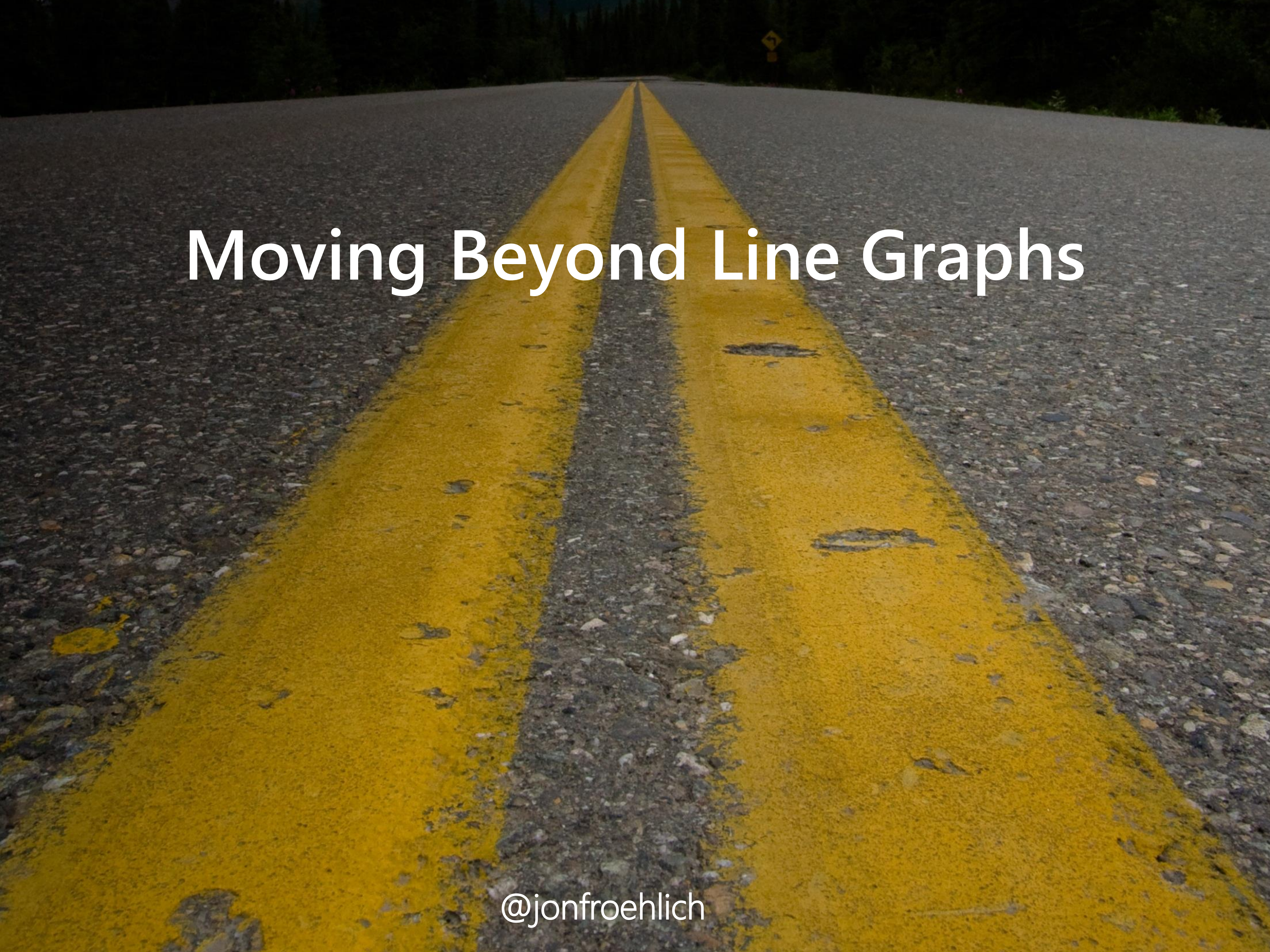
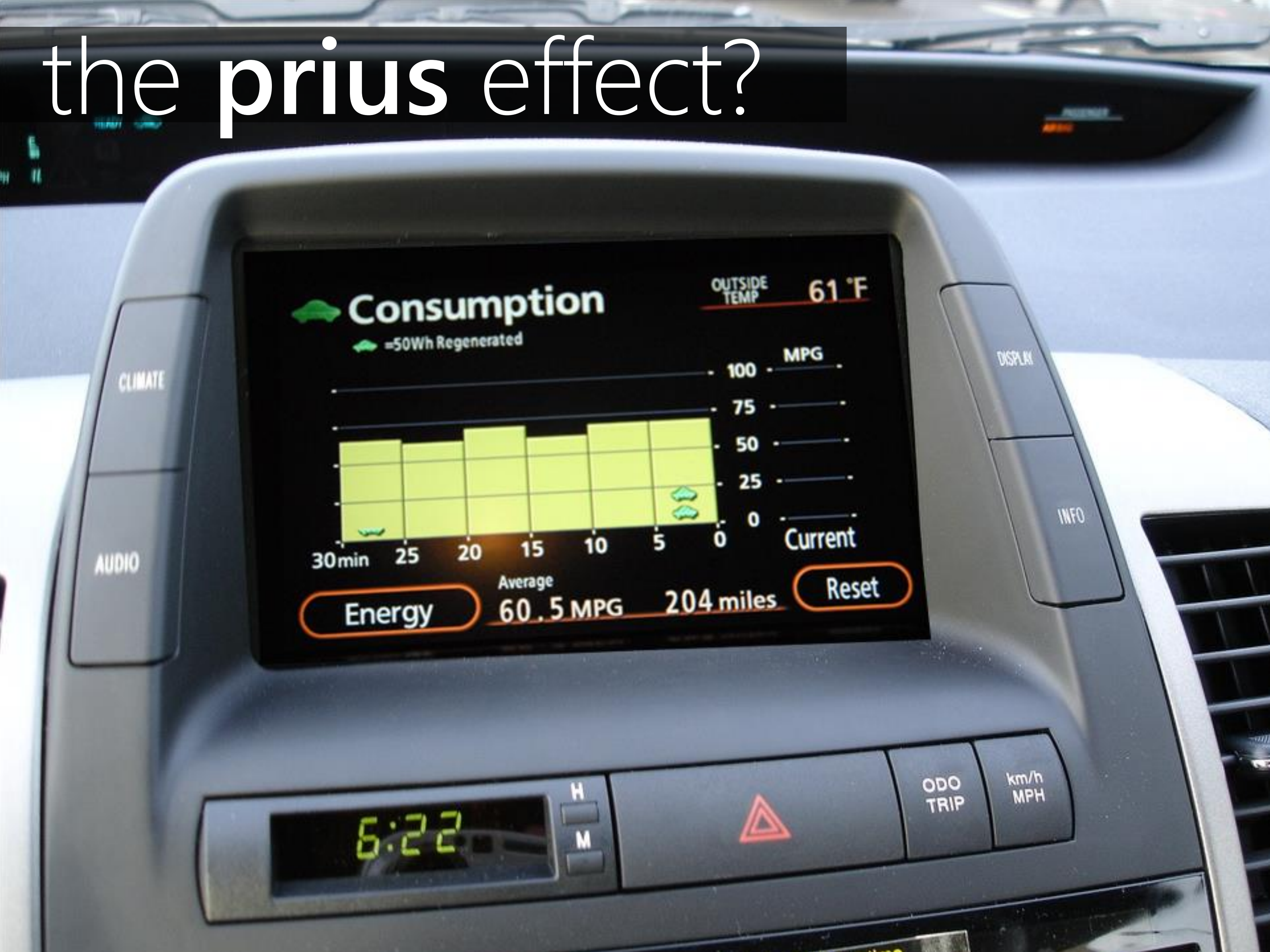


Moving Beyond Line Graphs

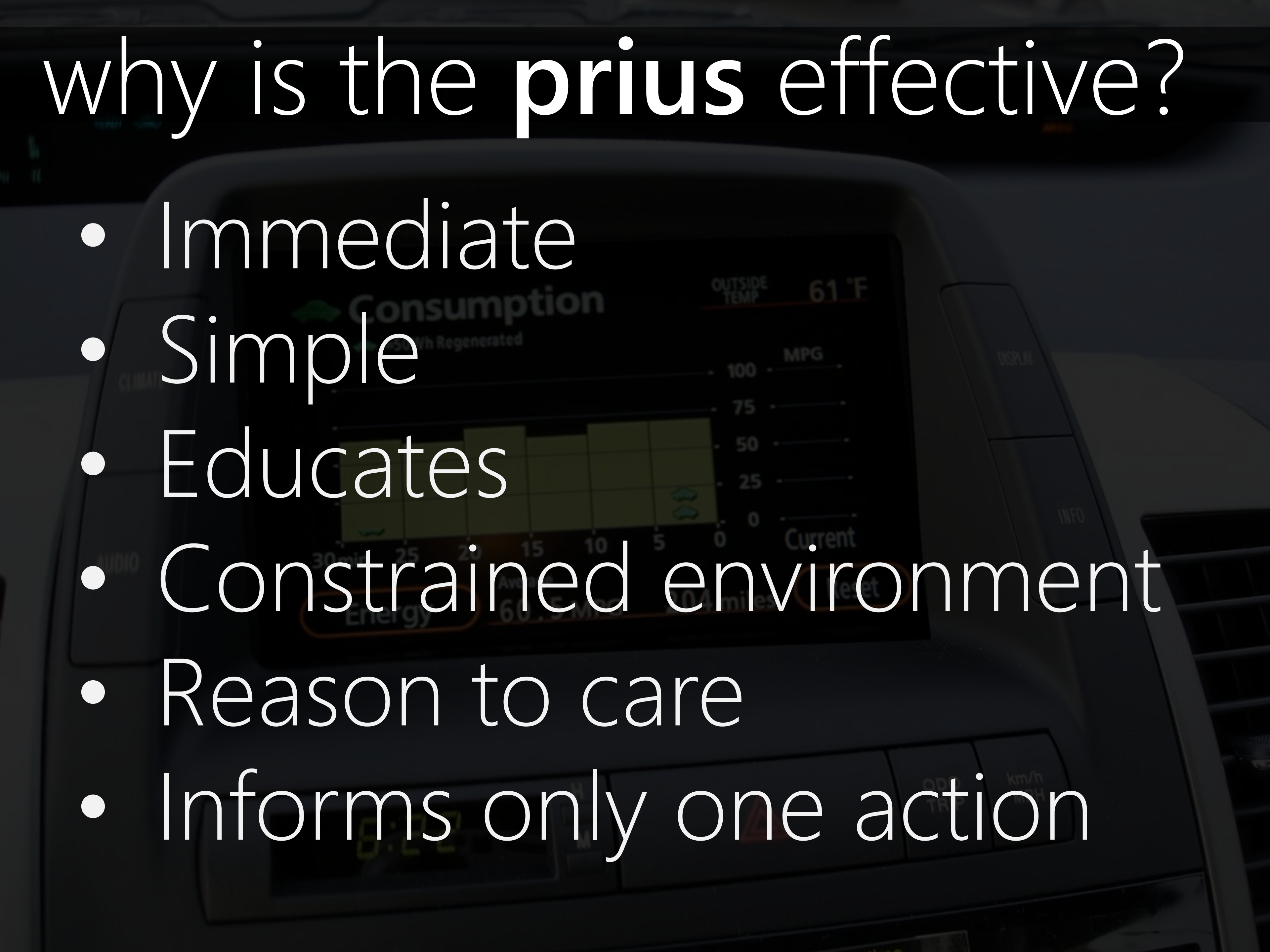
@jonfroehlich

Feedback is about empowering people with information to positively inform and change behavior

the **prius** effect?



why is the **prius** effective?

