The Need for Human Factors in the Sustainability Domain

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Curbing the over-harvesting of the earth's resources by the developed and developing world cannot be achieved solely by technological solutions. This paper reviews the literature on how reductions in energy consumption can be achieved through behavioral interventions. The literature shows that feedback, a consequence intervention, has been shown to be more effective than antecedent interventions in correcting erroneous heuristics and biases as well as encouraging both efficiency and curtailment behaviors. However, few feedback studies approach the feedback design problem systematically. Human Factors specialists have an opportunity to contribute their expertise in human-machine systems to help address these deficiencies and aid in shifting our societies toward sustainable resource consumption.

INTRODUCTION

The world's population, most notably that of developed and developing countries, is consuming resources at a rate that exceeds the replenishment capability of the earth. If this "business-as-usual" behavior continues, by 2050 the human ecological footprint will be twice that of the planet's capacity (Living Planet Report, 2006). If we do not soon balance our consumption with the earth's capacity we risk doing irreversible damage (Living Planet Report, 2006). Humans must find a way of reducing the amount of resources they are taking from the earth.

Because of the dire nature of this problem many of the world's best scientists have been commissioned to research means of reducing the human ecological footprint. The commonly sought-after methods of footprint reduction typically focus on developing more efficient technologies. Some scientists, however, claim that more efficient technologies actually *increase* the rate and level at which material and energy are consumed (Rees, 2007). This counter-intuitive finding highlights the importance of human factors in technology design; new technology must not only use fewer global resources but also encourage resource conservation.

Studies on conservation behavior have revealed that providing feedback about energy usage holds the most promise in successfully reducing resource consumption in the developed world (Abrahamse, 2005). However, the literature to date has not addressed feedback as a multi-dimensional variable. Human factors engineering has the theory and technical expertise to analyze feedback systematically and contribute much to the design of new conservation technology.

REVIEW

This paper reviews the research on behavioral means of encouraging resource conservation. The findings are organized into four categories: behavior taxonomy, human decision-making biases, intervention methods, and descriptions of successful and unsuccessful interventions.

Behavior Taxonomy

Pro-environmental behaviors have been grouped into two classes: efficiency behaviors and curtailment behaviors. *Efficiency behaviors* are one-time investments in efficient infrastructure (Abrahamse et al, 2005) such as a decision to install insulated windows. *Curtailment behaviors*, in contrast, are repetitive efforts to curb resource consumption (Abrahamse et al, 2005). An example of this behavior is continually ensuring that lights are turned off in unoccupied rooms.

Efficiency behaviors appear to be of greater benefit than curtailment behaviors as they tend to result in a greater overall reduction in energy use. They are also regarded as being independent of the purchasers' behaviors (Gardner & Stern, 1996). These assessments, however, often overlook the rebound effect. The *rebound effect* occurs when the benefits of more efficient technology are counteracted by stimulation of additional and unanticipated resource consumption (Berkhout et al, 2000). In other words, more efficient technologies tend to be used more than their more wasteful counterparts and this additional usage negates some of the expected gains. The magnitude of the rebound effect is disputed: some estimates range from 0 to 30% (Berkhout et al, 2000) while others argue that consideration of indirect effects would further increase the magnitude of the estimate (Midden et al, 2007). These findings suggest that large reductions in energy consumption will require consideration of efficiency losses due to the rebound effect by both designers and users of technology.

The two groups of pro-environmental behaviors are not mutually exclusive: "[B]oth curtailment actions and increased-efficiency actions have a significant role to play in any comprehensive program to conserve individual/household energy in the United States." (Gardner & Stern, 1996, p.265)

Decision-making Biases

As in many other domains, human biases and perceptions affect conservation behavior. Biases that appear most frequently in the literature have been summarized by Gardner and Stern (1996) and are outlined below.

The "framing" of information can significantly affect conservation behavior (Kahneman & Tversky, 1984). An experiment that labeled cost reductions from an insulation investment as “dollars not wasted” instead of “dollars saved” resulted in study participants being more likely to adopt the investment (Yates, as cited in Gardner & Stern, 1996, p. 233). Framing information appears to be an effective tool in making an environmentally prudent choice more attractive.

