewood locally sourced and sustainable (therefore reducing environmental burden), reduced demand for heat with heavier clothing (reduced demand for energy consumption)	Central furnaces and thermostats
House cooling	Strategic placement of trees outside home to shade parts of the house, large windows arranged in a configuration that encourages cross-ventilating currents	Reduced material and energy use because of elimination of air conditioner	Air conditioning
Hot water for bathing	Water collected from well boiled in kettles to fill up a bathtub	Reduced amount of water used	Running hot water
Drying clothes	Hanging outdoors in summer, and around central wood fired stove in the kitchen in winter	Reduced material and energy usage	Natural gas/electric dryers
Water for washing clothes	Manual washing machines, use of grey water from rain cisterns outside house	Reduced water consumption, reduced electricity consumption	Electrical washing machines connected to running water and electricity
Washing dishes	Hand pump, hydraulic pump or water from outside brought indoors	Reduced water consumption	Running hot water, electrical dishwashers
Obtaining drinking water	Well water collected from outside	Fewer processing steps for the water	Municipally treated running water
Lighting	Kerosene/propane powered lamps	Increased awareness of usage, motivation to save fuel	Electrically connected lighting fixtures
Cold storage of food	Kitchen pantry room with windows to allow cold air to enter during winter months, dark cool cellar below house	Reduced energy and material use, eliminated use of toxic refrigerants	Refrigerators, cold rooms in basements
Preparation of fuel before usage	Curing room for stored firewood	-	None needed, fuel is either directly connected or comes prepared
Maintaining appropriate indoor winter humidity level	Large vessel filled with water on the wood stove at all times, generating steam for the home	Use of already existing woodstove heat	Electrical humidifiers
Long term food storage	Cans and jars of preserved food stored in the cellar	Increased awareness of usage	None needed, food can be purchased when needed
Maintenance of furniture in the home	Done by family members, frequent repair and refurbishment, items designed to last long with reparability in mind	Reduced use of virgin materials and energy required for manufacturing new products	Furniture likely to be disposed and replaced when damaged.

Table 2: Examples of Discretization

Activity/Application	Discrete Units	Flow Alternative
Space heating	Bundles of firewood	Direct electrical/fuel connection
Water for bathing and washing	Buckets of water	Direct water/fuel connection
Lighting and heating	Volumes of propane, kerosene, diesel consumed	Direct electrical/fuel connection
Food consumption	Jars of preserved food	Multiple sources of food in different sizes and units

5. EXPERIMENTAL STUDY

5.1. Method

The experiment used a repeated measures design where subjects were asked to perform a washing task under four (later reduced to three) conditions. Subjects were given two plastic table tennis balls with a 15 mm^2 of acrylic Cadmium Red paint applied to them. The subjects were asked to remove the paint from the balls using as little water as possible. The amount of water used in each condition was measured.

In the first condition (continuous flow), subjects used water from a standard lavatory tap. In the second condition (containers), water was made available to the subjects in the form of 18 containers filled with 10mL of water each. In the third condition (work + containers), the same 18 containers with 10mL of water were made available to subjects but an additional requirement was added. To earn each container, subjects had to step on and off an aerobic step device for a 10 second period, and were only able to earn one container at a time. We added this condition because we had observed that in many cases, the use of discrete units of resources (such as buckets of water or bundles of firewood) was also associated with additional effort (i.e., raising buckets from the well, chopping and carrying firewood). We wanted to determine whether it was the discretization of these resources or the additional work required that encouraged conservation. In the fourth condition (regulated flow), subjects were given a garden hose with a pistol attachment that allowed them to access water in short pulses, as another way of discretizing the continuous water flow. This condition was developed to enable comparison of the efficacy of using containers versus pulsing as a strategy for discretization. The apparatus for this fourth condition failed after the third experimental subject. Thus, all subsequent tests were carried out under three conditions. The order of the conditions was counterbalanced to control for order effects.

