Moving Beyond Line Graphs

@jonfroehlich
Feedback is about empowering people with information to positively inform and change behavior
the prius effect?
why is the *prius* effective?

- Immediate
- Simple
- Educates
- Constrained environment
- Reason to care
- Informs only one action
the prius effect?
the **lightbulb** effect?

- Immediate
- Simple
- Educates
- Constrained environment
- Reason to care
- Informs only one action

Kohlenberg et al., *J. of Applied Behavior Analysis*, 1976
the lightbulb effect?

- Immediate
- Simple
- Educates
- Constrained environment
- Reason to care
- Informs only one action

Kohlenberg et al., J. of Applied Behavior Analysis, 1976
Feedback results in energy savings of between 5-12%.

Darby, 2000; Abrahamse, 2005; Fischer, 2008; EPRI 2009
But we’re still unsure what aspects of feedback are most effective.

Darby, 2000; Abrahamse, 2005; Fischer, 2008; EPRI 2009
<table>
<thead>
<tr>
<th>Data Update Frequency</th>
<th>Cost to Implement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Standard Billing</strong></td>
<td>Monthly or bi-monthly bill</td>
</tr>
<tr>
<td><strong>Enhanced Billing</strong></td>
<td>Household-specific info, advice, and comparisons</td>
</tr>
<tr>
<td><strong>Estimated Feedback</strong></td>
<td>Web-based energy audits + billing analysis, est. appliance disaggregation</td>
</tr>
<tr>
<td><strong>Daily/Weekly Feedback</strong></td>
<td>From Actual usage data, mail, email, self-read, day-lag web-based, etc.</td>
</tr>
<tr>
<td><strong>Real-Time Feedback</strong></td>
<td>Energy display devices, pricing display devices</td>
</tr>
<tr>
<td><strong>Real-Time Plus</strong></td>
<td>Real-time, appliance level monitoring or control, HAN</td>
</tr>
</tbody>
</table>

**Indirect** Feedback (Provided After Consumption Occurs)

**Direct** Feedback (Provided Real Time)

**OPower**

**Energy Savvy.com**

**PG&E Website**

**The Energy Detective**

*Residential Electricity Use Feedback: A Research Synthesis and Economic Framework, EPRI 2009*
**Data Update Frequency vs. Cost to Implement**

- **Low**
  - 1 Standard Billing: Monthly or bi-monthly bill
  - 2 Enhanced Billing: Household-specific info, advice, and comparisons
  - 3 Estimated Feedback: Web-based energy audits + billing analysis, est. appliance disaggregation
  - 4 Daily/Weekly Feedback: From Actual usage data, mail, email, self-read, day-lag web-based, etc.
  - 5 Real-Time Feedback: Energy display devices, pricing display devices
  - 6 Real-Time Plus: Real-time, appliance level monitoring or control, HAN

- **High**

**Percent Savings**

- Type 2
- Type 3
- Type 4
- Type 5
- Type 6
Talk about feedback intervention.

Talk about energy savings from feedback studies.

More information != More Behavior Change

Data Presentation > Data Update Frequency

Darby, 2000; Abrahamse, 2005; Fischer, 2008; EPRI 2009
Feedback du jour
line graphs
TED The Energy Detective
Google PowerMeter

Electricity used Oct 27–Oct 28

Day  Week  Month

Electricty in kW

- Tuesday Oct 27
  11 kWh used

Compared to others

1 bedroom apartment
2-bedroom apartment
2-bedroom house
3-bedroom house
4-bedroom house

Compared to past usage

12% under expected usage for Wednesday

<table>
<thead>
<tr>
<th>Time</th>
<th>9 kWh used</th>
<th>10 kWh expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>right</td>
<td>morning</td>
<td>afternoon</td>
</tr>
<tr>
<td>night</td>
<td>morning</td>
<td>afternoon</td>
</tr>
</tbody>
</table>
Wattson Holmes

POWER USAGE - WATTS (avg per 5 minutes)

Lucid Design Group
High cognitive burden on person. Why?
How much **time per day** do we expect people will spend exploring their consumption behaviors?
How much \textit{time per day} do people spend exploring their finances?
financially prudent
8.4 hrs/mo → 16.8 min/day

less financially successful
4.6 hrs/mo → 9.2 min/day

me (grad student)
0.5 hrs/mo → 1 min/day
< 1 min
Line Graphs

How **actionable** is this information?
which door do I push, which door do I pull?
which door do I **push**, which door do I **pull**?
which door do i **push**, which door do i **pull**?

