Applying **Iterative Design** to the Eco-Feedback Design Process

Human
Computer
Interaction
Laboratory

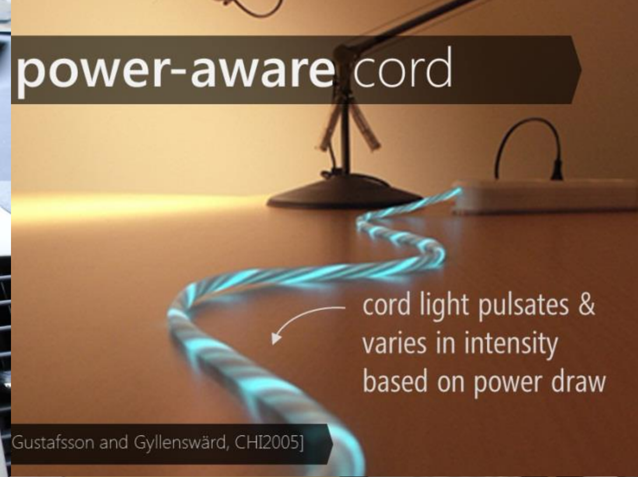
@jonfroehlich
Assistant Professor Computer Science

UNIVERSITY OF MARYLAND

eco-feedback

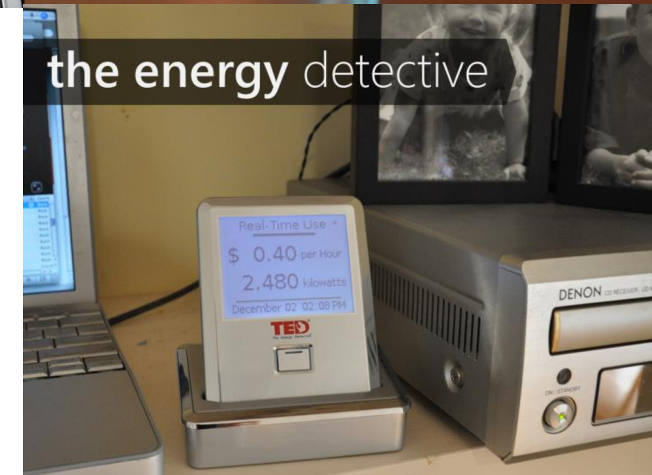
sensing and visualizing behavior to reduce environmental impact


toyota prius
Consumption
OUTSIDE TEMP 61 °F
MPG
Current
Energy
60.5 MPG
204 miles
Reset
6:22

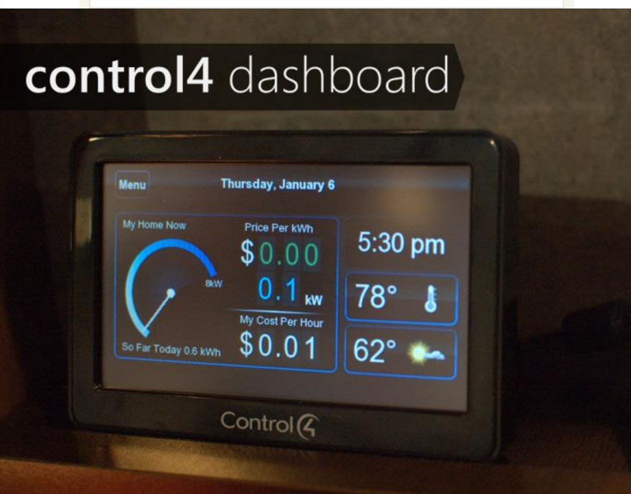

power-aware cord
cord light pulsates & varies in intensity based on power draw
Gustafsson and Gyllenswärd, CHI2005]

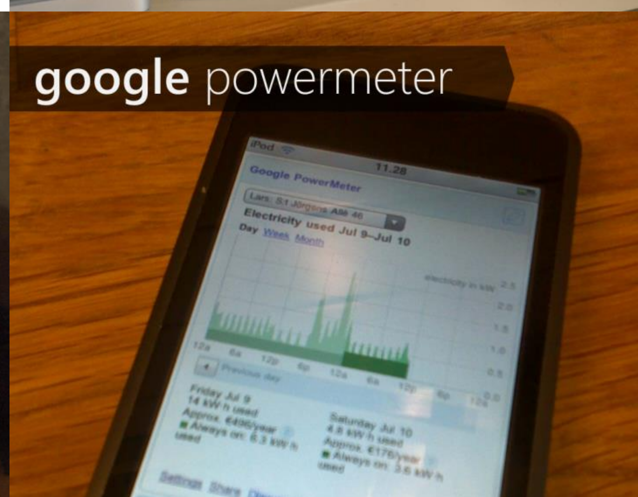

jetsam
visualization allows pedestrians to view amount and type of garbage at-a-glance
[Paulos and Jenkins, CHI2005]