How individuals perceive risk affects how they assign subjective costs to hazardous outcomes and therefore how they will prepare for such an outcome (Gardner & Stern, 1996). To assess risk, laypeople typically focus on the probability of an event, discount its severity, greatly desire certainty, and consider only risks that threaten something they value (Gardner & Stern, 1996). Use of the overconfidence bias (Bremmer et al, 1996) and the availability heuristic (Tversky & Kahneman, 1974) often result in misperceptions of the probability of rare and frequent as well as dramatic and mundane events by experts and laypeople (Gardner & Stern, 1996). These observations reveal that a method of intelligibly communicating the risk and severity of over-consumption could help in its reduction.

If opportunities for environmentally prudent behavior are not perceived they cannot be adopted. When asked what could be done to improve energy efficiency in the home, householders most often suggest those actions that are most readily available to memory (Gardner & Stern, 1996). Opportunities that have the greatest saliency and are more readily available are more likely to be recalled (Wickens & Hollands, 2000). For instance, heat escaping from the attic is much less noticeable than a light left on in the study; in this case, the need to turn off the lights would likely be recalled more frequently than the more pressing need to install insulation. This finding demonstrates that users require a more objective method of determining where to invest their time and money.

When perceptions and biases influence reactions to environmental problems, severe consequences can result. The perception of having little control over an environmental problem often results in maladaptive behaviors such as learned helplessness, avoidance, denial, wishful thinking, and fatalism (Gardner & Stern, 1996). Those exhibiting these maladaptive behaviors will not take simple steps to avoid hazards: in one study, homeowners displaying one of the above behaviors would not purchase highly subsidized insurance even though they lived in hazard-prone areas (Gardner & Stern, 1996). Informing citizens of appropriate responses to environmental threats may help reduce reliance on these coping mechanisms (Gardner & Stern, 1996).

Often environmentally prudent behaviors are not adopted because of perceived or real barriers. These barriers include investment of time and money, ignorance about how to perform a given action, and uncertainty about the benefit of an action (Gardner & Stern, 1996). Governmental bodies have offered rebates, discounts, or free audits to address these obstacles. However, removing or lowering financial barriers alone does not appear to be sufficient; for example, use of a home energy efficiency rebate program was very low even when it offered to reimburse 93% of the cost of renovations. However, in homes where energy audits were performed and homeowners knew how much they could expect to save, rebate use was almost certain (Gardner & Stern, 1996). This illustrates that supplying relevant and clear information about the benefits of pro-environmental behaviors are instrumental in spurring more individuals to adopt them.

The above discussion has illustrated that supplying information is important in effecting behavior change. The section below will describe the various methods through which such information can be disseminated.

Methods of Intervention

Methods used to elicit conservation behavior are often divided into two general categories: antecedent and consequence strategies. *Antecedent strategies* attempt to influence behavior by first modifying underlying determinants of behavior (Abrahamse et al, 2005). For example, the information provided by pamphlets is intended to increase knowledge about conservation, which is in turn expected to influence future behaviors. *Consequence strategies*, by comparison, attempt to affect actions by establishing positive or negative consequences to behaviors (Abrahamse et al, 2005). A driver informed of how her fuel efficiency changes as a result of conservative driving behavior is rewarded with the satisfaction of knowing that she has increased the amount of time before refueling, reduced her fuel costs, and lowered her ecological footprint (Rosenwald, 2008). Antecedent and consequence strategies can be implemented in various forms and have been shown to have differing effects.

Antecedent strategies. Antecedent strategies typically focus on providing general information about actions that can reduce energy consumption. There are many means through which this information has been circulated, such as workshops, mass media, and home auditing.

Geller (1981) studied the effectiveness of three-hour workshops that included lectures, discussions, and demonstrations. Analysis of surveys indicated that while these workshops successfully increased concern and knowledge about the energy crisis, follow-up home visits revealed no indication of behavioral change (Geller, 1981).