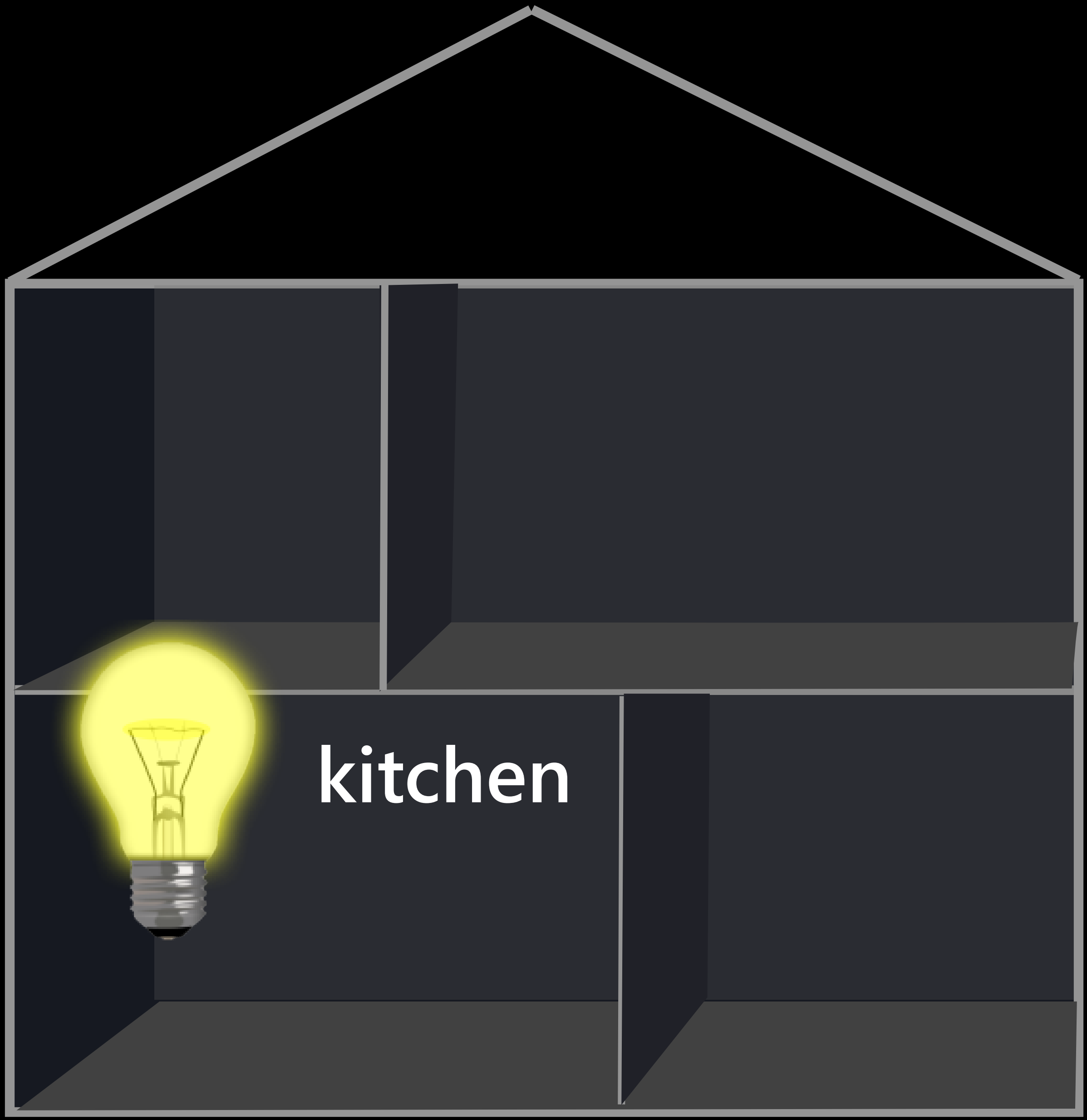


- Immediate
- Simple
- Educates
- Constrained environment
- Reason to care
- Informs only one action

the **prius** effect?


1976

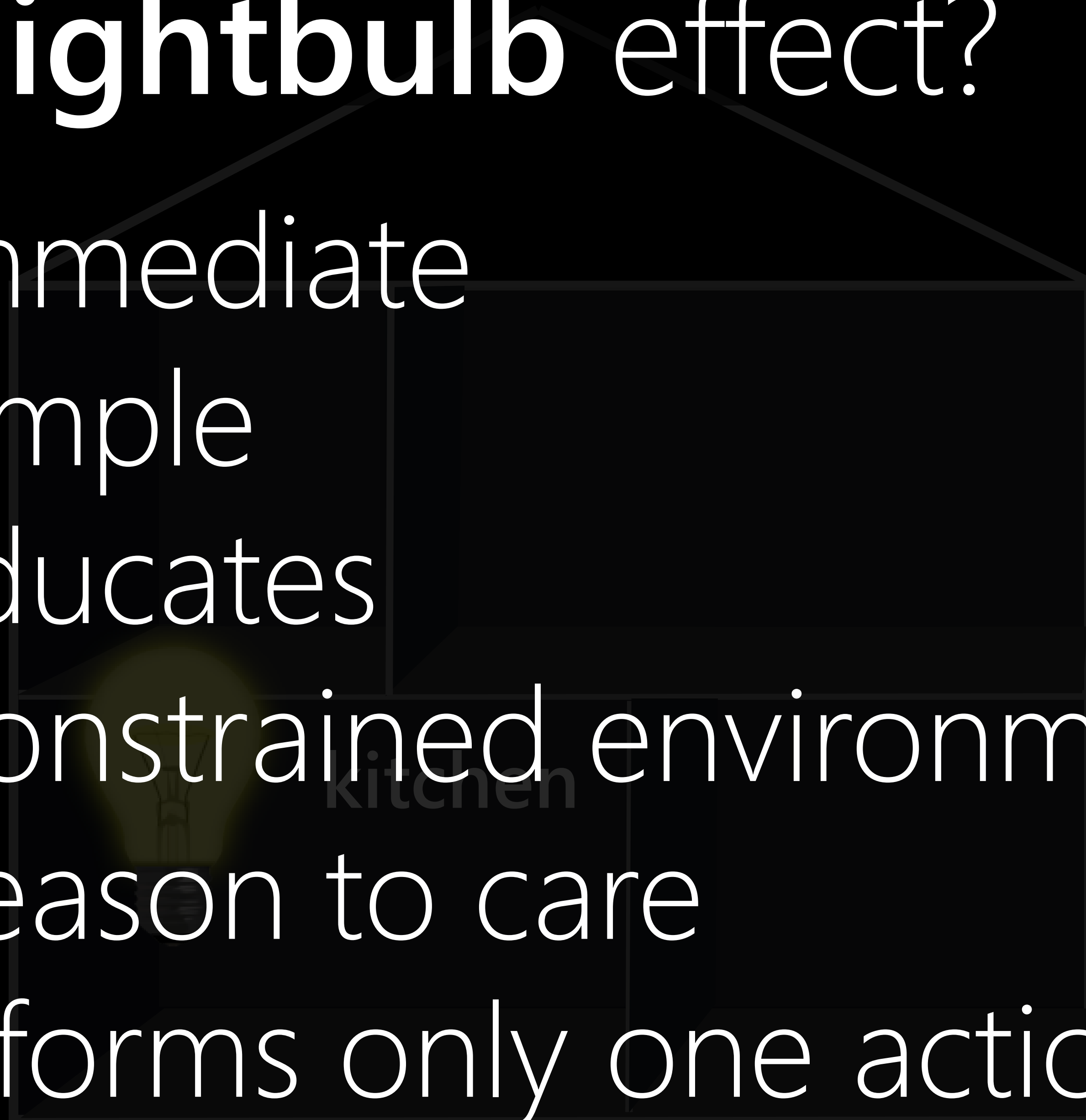
Kohlenberg et al., *J. of Applied Behavior Analysis*, 1976



Kohlenberg et al., *J. of Applied Behavior Analysis*, 1976

the **lightbulb** effect?

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



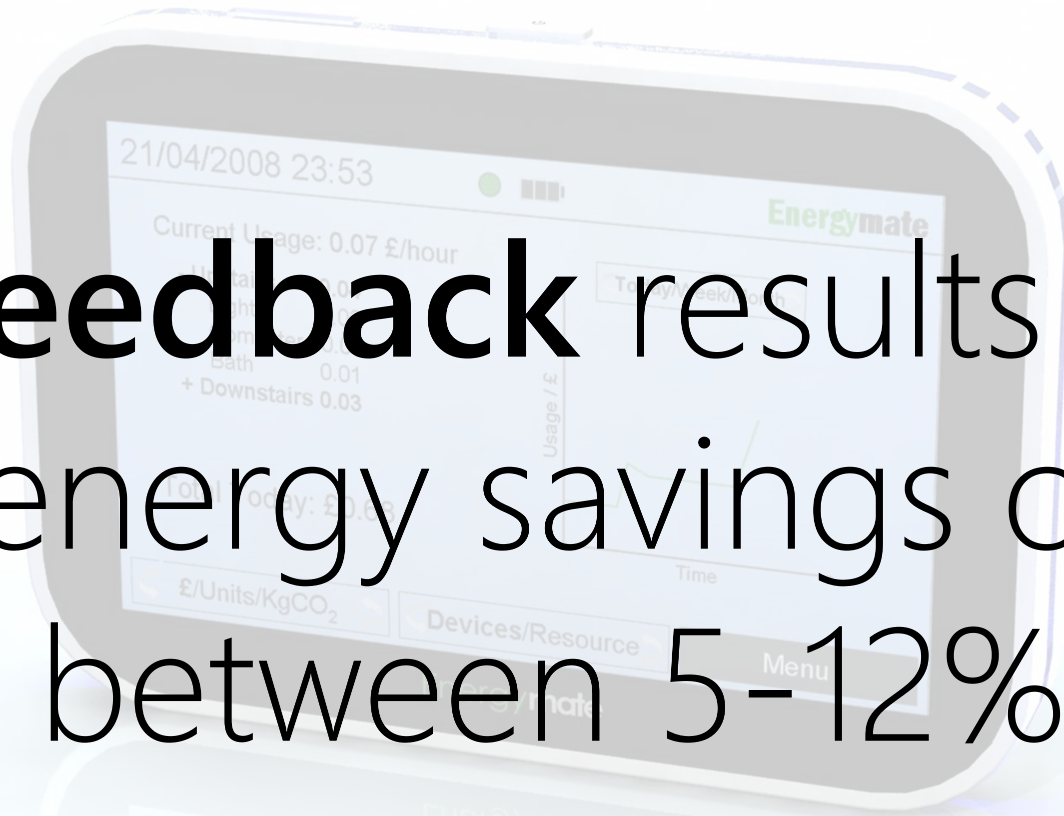
Kohlenberg et al., *J. of Applied Behavior Analysis*, 1976

the **lightbulb** effect?

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

Kohlenberg et al., *J. of Applied Behavior Analysis*, 1976


2010



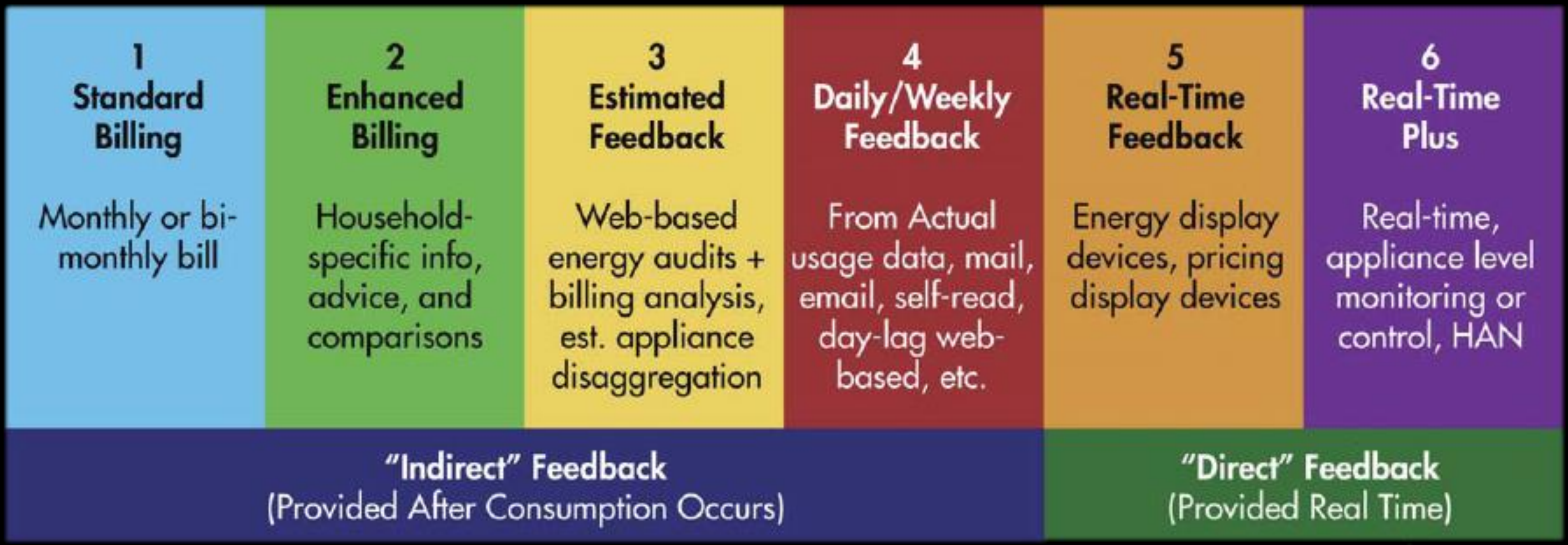
Feedback results in energy savings of between 5-12%