microsoft hohm
hohm
Energy Charts
Electricity Usage


the energy detective
Real-Time Use
$ 0.40 per Hour
2.480 kilowatts
TED
DENON


wattson


control4 dashboard
Menu
Thursday, January 6
My Home Now
Price Per kWh
$0.00
0.1 kW
My Cost Per Hour
$0.01
5:30 pm
78°
62°
So Far Today 0.6 kWh
Control4


google powermeter
Google PowerMeter


heat sink
[Arroyo et al., CHI2005]

eco-feedback

sensing and visualizing behavior to reduce environmental impact

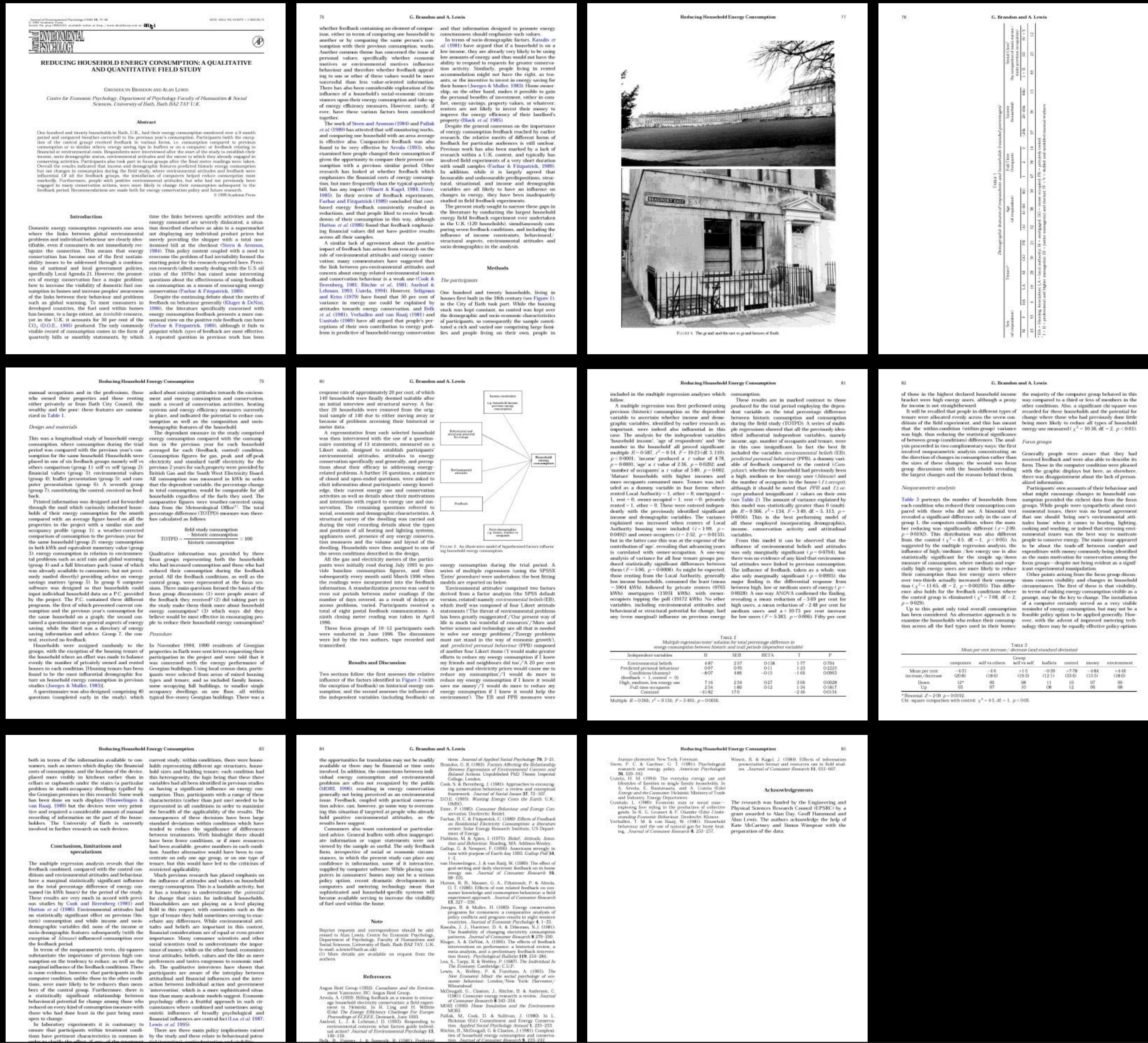
Talk focus: How can/should we create reusable design knowledge to support the eco-feedback design process