We first tested the data (N=28) for normality, and then performed a one-way repeated-measures ANOVA to determine within-subject effects. Post hoc comparisons using a Sidak correction were performed between each of the levels.

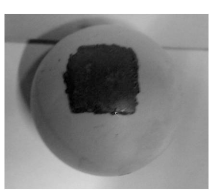

Figure 1: Table tennis ball with 15mm^2 mark of paint.

Figure 2: Discrete-condition container with 10mL of water.

5.2. Results

The quantities of water used in the continuous flow condition $D(28) = 0.19$, $p < .05$, the container condition $D(28) = 0.25$, $p < .05$, and the container plus work condition $D(28) = 0.29$, $p < .05$, were significantly non-normal. Histograms of the data suggested significant floor effects in each case. In the container conditions, many subjects needed only one container to perform the task. In the continuous flow case, there appeared to be a lower limit for how short a time one could leave the tap running. Nevertheless, ANOVA is generally considered to be robust with respect to violations of the normality assumption (Rutherford 2001), and therefore further analyses were carried out. The experimental data are presented in Figure 3.

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 0.02$, $p < .05$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .51$). The results show a large significant effect of the condition $F(1.01, 27.30) = 22.39$, $p < .01$, $\eta_p^2 = .45$. This confirmed that the way the water was made available had a substantial effect on subjects' ability to conserve it. We also confirmed that the sample size was sufficiently large for a high observed statistical power, $(1-\beta) > .99$.

Post hoc comparisons using a Sidak correction confirmed that the mean value for the continuous flow condition (M = 198.7mL, SD = 211.5) was significantly different from the container condition (M = 22.3mL, SD = 27.0) with $p < .01$, and the container with work condition (M = 16.0mL, SD = 16.0) with $p < .01$. Nevertheless, the container condition was not found to be significantly different from the container with work condition ($p = .19$).

The fourth condition, which utilized a garden hose to discretize water flow into pulses, was only used by three subjects, however it suggested the consumption of less water (M = 66.0mL) than the continuous flow, but not as little as the container conditions. Thus, discretization of the water source, either through the use of containers, or possibly through pulsed flow, appeared to successfully facilitate water conservation.

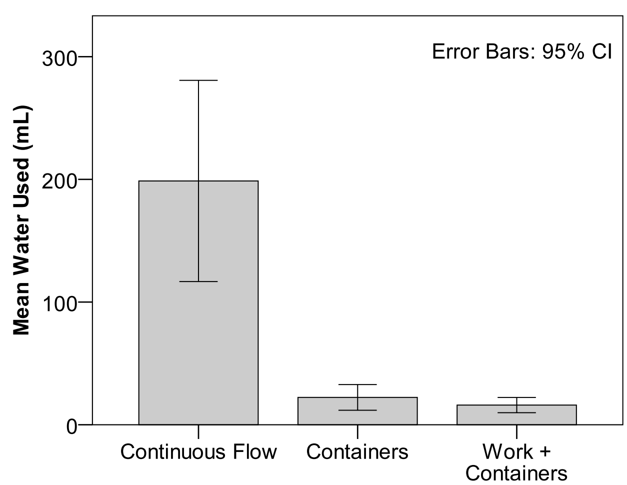

Figure 3: Mean water used under three conditions.

5.3. Qualitative Observations

During subjects' performance of the washing task, several interesting behaviours were observed. Subjects who encountered one of the discrete-water conditions first seemed more creative in their washing techniques when they performed the task under the continuous-flow condition. For example, some subjects turned the tap on and off quickly, long enough to wet their hands, which they would then use to scrub the paint off the balls. Conversely, subjects who encountered the continuous-flow condition first typically washed the ball as they would wash items using a flowing tap, and used an entirely different technique in the discrete-container conditions.

Prior to the above experiment, a pilot study was conducted with four subjects in slightly different conditions. In the pilot study, the discrete containers were each filled with 100mL of water. Participants tended to use much more water in the discrete container conditions and tended to use less creative washing techniques, which did not differ significantly from the typical washing of items under a tap. It appears that the size of the discrete unit in which a resource is made available has an effect on the ingenuity of the user in conserving that resource.