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

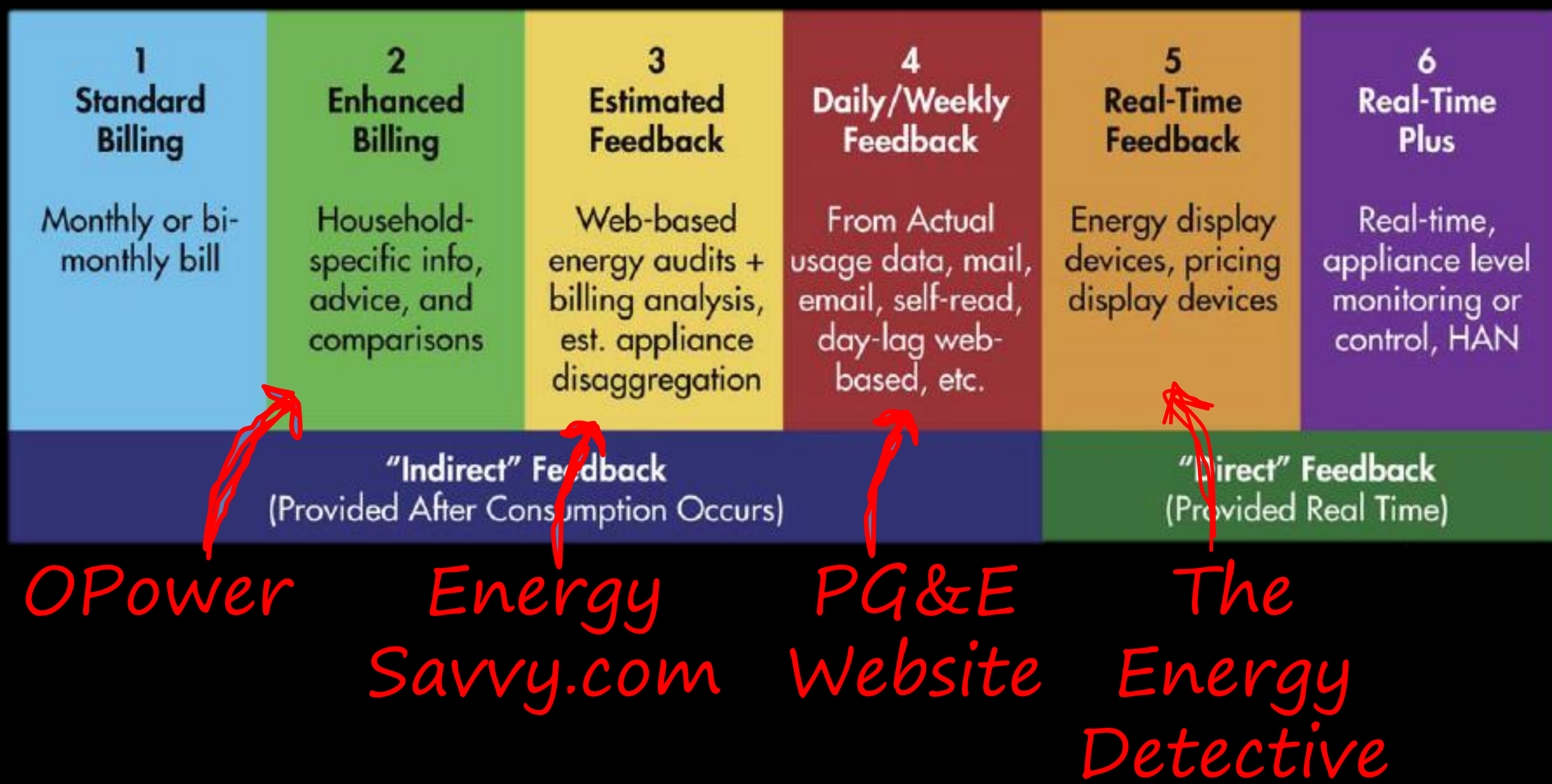
low — data update frequency / cost to implement → **high**



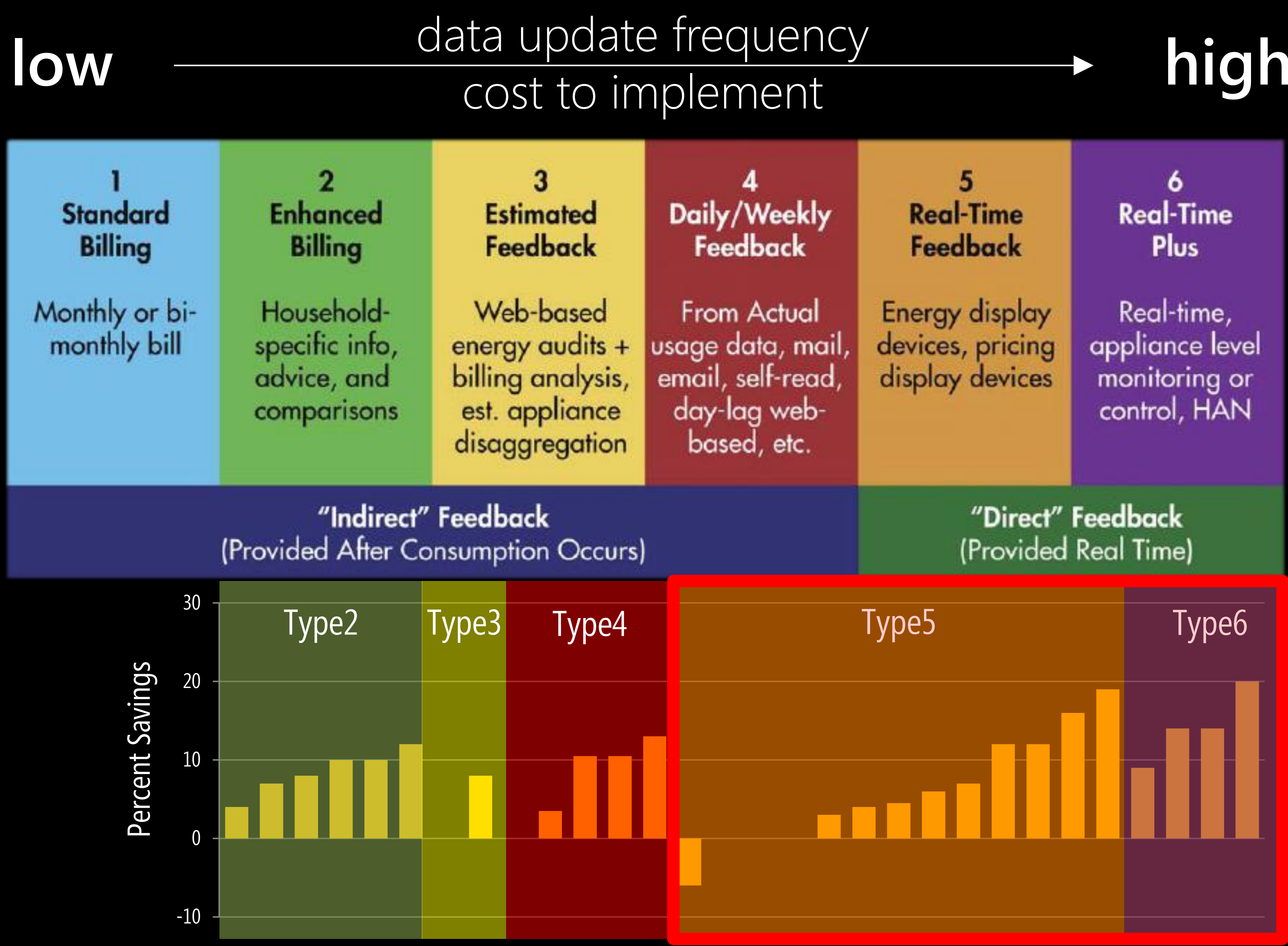
Residential Electricity Use Feedback: A Research Synthesis and Economic Framework, *EPRI 2009* low → high

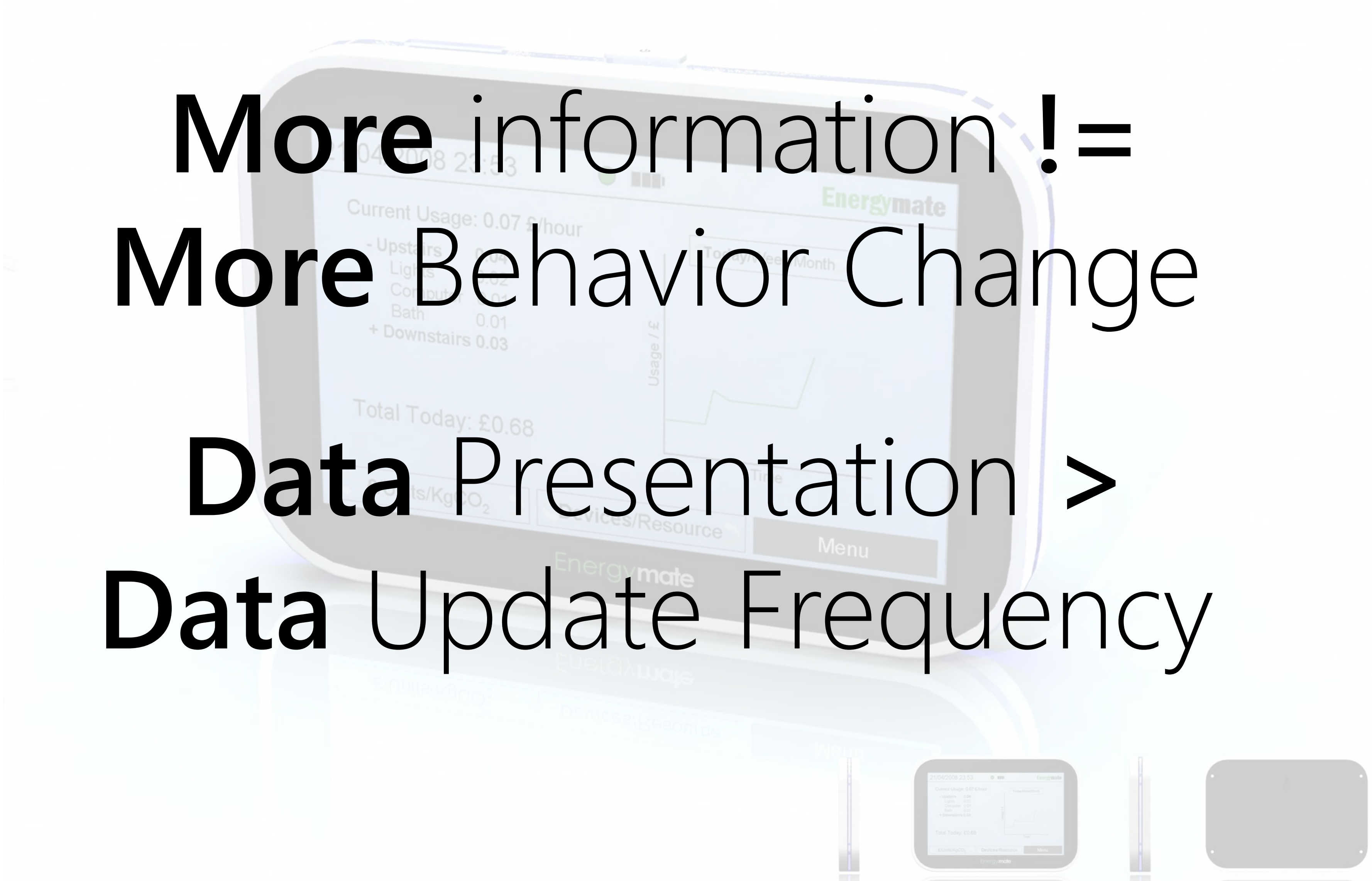
data update frequency

cost to implement



Residential Electricity Use Feedback: A Research Synthesis and Economic Framework, *EPRI 2009*


low
data update frequency
cost to implement
high
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
"Indirect" Feedback
(Provided After Consumption Occurs)
"Direct" Feedback
(Provided Real Time)
Percent Savings
30
20
10
0
-10
Type2
Type3
Type4
Type5
Type6