"Getting the **design right** and the **right design**."

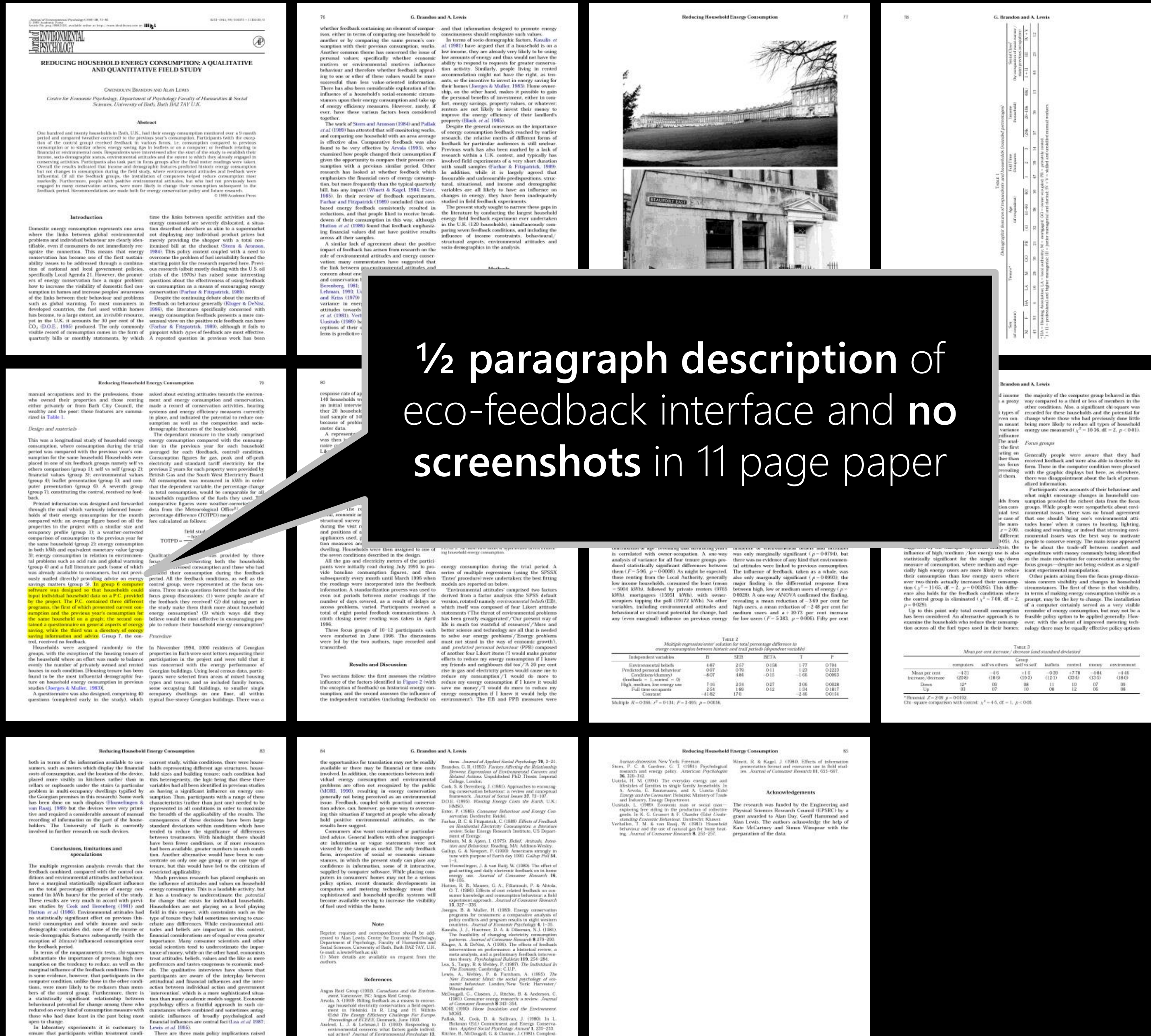
— **Bill Buxton**
Sketching User Experiences