6. HOW DISCRETIZATION MAY WORK

The principle of discretization applied to energy and water consumption, and waste production, appears to have many factors that facilitate and reinforce conservation behaviours.

6.1. Paying before Use

Working with discrete units of energy and materials often requires individuals to pay for resources *before* use, where the payment can take many forms. For OOMs, heating fuels such as propane and kerosene must be purchased, firewood must be chopped and collected during the summer, and drinking water must be extracted from wells. This requirement motivates the conservation of resources as individuals will seek to minimize cost in money, effort, or otherwise.

In contrast, the direct flows that provide mainstream society with energy and water provide no such inhibitory mechanisms. The payment for a resource also typically occurs much later than its use.

6.2. Awareness of Rate of Use

The discretization of energy and material resources is also beneficial in helping individuals gain a clear understanding of the amount of the resources they are consuming. More importantly, it helps individuals see the amount of resources they are consuming at the time of consumption. The OOMs we interviewed explained to us that they were able to monitor their fuel consumption for space heating by simply tracking how often they were replacing the firewood in the wood stove. This rate of replacement for discrete units of firewood gave them an intuitive and tangible understanding of their energy use. In mainstream settings, individuals are less aware of the amount of energy being used by a space heater, or the amount of water being consumed during a shower. Even monitoring devices, such as residential energy meters, provide information in abstracted units of energy like kilowatt-hours, which are less conceptually intuitive. Working in discrete units enables prompt, repetitive feedback to the user about the rate of use, and possibly requires additional user effort.

Many marketing campaigns intended to encourage environmentally significant behaviour have attempted to make people more aware of the quantities of resources they consume through comparisons. For example, a quantity of energy used by an average North American in a short period of time is presented as being enough to power a small house in a different part of the world for a much longer period of time (Abrahamse 2005). While moderately effective, such comparisons remain abstract and lack the explanatory power of physical quantities of discrete units, such as tanks of propane or buckets of water.

6.3. Real-Time Feedback – the Idea of a Fuel Gauge

Discrete units help individuals ration their usage because it is possible to see how much of the resource is "remaining" at any given time. The OOMs we visited received deliveries of propane tanks at set times during the year. If they noticed that they were running low on tanks and the next delivery was not expected for a few weeks, they could reduce their use of propane appliances to avoid running out before the next delivery. The number of tanks they purchased became an energy quota for them. In the current mainstream setting, there are no such quotas users can impose on themselves, as energy and water are always available without limitation and there is no concept of their "running out." However, such discrete quotas do exist for automobile usage. Drivers are able to continually monitor the amount of fuel remaining via the fuel gauge. Drivers who wish to conserve fuel can then adjust their driving habits. The fuel gauge also gives them real-time feedback about the effectiveness of their adjustments. Although individuals wishing to conserve energy at home can adjust their habits, they typically only receive feedback at month-end in the form of a bill, and do not have to worry about resources running out.

6.4. Deterrent to Starting a New Unit

A corollary to the benefit of real-time feedback is the way OOMs were deterred from using resources excessively because of the difficulty in subdividing discrete units further. Water was counted by the number of buckets, firewood was counted by bundles, and food was counted by jars. If a task required slightly more water than could be carried in two buckets, they would be motivated to find a way to make do with two buckets, as obtaining that additional small amount of water would require filling another bucket and making another trip. Similarly, if guests were arriving for a meal and it would require three and a half jars of a fruit preserves to feed them, the host OOM family would try to find a way to utilize three jars and prevent opening a fourth, which would result in half a jar of jam that would spoil more quickly in an opened jar.

7. ANALOGY: DISCRETIZATION IN SPENDING

Srivastava et al. studied how people spend money in various conditions. Raghubir and Srivastava (2008) demonstrated that people's spending decisions are contingent on the form of payment. Participants in their experiment were shown to spend more when using a prepaid credit card than when given an equivalent amount of money as cash. Their awareness of parting with money was much lower with credit card purchases than with cash. Srivastava et al. concluded that more highly abstracted forms of payment, such as credit cards, encourage spending. This is analogous to how discrete and physically intuitive units of energy increase people's understanding of how much energy they are consuming.