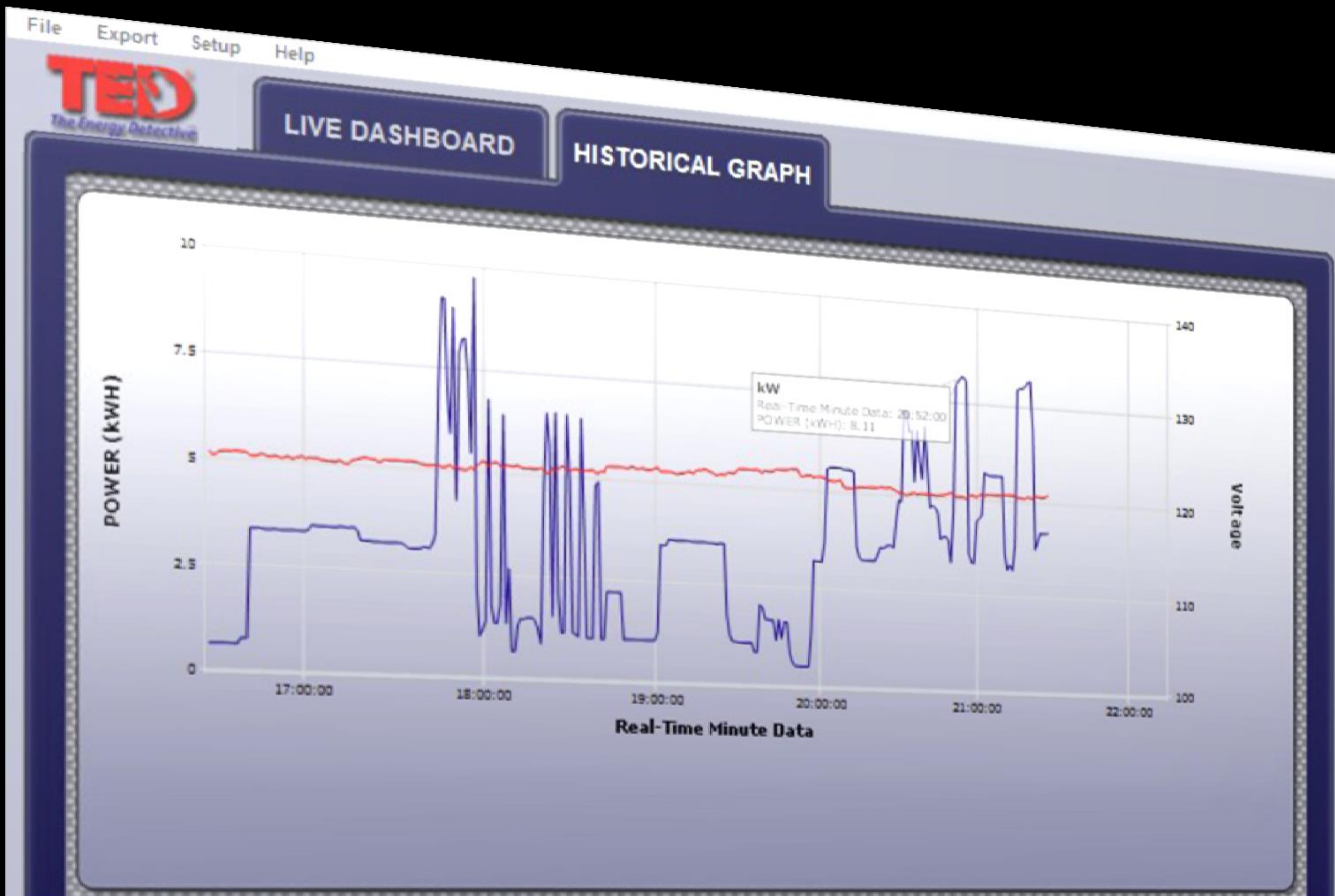
More information **!=**
More Behavior Change

Data Presentation **>**
Data Update Frequency

Darby, 2000; Abrahamse, 2005; Fischer, 2008; EPRI 2009

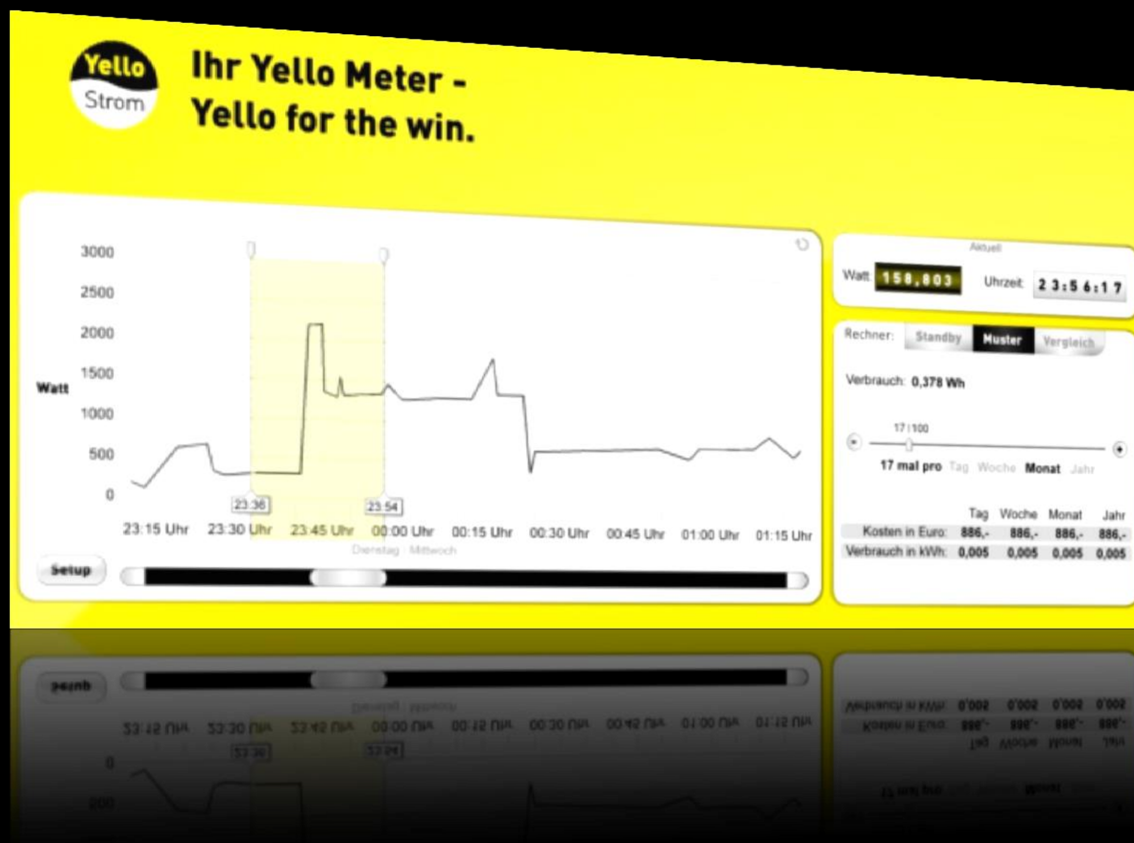

Feedback du jour
line graphs

TED The Energy Detective



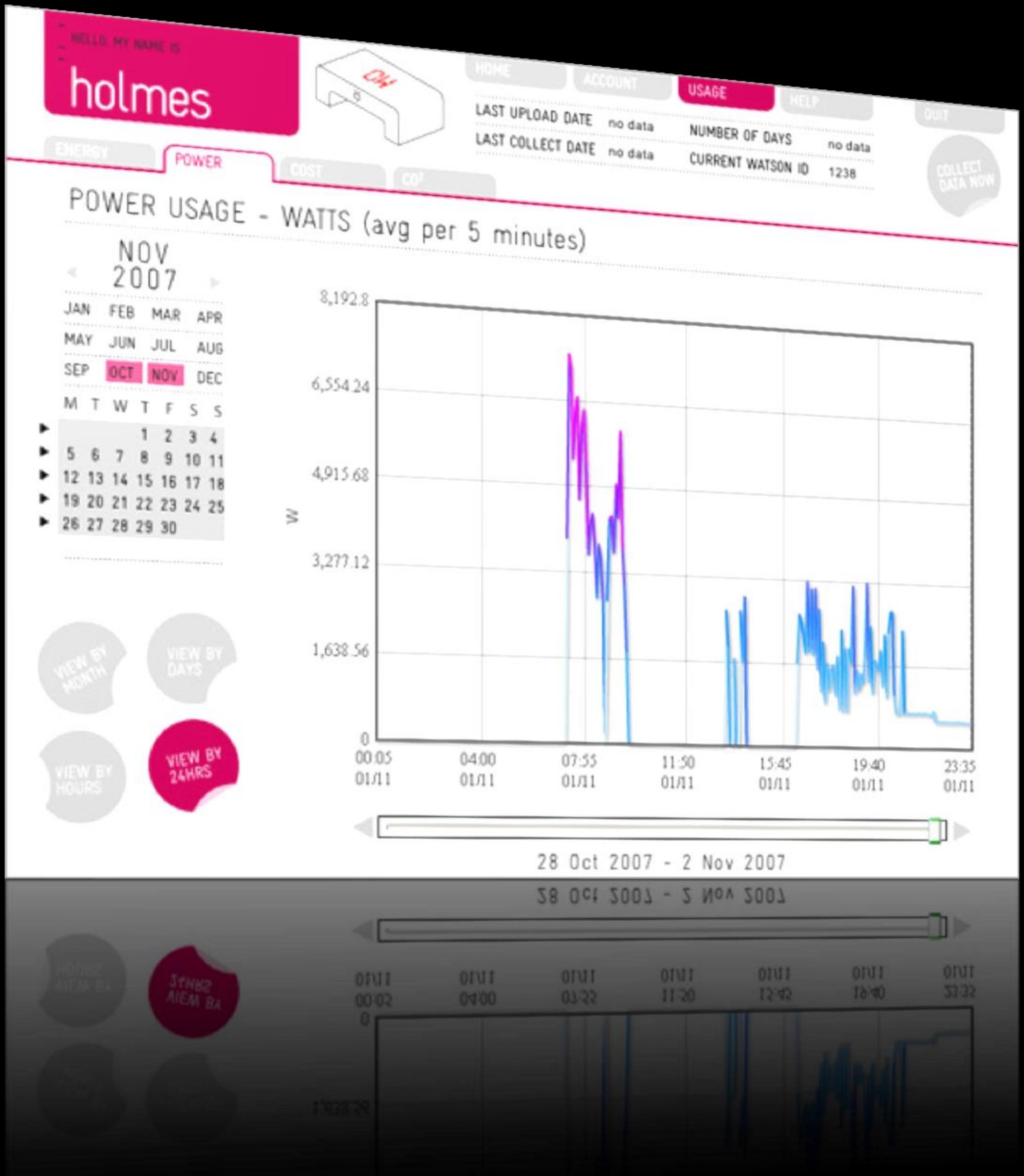
Google PowerMeter

Yello Strom



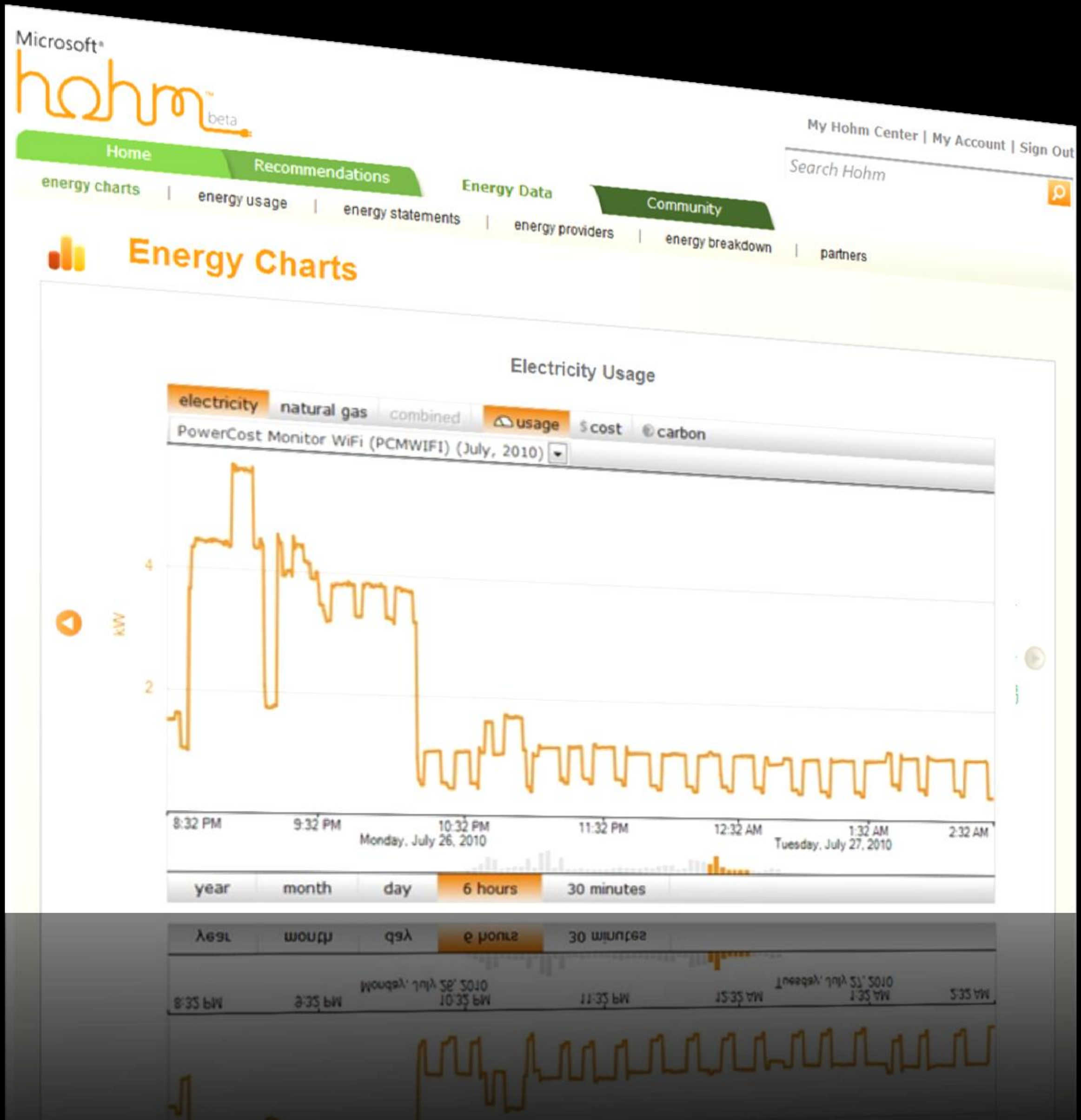
Yello
Strom
Ihr Yello Meter -
Yello for the win.
3000
2500
2000
1500
1000
500
0
Watt
23:36
23:54
23:15 Uhr
23:30 Uhr
23:45 Uhr
00:00 Uhr
00:15 Uhr
00:30 Uhr
00:45 Uhr
01:00 Uhr
01:15 Uhr
Setup
Watt
158,803
Uhrzeit
2 3:5 6:1 7
Rechner:
Standby
Muster
Vergleich
Verbrauch: 0,378 Wh
17 | 100
17 mal pro
Tag
Woche
Monat
Jahr
Tag
Woche
Monat
Jahr
Kosten in Euro: 886,- 886,- 886,- 886,-
Verbrauch in kWh: 0,005 0,005 0,005 0,005