Before moving forward, I want to ask a question…

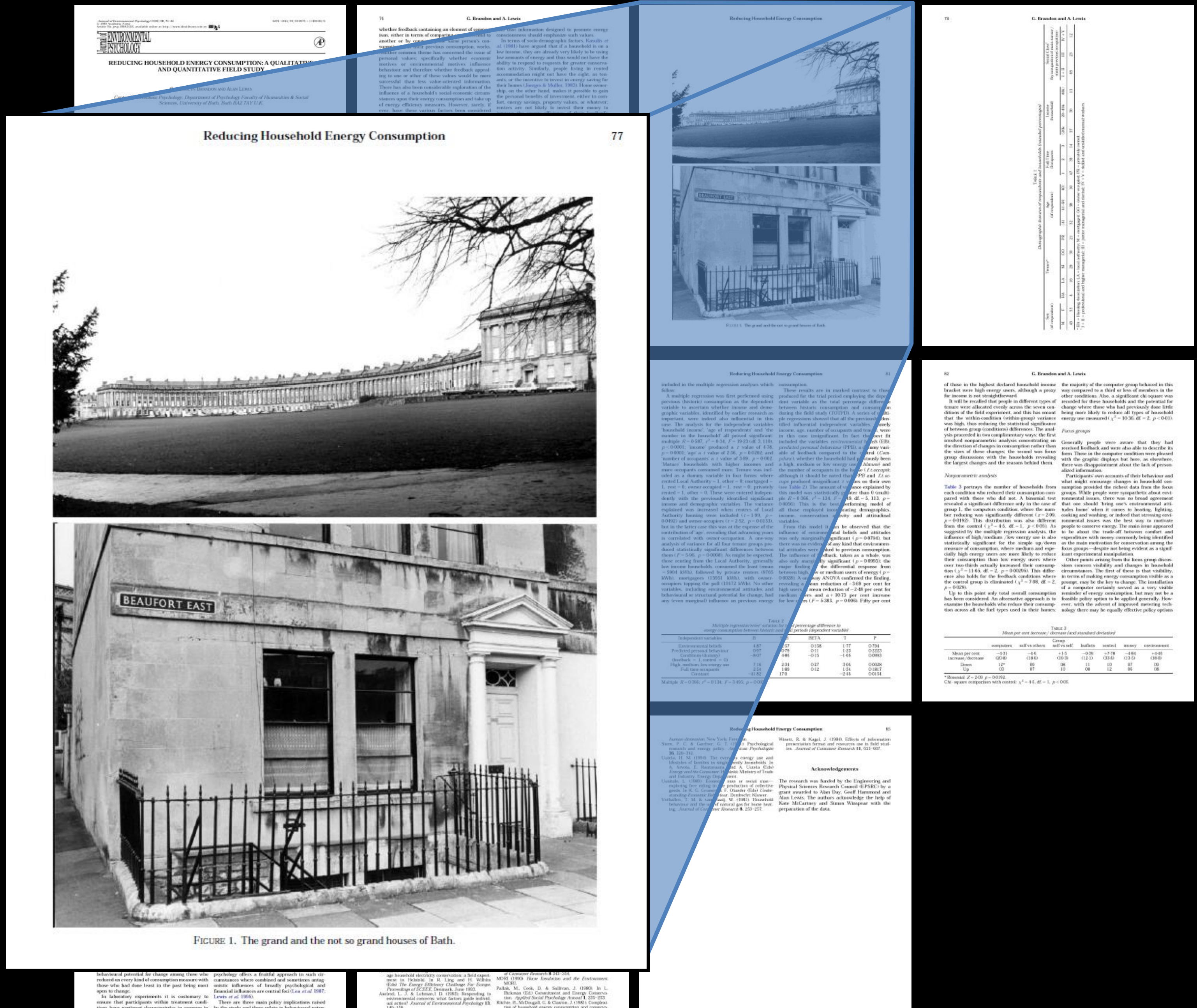
The following eco-feedback paper **is missing something**. What is it?