Srivastava et al. also found that people's spending habits could be moderated through the use of a "piecemeal decomposition" strategy, where participants were asked to think about the costs of individual items while shopping, instead of the total value of their final basket. Similar to the points system employed by Weight Watchers, by thinking about the value of each item in their diet discretely, their overall consumption was reduced.

Using similar ideas, Kestner et al. (2009) developed concepts for wallets with haptic feedback. In one of their concepts, the wallet would physically expand or contract depending on the user's account balance. Though not a direct application of the principle of discretization, the goal of the concept was to provide a fuel-gauge type mechanism to give users a more intuitive sense of the value of their accounts.

8. DISCRETIZATION AS DESIGN TOOL

As discussed at the beginning of this paper, pioneering research performed by environmental psychologists like Stern has been instrumental in understanding the emotional and cognitive mechanisms that underlie people's engagement in environmentally conscious behaviours. Abrahamse (2005) and Steg (2009) reviewed environmental psychology studies from the past several decades, many of which contributed to the development of frameworks to understand psychological mechanisms related to environmentally conscious behaviours. Almost all the studies reviewed provided recommendations for eliminating barriers to environmentally conscious behaviours. Most such recommendations, while insightful, vary greatly in scope and are not always easy to apply to product design. In terms of scope, recommendations can range from defining an optimal way to prompt users to engage in particular behaviours, to legislations that governments should enact to provide incentives to users. Applying this large body of collected insights at the level of individual products can be challenging.

More recently, product designers and computer scientists have developed tools for solving product design problems. These tools, in the emergent field of persuasive design (de Kort 2008), tend to fall along a spectrum defined by Lockton (2009) as ranging from *inspirational* to *prescriptive*. At the *inspirational* end are tools such as catalogues that list examples of Environmentally Significant Behaviour interventions. The product designer is expected to apply an element of one or more examples to the product design problem at hand. At the other prescriptive end, there is an effort to create a systematic TRIZ-like (Altshuller 1994) method, which generates specific solution principles to problems that designers enter. Fogg's Behaviour Grid (2009) is one such method, where designers can extract specific solution principles to design problems.

Lockton et al.'s Design with Intent method (2009) can be used in both prescriptive and inspirational ways. The method consists of a catalogue of examples of how similar design problems have been tackled in different disciplines. The examples are grouped into eight "lenses," (Architectural, Errorproofing, Interaction, Ludic, Perceptual, Cognitive, Machiavellian and Security) each of which represents a particular approach to solving problems. As an inspirational tool, the examples and accompanying images serve as creative stimuli for idea generation. As a prescriptive tool, Lockton created a guide for mapping particular examples to specific target behaviours. Designers can enter a target behaviour they would like users to perform and be directed to examples of how other products encourage that behaviour. We prefer the use of a method such as Design with Intent, which organizes the information available from past environmental psychology research in a usable format for designers, while also prescribing some general techniques for solving problems.

Having identified the relevance of discretization to encouraging conservation behaviours, there are a few ways the principle can be used with the methods discussed above. The examples of discretization we presented exhibit characteristics from many of the lenses in the Design with Intent method. The use of buckets for counting amounts of water is an expression of the *portions* tactic from the Errorproofing lens, which refers to limiting portion sizes to prevent users from consuming more than a predetermined quantity. The inherent deterrent discretization provides to starting new units can be seen as an expression of the *roadblock* tactic from the Architectural lens. Similarly, other examples of discretization embody more of the tactics listed in the Design with Intent lenses. The incorporation of these examples in the extant Design with Intent catalogue will add to its breadth and depth.