Wattson Holmes



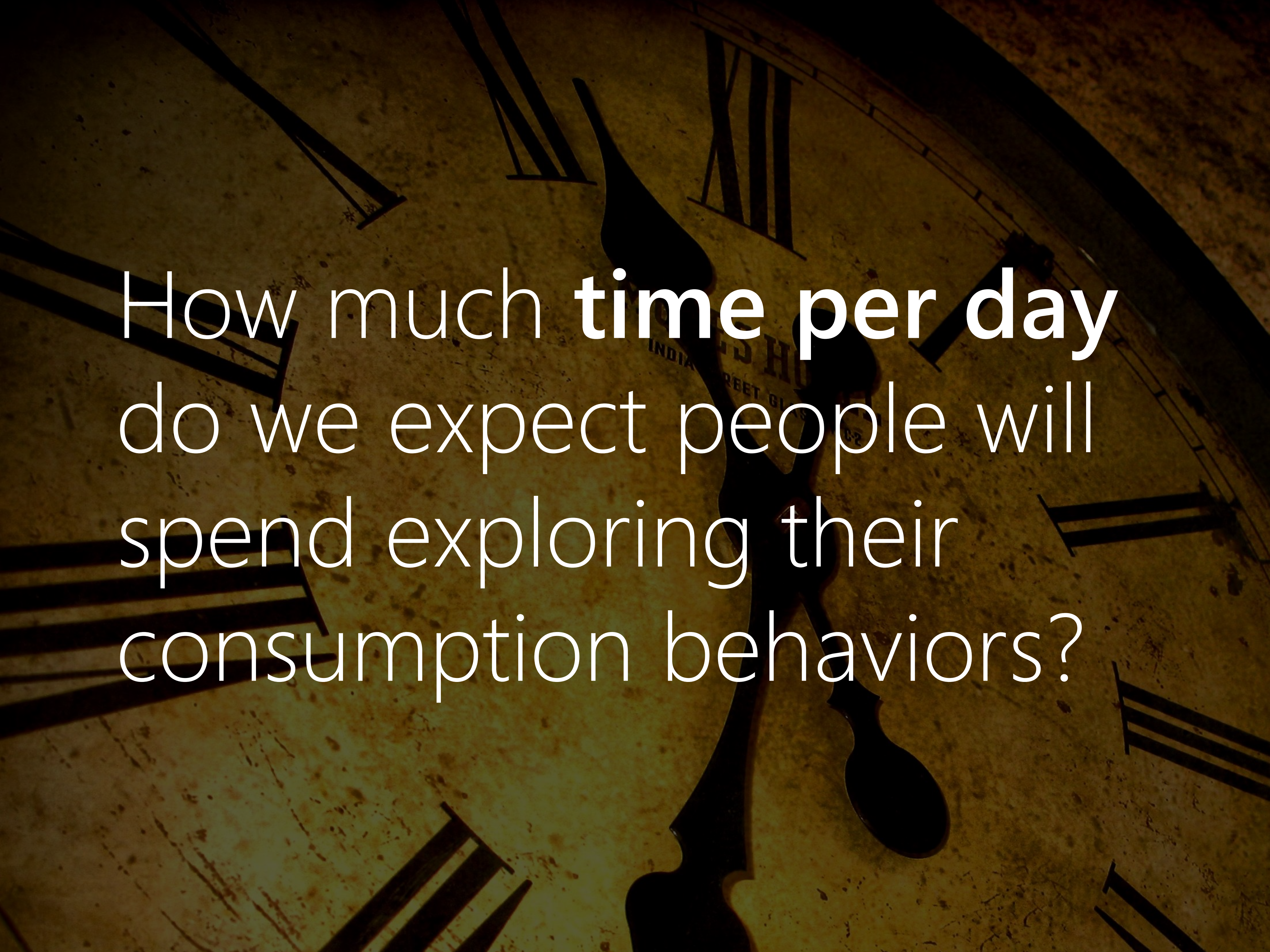
Lucid Design Group

Microsoft Hohm



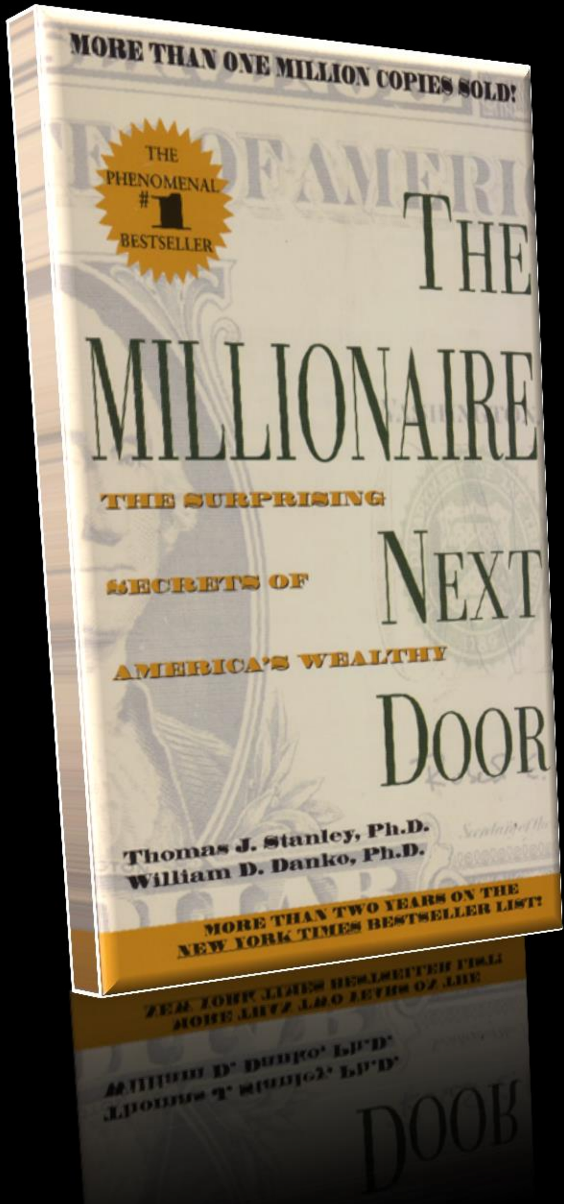

Just Juice

High **cognitive**
burden on person.
Why?



How much **time per day** do we expect people will spend exploring their consumption behaviors?


How much **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

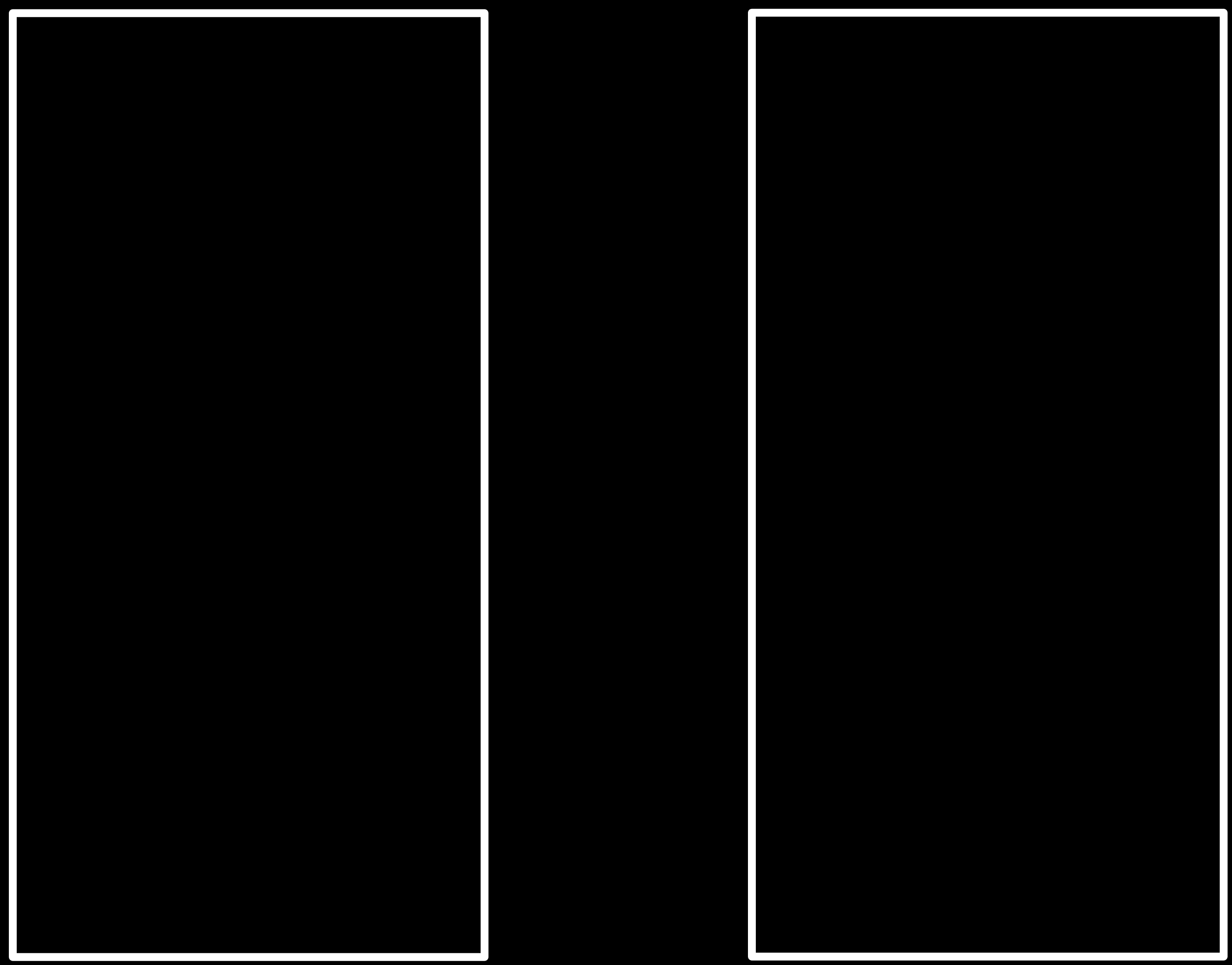
me (grad student)
0.5 hrs/mo → 1 min/day