Similar results have been found for energy conservation information communicated through mass media such as television and pamphlets. Studies have often shown significant changes in self-reported behavior, while actual behavior and knowledge about environmental programs, problems, and processes remain unchanged (Abrahamse et al, 2005). Similarly, the effectiveness of written communication with US citizens of lower socio-economic status has shown to be minimal and communications must be perceived to have been sent by a trusted source to be heeded (Gardner & Stern, 1996).

Television and print have also been used to provide examples of model behavior. Although short-term reductions in energy use have been realized by those viewing these examples (Abrahamse et al, 2005), this method appears to be difficult and costly to maintain (Gardner & Stern, 1996).

Face-to-face methods such as home auditing relay information relevant to the specific user, thereby reducing information overload (Abrahamse et al, 2005). Results of home audit programs, however, vary greatly and appear to degrade with time (Abrahamse et al, 2005).

The above strategies, and indeed conservation strategies in general, are often used in tandem with other interventions such as goal setting. When individuals set and commit to goals it is thought that the activation of personal and social norms will result in attainment of those energy-conservation goals (Abrahamse et al, 2005). The results of these studies vary, but it appears small long term gains can be realized (Abrahamse et al, 2005; Gardner and Stern, 1996). These results, however, depend on the size of the goal. A study by Becker (1978) showed that households who received both a difficult goal (20% reduction in energy use) and performance feedback were the only group to statistically differ from control (Abrahamse et al, 2005). Introducing simpler interventions such as providing reminders and highlighting norms are difficult to implement successfully (Gardner & Stern, 1996)

In summary, the literature reveals that antecedent strategies obtain insignificant and/or short-term results.

Consequence strategies. Consequence strategies also provide information about energy-saving behaviors but they differ from antecedent strategies in their specificity and timing. Consequence strategies supply information that informs an energy user about the effects of a specific behavior *after* they have performed it.

Providing feedback about energy usage in the home has been shown to reduce consumption by up to 20% (Darby, 2006). Most studies, however, have shown reductions averaging around 10-15%. These reductions appear to continue as long as the feedback apparatus remains in place.

While feedback about variable pricing does not always decrease overall energy consumption, it has been successful in shifting electricity consumption away from peak periods (Faruqui & George, 2005; Abrahamse et al, 2005). This shift is beneficial as peak loads are often met through inefficient methods of generation (Faruqui & George, 2005).

Providing *comparative* feedback to households attempts to foster a sense of competition, social pressure, or social comparison to encourage reduction in resource usage (Abrahamse et al, 2005). Previous studies have shown, however, that this approach garners either little to no positive effect and sometimes results in negative effects (Abrahamse et al, 2005). Study participants have been reported to argue that their comparison group is inappropriate or that they would only take action if they consumed appreciably more energy than others in their comparison group (Darby, 2006).

The other major consequence strategy, provision of rewards, seems to garner only short-term behavioral effects (Abrahamse et al, 2005).

This survey of studies shows that the consequence strategy of feedback holds the greatest promise in helping individuals reduce the amount of energy they consume. This intervention obtains significant and long-term results unlike almost all other strategies.

The role of attitudes and competencies. One explanation for why many antecedent methods are ineffective over the long term may be that a change in attitude does not reliably produce a change in behavior. This claim is supported by a study by Gatersleben et al (2002) that found that income and household size were better predictors of household energy use than attitude. Another found that performance in controlling a simulated central heating system was related to self-reported environmental concern only when feedback was not present (Sauer et al, 2007). This finding suggests that when a consequence strategy (e.g., feedback) is used, the underlying determinants that antecedent strategies attempt to influence (e.g., attitude) play a sub-ordinate role. Previous reviews of the literature have come to similar conclusions: “[C]ontrolled studies show that educational efforts to change environmental attitudes and beliefs generally have little effect on behavior.” (Gardner & Stern, 1996, p.74)

The previous conclusions may not pertain to all attitudes: Recyclers and non-recyclers have been found to have similar beliefs about the benefits of recycling but different beliefs about the *difficulty* of performing the act of recycling (Gardner & Stern, 1996). This finding and others (e.g., Van Kesteren, 2006 on the specificity of attitudes studied) suggest that more study of the relation between attitudes/beliefs and behavior is merited.