In the prescriptive mode of the Design with Intent method, discretization becomes the solution strategy for the target behaviour of encouraging conservation of energy and resources. This may necessitate a change in the ontology of the method as currently formulated. Presently, designers enter a target behaviour and are led directly to examples of solutions. We propose the insertion of an intermediate step where an overarching strategy is first identified and the examples provide different manifestations of that strategy. Conservation of resources would be the target behaviour, discretization the strategy, and portion control enforced by physical units of resources or roadblocks imposed by the difficulty in starting new units, the examples.

9. APPLICATION TO PRODUCT DESIGN

Having established the relevance of discretization for encouraging and facilitating environmentally significant behaviour related to residential resource consumption, we now explore how it can be applied to the design of products.

First, it is useful to further define the problem. Residential resource consumption can be defined as the sum of energy and materials consumed by inhabitants of a household (or users) for uses such as cooking, heating, entertainment, washing and lighting. Wherever there is a flow in the system, the principle of discretization can be applied. The users interact with a device or appliance that extracts energy from a source, e.g., the electrical grid, and sometimes also certain materials, e.g., water, and uses them to meet a particular need. The energy coming into the device or appliance is typically in a flow, e.g., electricity, natural gas, etc., and can be discretized. The energy output of the device or appliance itself (light, heat, etc.) is also a flow that can be discretized.

9.1. Discretization at the Source

The energy entering devices can be discretized in many ways. The easiest to envision is to simply utilize discrete containers as sources of energy, e.g., batteries. In this approach, residents would have a collection of batteries that would be charged at the beginning of the day, and all of their appliances and electronic devices would be battery powered. Residents would connect batteries to the appliances and devices, and be able to observe the reduction in charge over time. This would enable a tangible understanding of the amount of electricity consumed. Additionally, if a battery were close to running out, residents may be motivated to turn the device/appliance off or put it into a low power mode to last longer.

Another, more practical, approach is to discretize the energy conceptually. Appliances and electronic devices could be made or be modified to require the input of energy tokens. These could be physical tokens, each representative of a particular quantity of energy. The tokens would have to be entered into a device or appliance for it to function. Depending on the settings selected, each device or appliance would operate for different periods of time with one token. Again, residents could have a daily quota of energy tokens. They would be aware of their energy usage and if they wished to reduce usage, may experiment with device and appliance settings to determine how to get the most use from each token. An analogue exists for water usage in coin-operated self-serve car washes, where users buy time in the car wash.

It is also possible to discretize the energy flowing into devices without significant modification to those devices. Energy meters for homes can be reconfigured to take advantage of the benefits of discretization. Energy meters could count down from a preset quota rather than count upwards as they currently do. The amount of energy remaining in that preset quota would allow users to understand their rate of energy usage and how close they are to meeting a target. Dillahunt et al. (2009) found that simple light indicators that measured domestic energy use, and changed colour from green to yellow to red based on set monthly quotas, were effective in encouraging and reinforcing energy conservation behaviours in residents.

Home automation systems can also be employed to support the conceptual discretization of residential energy. The interface of a home automation system could be designed to provide residents targets for total weekly energy consumption. These targets could be in generic units of energy, which could be divided between all the different energy draws in the home. For example, a homeowner could set a target of using only 28 generic units of energy every week. The homeowner could then divide the overall home energy quota among all the appliances. Devices and appliances that used more than their allotted share would then either be remotely turned off, or a warning would be sent to the homeowner. The homeowner would gain awareness of which devices and appliances were overused and be motivated to reduce consumption in these devices. Using a home automation system, the homeowner would also be able to 'trade' units of energy between devices to meet targets. For example, if he or she were planning to host a dinner party, the energy quota for the stove and dishwasher could be increased with energy units taken from the home computer, televisions, etc. Therefore, the family could use the television and computer significantly less that week to be able to have a party without increasing total energy use. Discretization in such a system would give homeowners more control over their domestic energy usage.