< 1 min

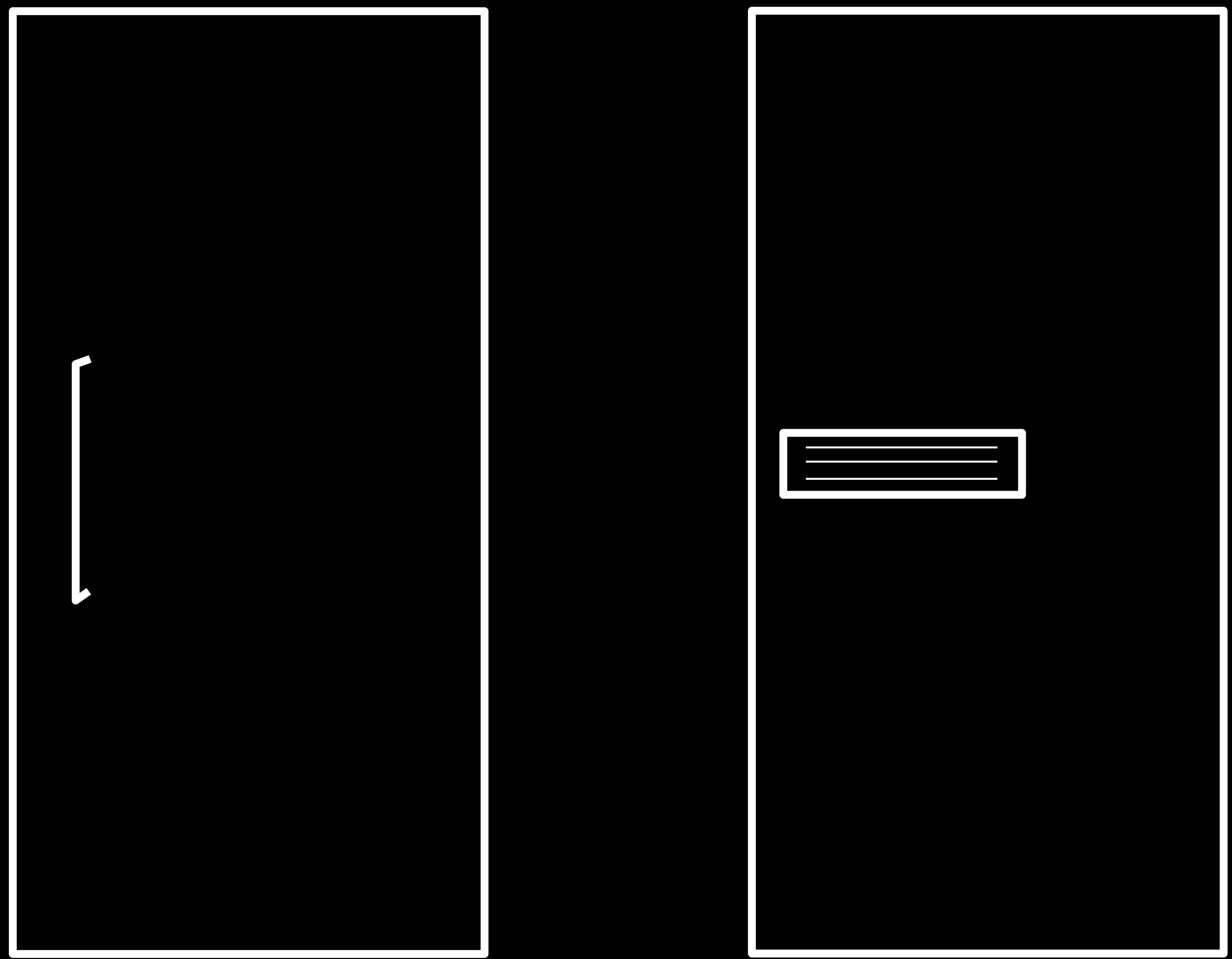
Line Graphs

How **actionable** is this information?

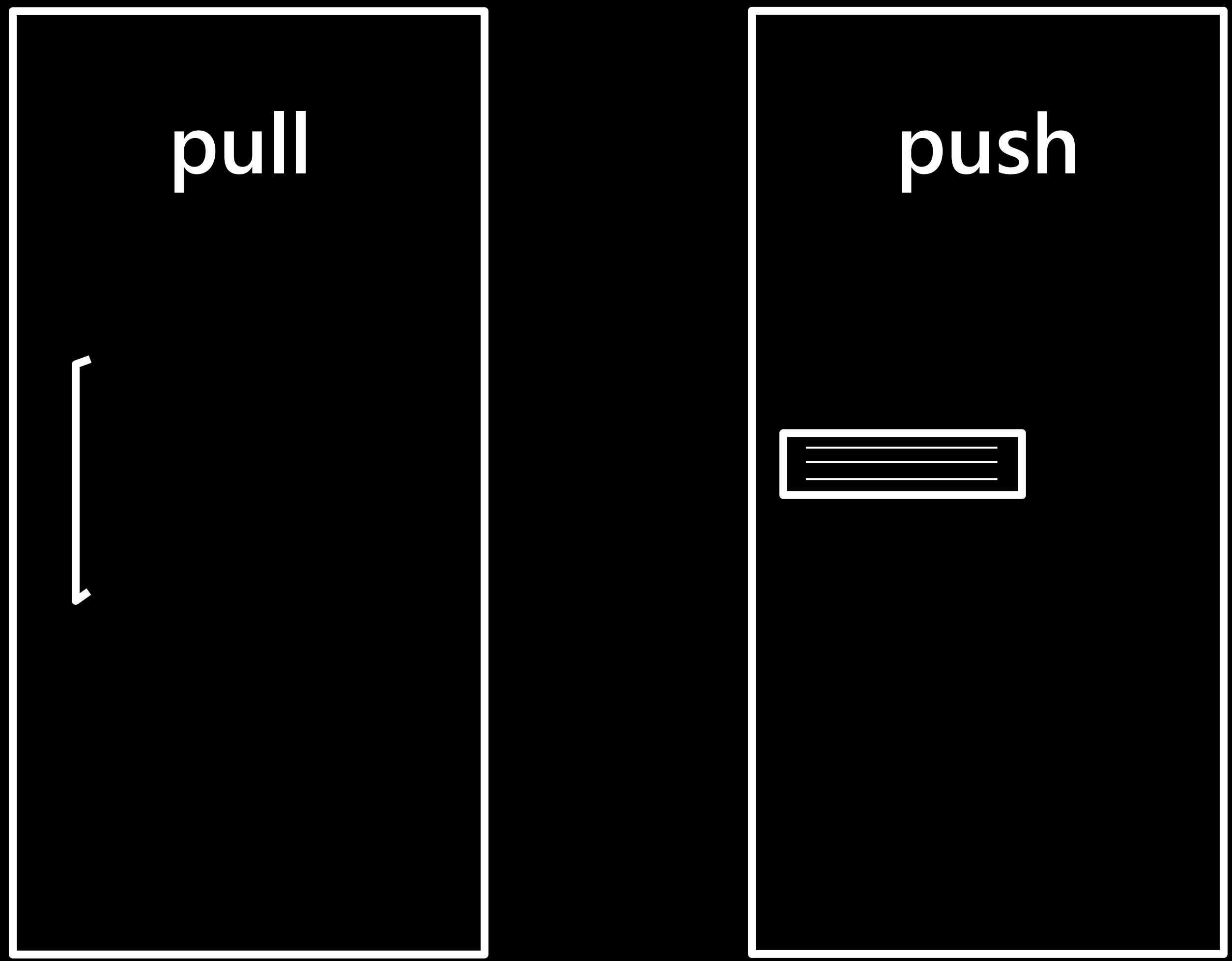
which door do i **push,**
which door do i **pull?**



which door do i **push,**
which door do i **pull?**



which door do i **push,**
which door do i **pull?**



which door do i **push,**
which door do i **pull?**


PULL


PUSH

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


PUSH
FAIL #1


PULL
PULL
FAIL #2


FAIL #3
FAIL #4
DUNK IT IN
DROP IT IN
PUSH
You can HAVE IT YOUR WAY and pull if you want, but this hinge is pretty stubborn.
BURGER KING
Pull
BURGER KING


PULL
MIDVALE
SCHOOL FOR
THE GIFTED


WE CARD
BECAUSE
WE CARE

affordances affect our perception of use

can affordances change our **behavior?**


In-N-Out
Burger!

Battle of the Cans

Environmental protection
可回收物
Recyclable
纸类、玻璃、金属、塑料等
政府提倡使用的资源再生利用产品
爱我家园
Love our homeland
其它垃圾
Other waste
剩饭菜、瓜果壳、灰土等
政府提倡使用的资源再生利用产品


WASTE
WASTE
CANS & BOTTLES
CANS & BOTTLES
NEWSPAPERS
NEWSPAPERS

Battle of the Cans

Duffy, *Environment and Behavior*, 2010


WASTE
WASTE
CANS & BOTTLES
CANS & BOTTLES
NEWSPAPERS
NEWSPAPERS
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

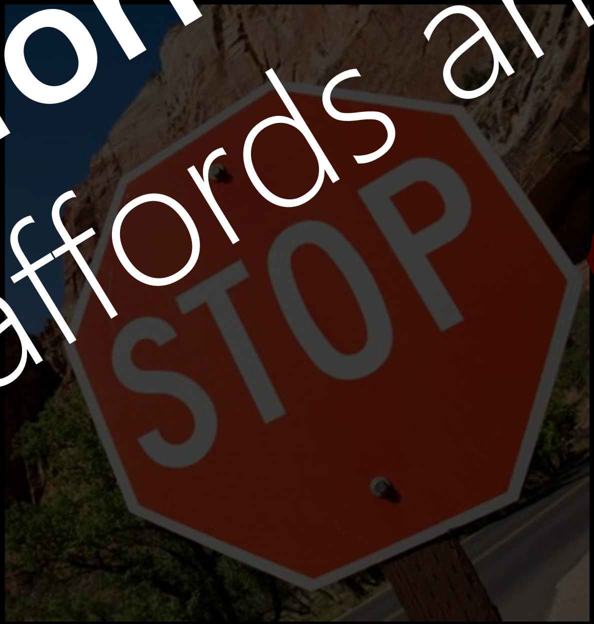
Flat textured surface affords pushing!

Motivational affordance refers to the perceived properties of information that determine how that information is acted upon

Highly effective at stopping drivers

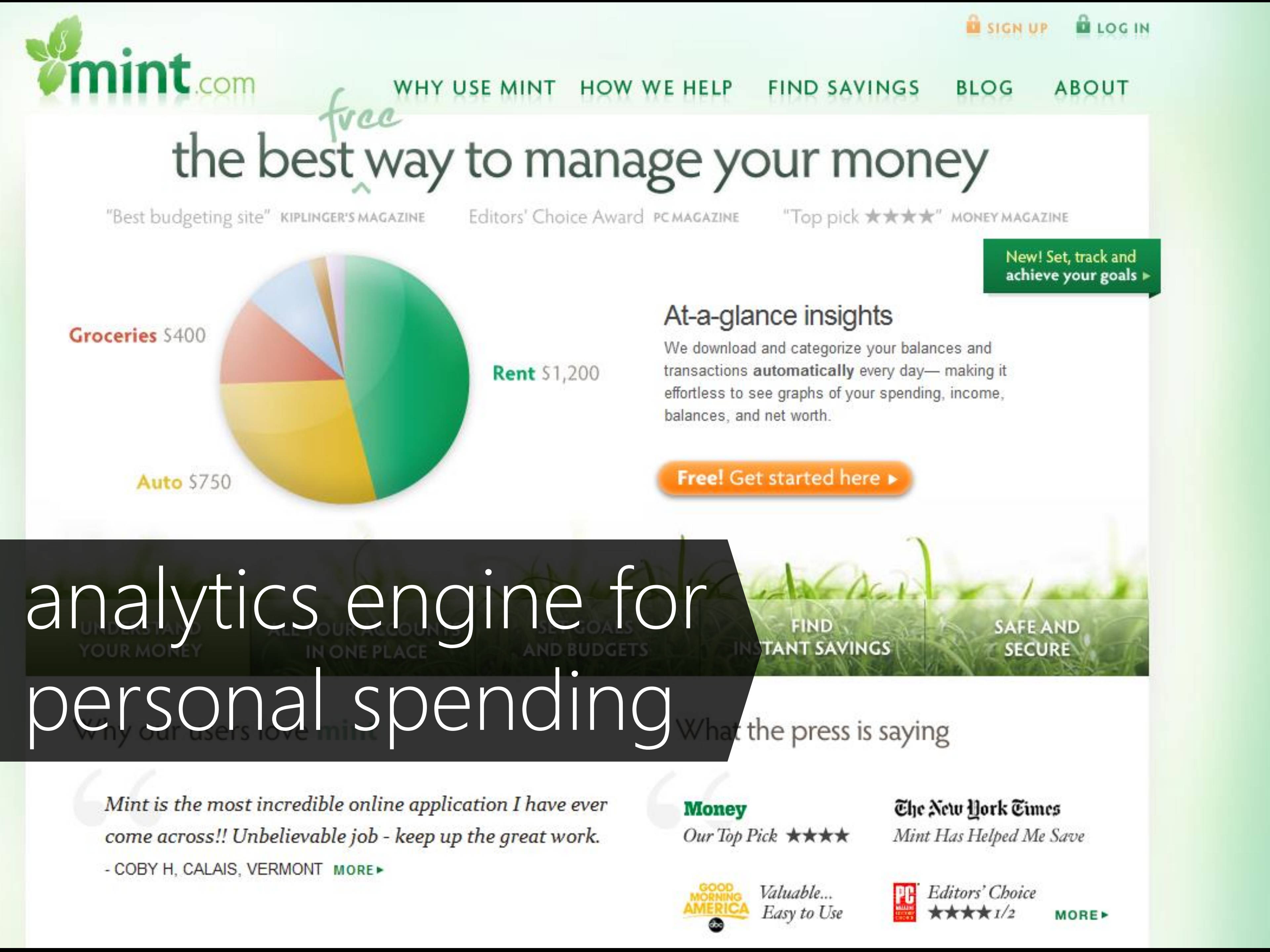
Motivational affordance refers to the perceived properties of information that determine how that information is acted upon