Competence in performing environmentally-prudent behavior is critical. It has been shown to be a better predictor of pro-environmental behavior than beliefs about the importance of conservation (Corral-Verdugo, 1997). Similarly, it has also been found that one of the strongest predictors of involvement in political environmental movements is knowledge of *how* to participate in these movements; environmental attitudes, however, were deemed much less significant (Gardner & Stern, 1996). In another study, participants used 12% less electricity to cook meals at home with the help of an electronic feedback display. These results were obtained without participants having been given economic incentives or instructions to conserve energy (Wood & Newborough, 2003). This suggests that well-designed feedback tools can increase competence in conserving energy.

Successful Methods

Past research has shed light on what characterizes a successful method of encouraging environmentally prudent behavior. An ideal method should: 1) garner attention, 2) contain a carefully designed and intelligible message that separates important from unimportant information, 3) make visible pertinent but normally imperceptible information, 4) be close in space and time to where the behavior takes place, 5) consider the audience, 6) be credible, and 7) encourage participation (Gardner & Stern, 1996). Almost every type of intervention previously mentioned can satisfy at least one of these characteristics but well-designed feedback is the intervention that exhibits the most of these characteristics. Well-designed feedback is: specific and personalized (Benders et al, 2006; Brandon and Lewis, 1999), related to behavior in an intelligible way (Winett & Neale, 1979), frequent and available immediately before and after an action (Abrahamse et al, 2005; Gardner & Stern, 1996), credible (Seligman et al, 1977), and able to give insight about *how* to act upon the given information (Sauer et al, 2007). This overlap suggests that feedback is one of the best tools to facilitate energy conservation. Three decades of research substantiates the conclusions of Seligman et al (1977, p.331): "In general, feedback research has shown that performance feedback, displayed to the human operator, is critical in producing effective performance."

Benefits of successful interventions. Successful implementation of feedback has been shown to improve objective performance (Sauer et al, 2007), motivation, and the rate and level of learning (Seligman et al, 1977). Since the effects of user actions are demonstrated (Seligman et al, 1977), users are able to see the relationship between their behavior and energy consumption (Benders et al, 2006).

Despite favorable experimental results, feedback does not appear to be widely implemented in the conservation domain. Seligman et al (1977) describe the environment of the average homeowner as "information deficient" (p. 331). Unfortunately, not much has changed in the past thirty years: A recent study has found that more than half of homeowners did not know where their gas/electricity meters were and almost half could not read them (Wood & Newborough, 2003).

Drawbacks of weak interventions. There are many negative effects of living in an information-impoverished environment that illustrate the need for effective interventions.

Without information, individuals perceive themselves as unable to control their consumption: "[T]here appeared to be virtually no sense of being able to actively and significantly reduce energy consumption in the household" (Darby, 2006, p. 5). Providing the right tools can relieve this sense of powerless-ness; even without prompting (Wood & Newborough, 2003).

Lack of relevant and intelligible information about the energy environment also results in ignorance of how energy is consumed. Hutton et al (1986) report "many surveys over the last 10 years have indicated a general lack of knowledge about the rate of energy consumption associated with specific appliances, energy systems, and appropriate behavioral patterns" (p. 329). This lack of understanding often results in poor decision making (Gardner & Stern, 1996). As was stated earlier, individuals will often rely upon non-optimal biases and heuristics to select their actions.

The paucity of feedback given to individuals also results in their being unable to understand how the physical world around them operates – they have difficulty understanding relationships between their behavior and environmental problems (Brandon & Lewis, 1999). One study showed that 25%-62% of the population has an inaccurate mental model of how a thermostat works (Kempton, 1986). Such poor understandings of technology and environment lead to inefficient use of resources.

The results from previous studies of conservation behavior have been helpful in identifying feedback as the most promising intervention. However, several weaknesses make the findings from many studies difficult to generalize.