9.2. Discretization at the Output

The transfer of energy out of devices to the user could also be made discrete. For example, many people currently use Digital Video Recorders (DVRs), which allow them to watch specific television programs at any time. Television programs have standard lengths that are known. It could be possible to make it such that users would turn on their DVR and select the number of shows they plan on watching in one sitting (in units of programs). The DVR and television would remain on for precisely that amount of time and turn off afterwards. Rather than considering the activity of watching television as consuming a stream of visual information with no discernable beginning or end, users would be able to set and measure their usage in terms of television programs watched. This would also reduce the need for the television and DVR being on when no program was being watched.

An example of output discretization is also provided by the Fisher & Paykel Dish Drawer dishwasher. The dishwasher is the same size as a typical dishwasher but has two separate compartments instead of the usual one (Beverland and Farrelly 2007). Users are able to think of their dishwashing in terms of numbers of drawers they need to use. Users only utilize one drawer most times and if they have one or two more dishes than can be fit into one drawer, may be motivated to wash those by hand rather than use another whole drawer for them.

Figure 4: A compartmentalized dishwasher (Beverland and Farrelly 2007).

The discretization of water is already in place in some public showers via the use of push-release timer valves. With the use of such valves, the shower knob must be depressed to start the flow of water. The knob slowly returns to its start position at which point the water stops. This allows users to measure their showering time by the number of times the knob must be depressed. Also, as they see the knob returning to its original position, they may be motivated to finish showering quickly rather than having to push the knob again, especially if another task is required, e.g., the temperature must also be reset each time. However, it is also possible that the timer valve wastes water by continuing to run after the user is done. In addition, current knobs are not properly designed to provide visual feedback on the time left until they require another push.

Figure 5: Timed shower valve (http://www.archiexpo.com)

10. FUTURE WORK

There are multiple areas of this research that will be pursued further. Firstly, the discovery of valuable insights from the study of OOMs as lead users in resource conservation is promising. We will carry out more detailed observations of additional members of this community for more insights. There are also other groups and communities who use energy, water and other resources very sparingly for various reasons. There are certain communities in countries such as Morocco and Jordan that have a decentralized infrastructure for the distribution of water. In arid countries such as those, water is especially scarce and is typically distributed by tanker trucks that fill up individual household tanks at set periods (Othman 2008). Further investigation of the practices of individual households in such situations may yield interesting results.

Secondly, we will continue to empirically test the effectiveness of the principle of discretization in facilitating conservation behaviours. It will be useful to determine whether there is a difference in the level of success of an intervention depending on the intervention strategy used. We are in the process of planning a study with a university residence that wishes to reduce the duration of showers of its students. One intervention could be the placing of countdown timers in each shower stall. These countdown timers would be triggered by the shower beginning and emit audible beeps every five or fewer minutes until the water is turned off. This would provide the students with the ability to measure the length of their showers in discrete units marked by audible beeps. Another simultaneous intervention would involve the use of self-closing shower taps that would shut off after five or fewer minutes. In this case, the students would be able to measure their water and energy usage by the number of times they had to push the knobs. By comparing the success of each intervention against each other and a control group, we expect to be able to draw conclusions about the utility of the discretization principle and whether there exists a difference between physical discretization and conceptual discretization.

Thirdly, the application of the principle of discretization as a tool for designers will be further explored. We plan to perform idea generation experiments with professional designers where they will be presented with the principle of discretization in different ways. This will help us determine how best to present the principle, as well as identify further factors in its application.

11. CONCLUSION

Our research expands the definition of lead users to include OOMs as lead users for residential environmentally significant behaviour. Von Hippel's original definition of lead users related to high-performance individuals who "lived in the future" and were at the leading edge of their industries. Hannukainen and Hölttä-Otto demonstrated that low-performance users could be as useful a source of needs identification as high-performance users. Thus, we suggest that communities living a less modern lifestyle are just as suitable as lead users as those who are living leading-edge modern lifestyles. Restrictions on energy in the future could resemble restrictions placed on communities in the past.

Discretization as a strategy was observed as facilitating and encouraging private sphere conservation behaviours. We intend to further explore discretization strategies, as well as determine how to best incorporate it into design practice.

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