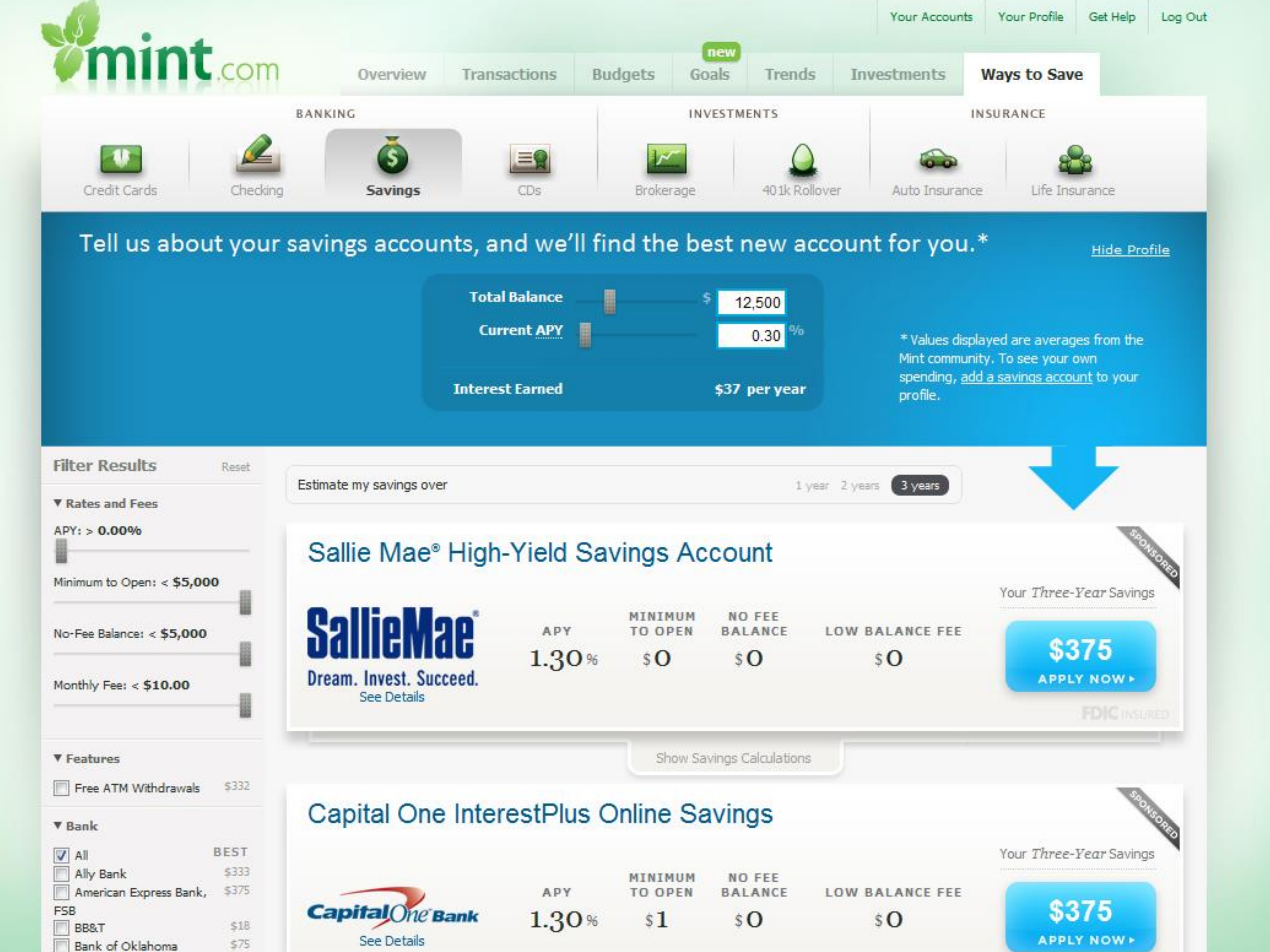
Information that affords an action



Highly effective at stopping drivers

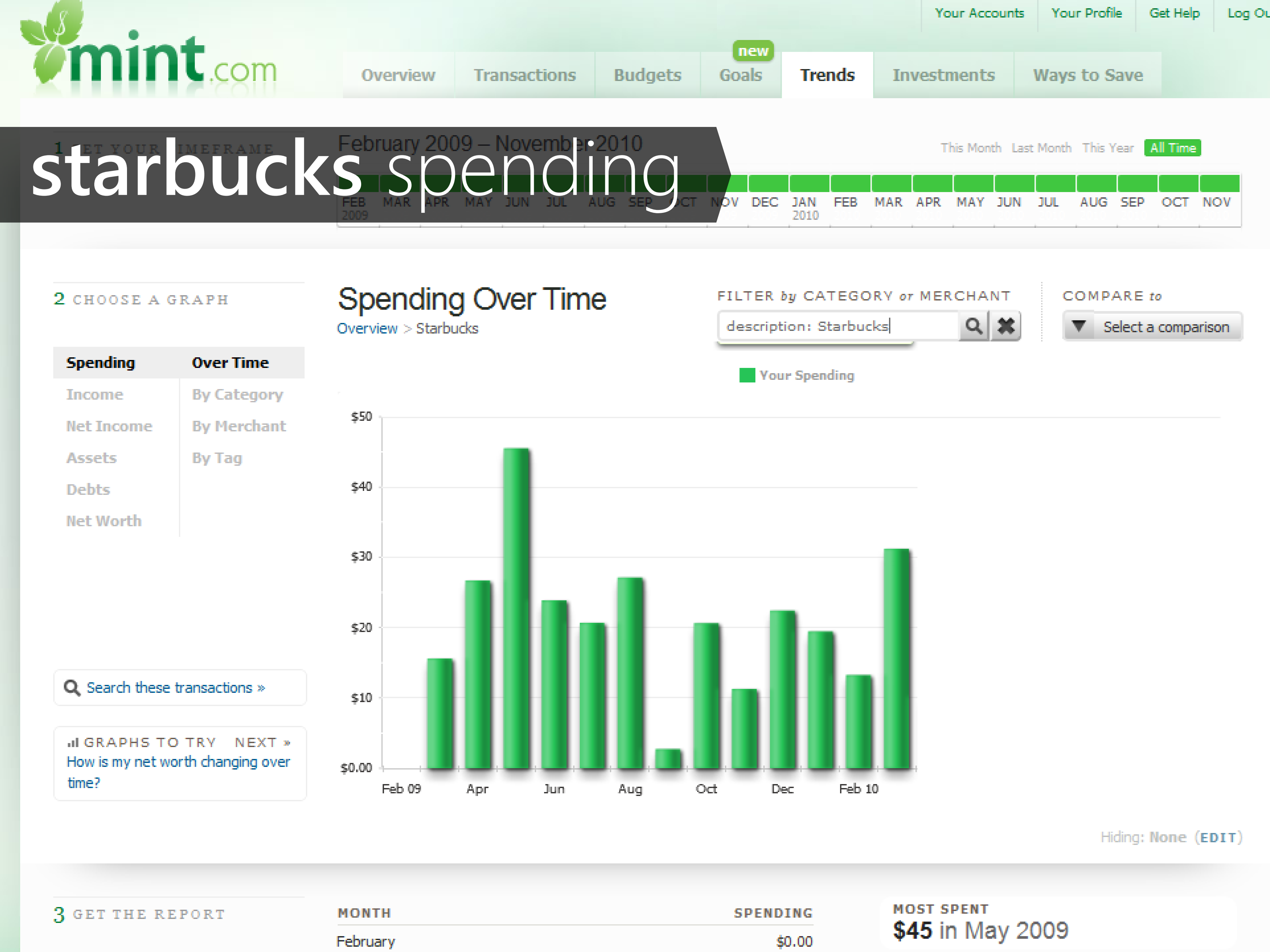
analytics engine for personal spending

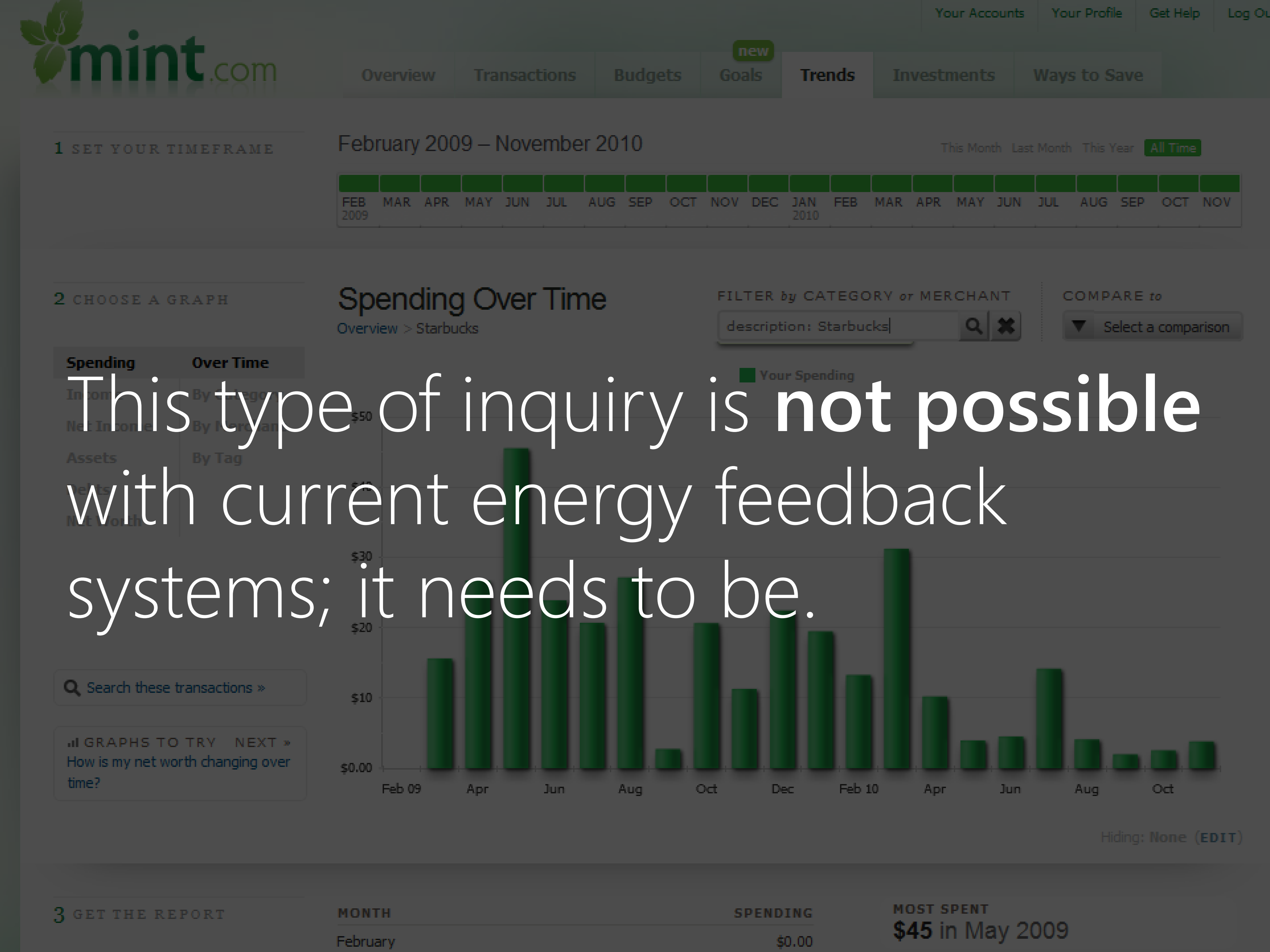



mint.com
Your Accounts
Your Profile
Get Help
Log Out
Overview
Transactions
Budgets
new
Goals
Trends
Investments
Ways to Save
BANKING
INVESTMENTS
INSURANCE
Credit Cards
Checking
Savings
CDs
Brokerage
401k Rollover
Auto Insurance
Life Insurance
Tell us about your savings accounts, and we'll find the best new account for you.*
Hide Profile
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
Reset
▼ Rates and Fees
APY: > 0.00%
Minimum to Open: < $5,000
No-Fee Balance: < $5,000
Monthly Fee: < $10.00
▼ Features
Free ATM Withdrawals $332
▼ Bank
BEST
All
Ally Bank $333
American Express Bank, FSB $375
BB&T $18
Bank of Oklahoma $75
Estimate my savings over
1 year
2 years
3 years
Sallie Mae® High-Yield Savings Account
SPONSORED
SallieMae®
Dream. Invest. Succeed.
See Details
APY 1.30%
MINIMUM TO OPEN $0
NO FEE BALANCE $0
LOW BALANCE FEE $0
Your Three-Year Savings
$375
APPLY NOW ▸
FDIC INSURED
Show Savings Calculations
Capital One InterestPlus Online Savings
SPONSORED
Capital One Bank
See Details
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
dissaggregated feedback