Deficiencies in Previous Research

Prior reviews of conservation behavior studies have cited widespread design flaws that compromise the ability to draw strong conclusions. Many of these problems are fundamental, such as the use of small sample sizes or short-term horizons (Abrahamse et al, 2005). A significant number of studies confound independent variables, making it impossible to determine the degree to which each variable was responsible for the observed result. (Abrahamse et al, 2005). In addition, it is often difficult to determine how independent variables were defined. For instance, when "information" was presented to participants, it was often unclear as to what it comprised (Abrahamse et al, 2005). Previous reviewers had difficulty summarizing the literature because the dearth of information provided by many past experiments made it difficult to calculate simple measures like effect size. Indeed, "conducting a thorough meta-analysis was not deemed feasible" (Abrahamse et al, 2005, p. 275).

The above examples illustrate that study designers often choose target behaviors for a study that they *perceive* to be appropriate, not necessarily ones that have been validated. Target behaviors chosen through intuition rather than understanding often result in experiments that concentrate on actions that relate to the manifestations of a problem rather than the origins of a problem (Gardner & Stern, 1996).

NEW CONTRIBUTIONS

Past studies often appear to lack a theory of the relationship between actor and environment. Consequently, experimenters did not often structure their studies or explain their results in relation to an overarching scheme. Having no systematic approach to feedback design has hindered experimenters from asking and answering more and bigger questions. "More systematic research on the effectiveness of interventions under various circumstances would be advisable." (Abrahamse et al, 2005, p. 282)

Previous studies have focused on where and when to supply information but are generally weak in information design. In most cases little attention was paid to what information was available (content), how the content was interrelated (structure), and how the structure and content were represented to individuals (form). Instead, it was assumed that any feedback in any form was comprehensible by, and helpful to, study participants. Authors often did not consider that various methods of information presentation may result in differing behavioral effects; they did not consider feedback to be a multi-dimensional variable. If these experiments did not result in a significant effect, experimenters often concluded that feedback in general can do little to change behavior. One study concluded; "This study cautions against saying that any type of feedback, under any conditions, directed at any population, will produce positive results." (Hutton et al, 1986, p.336), More attention must be paid to aspects of information design to determine what causes observed effects.

Uni-disciplinary approaches. In the past, approaches to tackle the unsustainable nature of developed countries have typically been uni-disciplinary. These approaches are likely to be inadequate for achieving major reductions in resource consumption (Darby, 2006). Combating a problem as large as the over harvesting of the earth's resources requires input from many disciplines so erroneous assumptions about system behavior can be reduced. The general idea that many disciplines are required to solve this problem has been frequently suggested (Abrahamse et al, 2005; Gardner & Stern, 1996; Midden et al, 2007) but human factors engineering has been specifically mentioned on a number of occasions (Seligman et al, 1977; Midden et al, 2007; Wood & Newborough, 2003). It has also been recognized that the interaction between humans and technology has been overlooked (Midden et al, 2007; Van Kesteren, 2006). Human factors engineering is well equipped to respond to these concerns.

CONCLUSION

The gaps in past research have resulted in calls for an interdisciplinary approach to the study of conservation behavior. In particular, the inherently multidisciplinary perspective of the human factors community is sorely missing.

Human factors engineers can contribute their knowledge of decision making, mental models, and displays and controls, as well as their skills in experimental design and usability assessment, to name just a few. The theoretical frameworks already in use by human factors practitioners may be promising candidates to systematically integrate existing findings, identify research opportunities, and guide design of innovative feedback interventions. This skill and knowledge could help supply consumers with better tools to conserve resources in many of the domains that the human factors and ergonomics community knows well, such as transportation, manufacturing and product design.

Although no specific solutions have been proposed, we believe that human factors and ergonomics specialists have much to add by simply applying their skills and knowledge to the domain of sustainability. With this change in focus we believe our discipline can and will aid our societies in becoming sustainable. While this is not the first call to action within the human factors community (Moray, 1995), it is our hope that future research will address the opportunities outlined in this review and add to those who have begun to heed the call (see Sauer et al, 2007).

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