**pull**

**push**
which door do I push, which door do I pull?
Norman door!
affordance refers to the perceived properties of a thing that determine just how that thing could possibly be used.

don norman

vertical handle cues pull behavior
affordances affect our perception of use

can affordances change our behavior?
In-N-Out Burger!
Battle of the Cans
Environmental protection

Recyclable

Love our homeland

Other waste
Battle of the Cans
Winner!
34% increase in recycling

Duffy, Environment and Behavior, 2010
Holes constrain behavior and also remind what is recyclable

Duffy, Environment and Behavior, 2010
What does this have to do with feedback?
Perceptual affordance refers to the perceived properties of a thing that determine how that thing is used.

- Vertical handle affords pulling
- Flat textured surface affords pushing!
Motivational affordance refers to the perceived properties of information that determine how that information is acted upon.
Motivational affordance refers to the perceived properties of information that determine how that information is acted upon. Highly effective at stopping drivers.
analytics engine for personal spending

Mint is the most incredible online application I have ever come across!! Unbelievable job - keep up the great work.
- COBY H, CALAIS, VERMONT

Money
Our Top Pick ★★★★★

The New York Times
Mint Has Helped Me Save

Good Morning America
Valuable... Easy to Use

Editors' Choice
★★★★½
Tell us about your savings accounts, and we’ll find the best new account for you.*

Total Balance: $12,500
Current APY: 0.30%
Interest Earned: $37 per year

* Values displayed are averages from the Mint community. To see your own spending, add a savings account to your profile.

Filter Results

Rates and Fees
APY: > 0.00%
Minimum to Open: < $5,000
No-Fee Balance: < $5,000
Monthly Fee: < $10.00

Features
Free ATM Withdrawals

Bank
All Bank
Ally Bank
American Express Bank
BB&T
BofA
Capital One
FDIC Insured

Sallie Mae® High-Yield Savings Account
SallieMae
APY: 1.30%
Minimum to Open: $0
No Fee Balance: $0
Low Balance Fee: $0

Your Three-Year Savings
$375
APPLY NOW

Capital One InterestPlus Online Savings
CapitalOneBank
APY: 1.30%
Minimum to Open: $1
No Fee Balance: $0
Low Balance Fee: $0

Your Three-Year Savings
$375
APPLY NOW
How much **money** do I spend per month on **Starbucks**?
starbucks spending
This type of inquiry is **not possible** with current energy feedback systems; it needs to be.
Future
Feedback system provides diss aggregated feedback
<table>
<thead>
<tr>
<th>Item</th>
<th>Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedroom TV</td>
<td>300 W</td>
</tr>
<tr>
<td>Playstation 3</td>
<td>455 W</td>
</tr>
<tr>
<td>Cooking Range</td>
<td>1235 W</td>
</tr>
<tr>
<td>Lighting</td>
<td>750 W</td>
</tr>
</tbody>
</table>

Real Time Usage: 682 Watts

Cost: $34.50

Energy Cost: $0.15/kWh

Total kWh: 1265 kWh

Image credit: Sidhant Gupta
Hot Water Heater
Consumes 19% of Your House’s Energy
Feedback system suggests lowest effort actions for greatest efficiency gain
Replace Your Hot Water Heater with a Tankless System and Save $250/yr
You are losing $250/yr by using this water heater.
< 1 min
See also: CHI 2010 talk


the design of eco-feedback technology

Jon Froehlich, Leah Findlater, James Landay

UNIVERSITY of WASHINGTON
See also: these two papers

Promoting Energy Efficient Behaviors in the Home through Feedback: The Role of Human-Computer Interaction

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ABSTRACT

The consumption of energy is unlike most consumable goods. It is abstract, invisible, and unavoidable. Without a tangible manifestation, home energy usage often goes unnoticed. Advances in sensor monitoring systems will soon provide real-time data on electricity, gas, and water usage in the home. This will produce a tremendous amount of data that can be analyzed and fed back to theuser—creating a rich space of opportunities for HCI research. This paper articulates common misconceptions of energy usage in the home, establishes the potential for feedback to change energy consumption behavior, and introduces ten design dimensions of feedback technology with which to build understandable future systems.