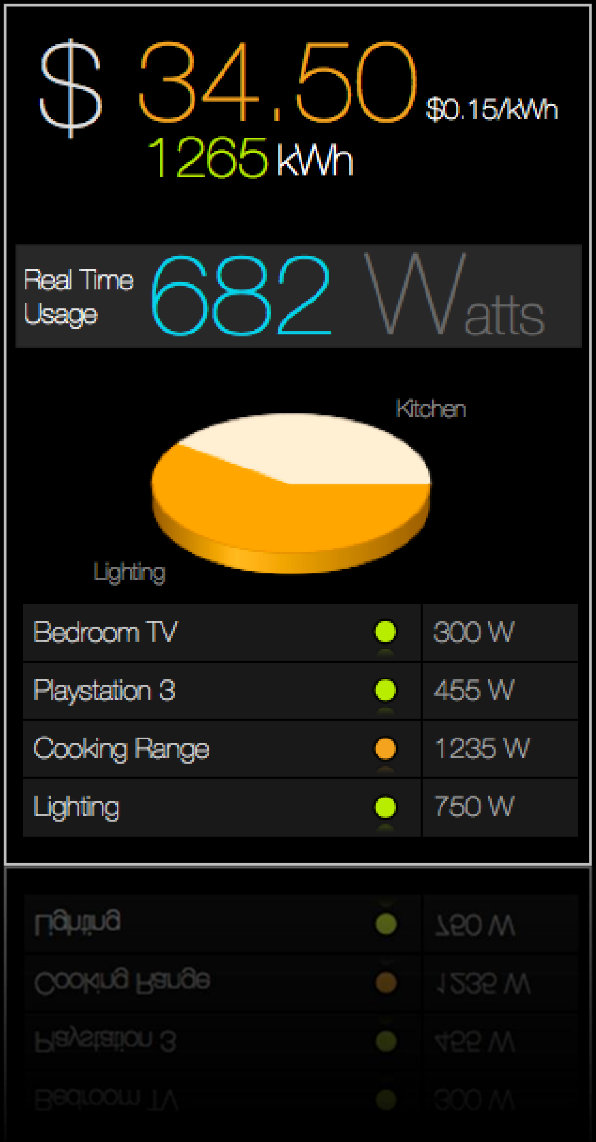
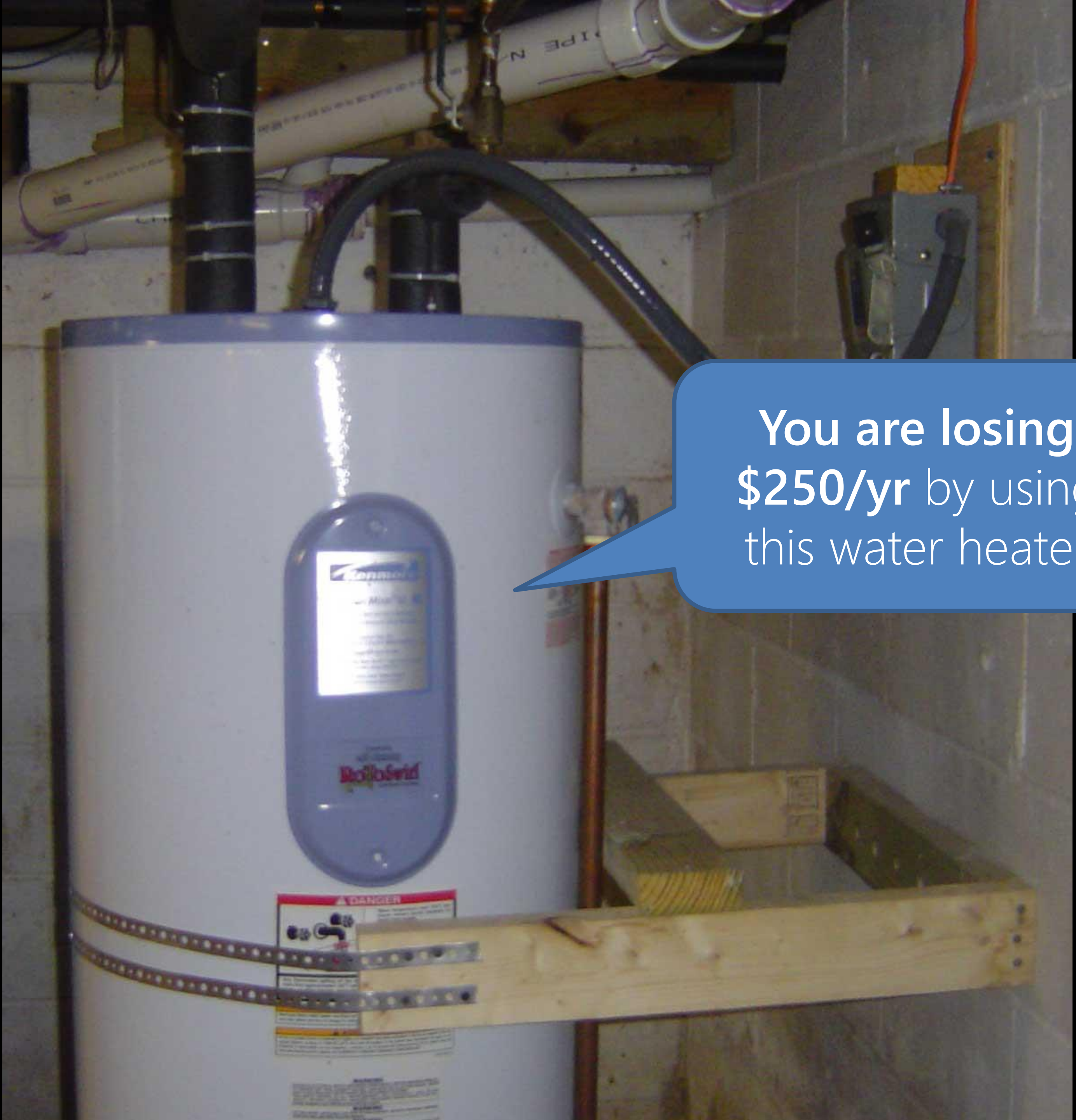


image credit: sidhant gupta

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

http://bit.ly/jonuw

See also: **CHI 2010** talk

http://bit.ly/jonuw

See also: these **two** papers

This paper was originally presented as a Reader at the HCIC 2009 Workshop and subsequently released as a UW tech note #09-02-01.

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 untouchable. Without a tangible manifestation, home energy usage often goes unnoticed. Advances in resource 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 the user—creating a rich space of opportunities for HCI research. This paper outlines common misconceptions of energy usage in the home, establishes the potential of feedback to change energy consumption behavior, and introduces ten design dimensions of feedback technology with which to build and evaluate future systems.

Keyword

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). The residential sector accounts for 21% 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 the top two contributors of the average American's CO_2 emissions into the environment (Weber and Matthews, 2007), accounting for over 50% of their total carbon footprint. To date, the primary methods applied to improving energy efficiency and/or reducing energy usage been technological and economic (Armel, 2008). For example, the production of hybrid or hydrogen vehicles has been emphasized as a major solution to CO_2 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 10 identical Habitat for Humanity all-electric homes outfitted with the same appliances and equipment, homes were found to exhibit a large range in energy consumption, with the most energy intensive home consuming *2.6 times* more energy than the least (Parker et al., 2008). Indeed, it has been consistently found that energy use can differ by two to three times in identical homes, occupied by people with similar demographics (Socolow, 1978; Winett et al., 1979). Such findings reveal how differences in human behavior can significantly affect energy consumption and suggest that intervention strategies to promote sustainable behaviors 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 untouchable (Fischer, 2008). Without a tangible manifestation, home energy usage often goes unnoticed—unlike, 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

Best Paper!

The Design of Eco-Feedback Technology

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DUB Institute, University of Washington
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ABSTRACT

Eco-feedback technology provides feedback on individual or group behaviors with a 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 89 papers from environmental psychology and 44 papers from the HCI and UbiComp literature. We also provide an overview of predominant models of proenvironmental behaviors and a summary of key motivation techniques to promote this behavior.

Author Keywords

Eco-feedback, Environmental HCI, Reflective HCI, Survey

ACM Classification Keywords

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

INTRODUCTION

As environmental issues such as climate change, air pollution, and water scarcity become more salient in the global consciousness, so too have they become more active targets of research within HCI and Ubiquitous Computing [6, 19, 57]. One particularly popular form of environmental HCI research is the design and study of *eco-feedback technology*, which we define as technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact (adapted from [39] and [28], see Figure 1 for examples). Despite this goal, few HCI eco-feedback studies have even attempted to measure behavior change. Although eco-feedback may be seen as an extension of research in *persuasive technology* [17], it actually extends back much further to over 40 years of research in environmental psychology. This leads to two interrelated questions: (1) What can HCI learn from

CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.

Figure 1. Examples of eco-feedback technology. (left-to-right) The Infotropism display uses sensors and living plants to provide feedback about recycling and waste disposal [29]. Waterbot provides ambient feedback information about water usage [3]. The UbiGreen Transportation Display semi-automatically senses and feeds back information about transportation to encourage green transit [19].

environmental psychology and (2) what should be the role of the HCI community in contributing to eco-feedback research? To explore these questions in detail, we present a review of the related environmental psychology literature as well as a comparative survey of eco-feedback studies in both HCI and environmental psychology.

Eco-feedback technology is based on the working hypothesis that most people lack awareness and understanding about how their everyday behaviors such as driving to work or showering affect the environment; technology may bridge this "environmental literacy gap" by automatically sensing these activities and feeding related information back through computerized means (e.g., mobile phones, ambient displays, or online visualizations). HCI and UbiComp researchers have built eco-feedback technologies for a variety of domains including energy consumption [28], water usage [3], transportation [19], and waste disposal practices [29].

Contributing to this growing interest in eco-feedback technology is the parallel advancement and availability of sensing systems for environmentally related activities (e.g., human activity inference [35]) *and* interactive displays to feedback this data (e.g., iPods and mobile phones). Such advances provide a rich space of opportunities for new types of eco-feedback that could not be considered in the past. Moreover, the next generation of resource measurement systems (often referred to as "smart meters") will soon provide real-time (or near real-time) data on electricity, gas, and water usage in homes and businesses. This will produce tremendous amounts of data that can be

http://bit.ly/jonuw

fresh **off** the presses:

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.

Jon Froehlich, Eric Larson, Sidhant Gupta, and Gabe Cohn
University of Washington

Matthew S. Reynolds
Duke University

Shwetak N. Patel
University of Washington

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. Our team's contributions are focused on approaches for obtaining this disaggregated data from a single sensing point. Our vision is to provide high granularity resource-sensing systems for homes and businesses that will fundamentally transform how electricity, water, and natural gas are understood, studied, and ultimately consumed. This article focuses on electrical energy, but we've also developed systems for disaggregating water and gas usage (see the sidebar). All three of our systems share a common approach: they monitor side effects of resource usage that are manifest throughout a home's internal electricity, plumbing, or gas infrastructure.

Although our techniques should function in commercial and industrial sectors, we've concentrated so far on validating our methods in the residential sector, which presents many challenges. In addition to the significant amount of energy use and CO_2 emissions in the residential sector,[1,2] there's a higher degree of decentralized ownership. Also, levels of self-interest and expertise in reducing energy consumption vary, compared with the industrial and commercial sectors. Perhaps more compelling, however, is that energy consumption can vary widely from home to home based simply on differences in individual behavior. Indeed, it has been found

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