Keywords
Feedback

Introduction

The United States consumes one quarter of the world’s energy resources, despite accounting for less than five percent of the world’s population (US Department of Energy, 2002). This residential sector accounts for 25% of the nation’s energy use and the average American household spends nearly $2,000 on energy bills per year (US Department of Energy, 2006). Home energy and personal transport are two of the top contributors to the average American’s CO2 emissions into the environment (Nakicenovic and Matschoss, 2001), accounting for over 50% of their total carbon footprint. To date, the primary methods applied to improving energy efficiency and/or reducing energy usage have been technological and economic (Maslowsky, 2008). For example, the production of hybrid or hydrogen vehicles has been emphasized as a major solution to CO2, reduction and oil dependence. However, there is growing evidence that a human-centered, behavioral approach should also be pursued to educate, inform, and motivate energy efficient human behaviors.

In a study evaluating the energy consumption of 16 identical households, Blum et al. found that some households consumed 2.6 times more energy than the average during the six months of the study (Blum et al., 2008). While the average household consumed 2.6 times more energy than the average during the six months of the study (Blum et al., 2008), this has been consistently found that the energy usage can be reduced by 20% or 30% in the same households, accounted for by people with similar demographics (Blum et al., 2008). Such findings reveal how differences in human behavior can significantly affect energy consumption, and suggest that intervention strategies to promote sustainable behavior could result in significant energy savings.

Yet, curtailing energy usage in the home is a difficult task. The consumption of energy—be it heating fuel or electricity—is unlike most consumable goods. It is abstract, invisible, and unavoidable (Broshi, 2000). Without a tangible manifestation, home energy usage often goes unnoticed. For example, the decreasing amount of milk in the fridge, the increasing dullness of a razor blade, or a gas gauge nearing empty. Most people have no

The Design of Eco-Feedback Technology

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The Information School
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ABSTRACT

Eco-feedback technology provides feedback to individuals or groups with the goal of reducing environmental impact. The history of eco-feedback extends back more than 40 years to the origins of environmental psychology. Despite its stated purpose, few HCI eco-feedback studies have attempted to measure behavior change. This leads to two overarching questions: (1) what can HCI learn from environmental psychology and (2) what role should HCI have in designing and evaluating eco-feedback technology? To help answer these questions, this paper conducts a comparative survey of eco-feedback technology, including 83 papers from environmental psychology and 44 papers from the information and computer literatures. We also provide an overview of prominent models of environmental behavior and a summary of key motivational techniques to promote this behavior.

Keywords
Eco-feedback, Environmental HCI, Feedback, HCI Survey

Introduction

As environmental issues such as climate change, air pollutants, and water scarcity become more salient in the global consciousness, so have they become more salient. In many of the papers in this special section on eco-feedback studies, the authors make the case that environmental psychology research is the design and study of eco-feedback technology, which we define as technology that provides feedback to individuals or groups with the goal of reducing environmental impact (adapted from [9] and [3]). No single article or set of articles can encompass the entire scope of research in this area. This paper is intended to provide an overview of the research in eco-feedback technology and to provide a summary of key motivational techniques to promote sustainable behavior.

To answer the two overarching questions: (1) what can HCI learn from environmental psychology and (2) what role should HCI have in designing and evaluating eco-feedback technology? To help answer these questions, this paper conducts a comparative survey of eco-feedback technology, including 83 papers from environmental psychology and 44 papers from the information and computer literatures. We also provide an overview of prominent models of environmental behavior and a summary of key motivational techniques to promote this behavior. Best Paper!
Disaggregated End-Use Energy Sensing for the Smart Grid

This article surveys existing and emerging disaggregation techniques of energy consumption data and highlights signal features that might be used to sense disaggregated data in a viable and cost-effective manner.

Imagine an energy feedback system that displays not only total power consumption and cost, but also suggests specific cost-effective measures to improve energy efficiency. Such a system could report, for example, "Based on your energy consumption patterns, you could save $360 per year by upgrading to a more efficient refrigerator, which would pay for itself after 21 months." The challenge in this scenario is how to sense end uses of energy to provide feedback at the individual device or appliance level. Emerging smart meters promise a tighter temporal coupling between energy usage and feedback (up to 15-minute sampling intervals). However, the focus still is on aggregate consumption, making it difficult for consumers to ascertain which devices or appliances are responsible for their energy usage. Disaggregated end-use energy data promises to transform the way residents, utilities, and policy makers think about and understand how energy is consumed in the home.

Our research team, as well as many other teams worldwide, is working toward a new generation of electricity, water, and natural gas measurement systems that are low-cost, easy to install, and, most important, capable of providing disaggregated data about consumption at the level of the individual appliance or device.

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Moving Beyond Line Graphs

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