REDUCING HOUSEHOLD ENERGY CONSUMPTION: A QUALITATIVE AND QUANTITATIVE FIELD STUDY

Brandon *et al.*, **Reducing Household Energy Consumption: A Qualitative & Quantitative Field Study**, *Environmental Psychology 1999*



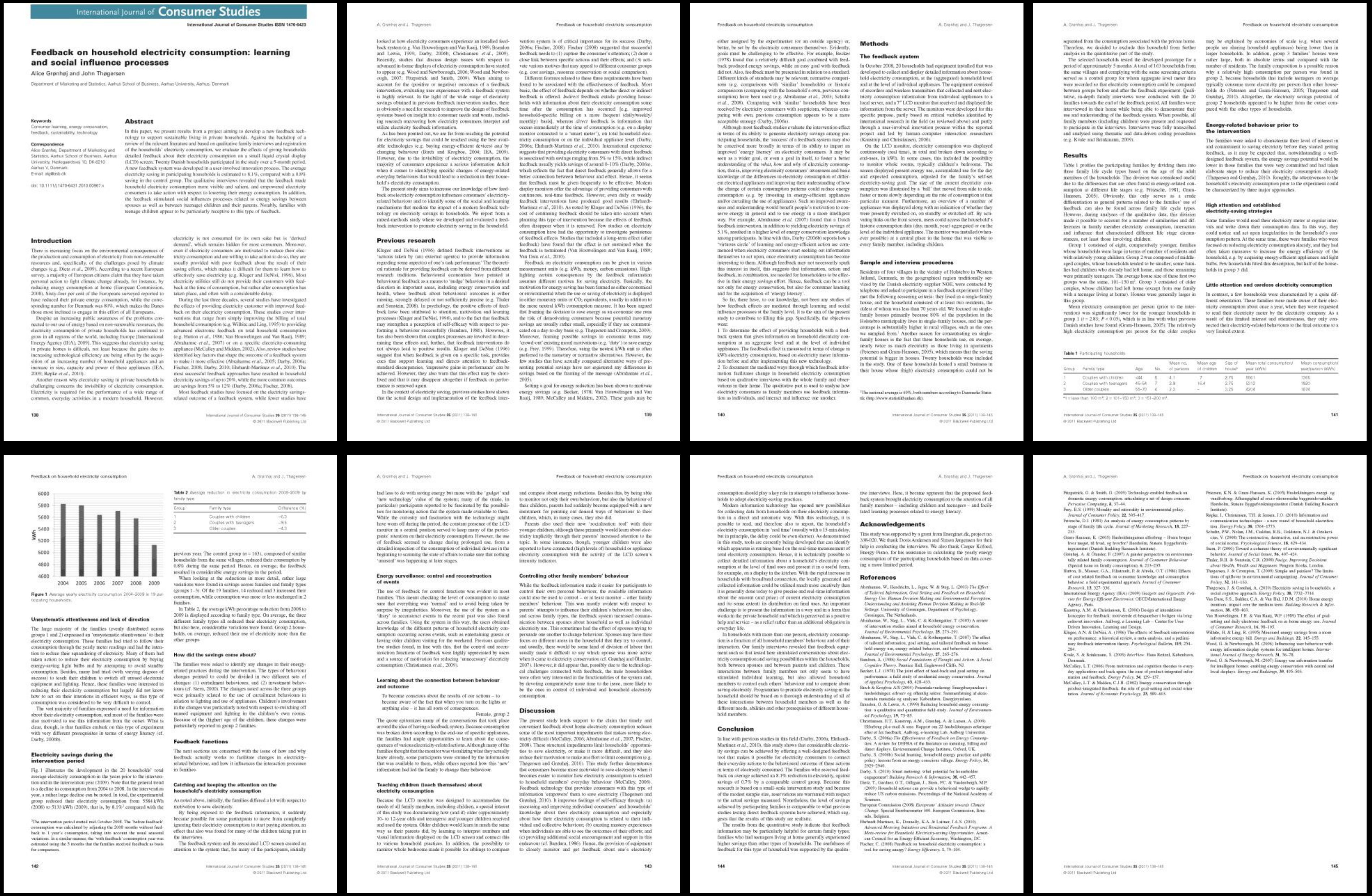
Brandon *et al.*, **Reducing Household Energy Consumption: A Qualitative & Quantitative Field Study**, *Environmental Psychology 1999*



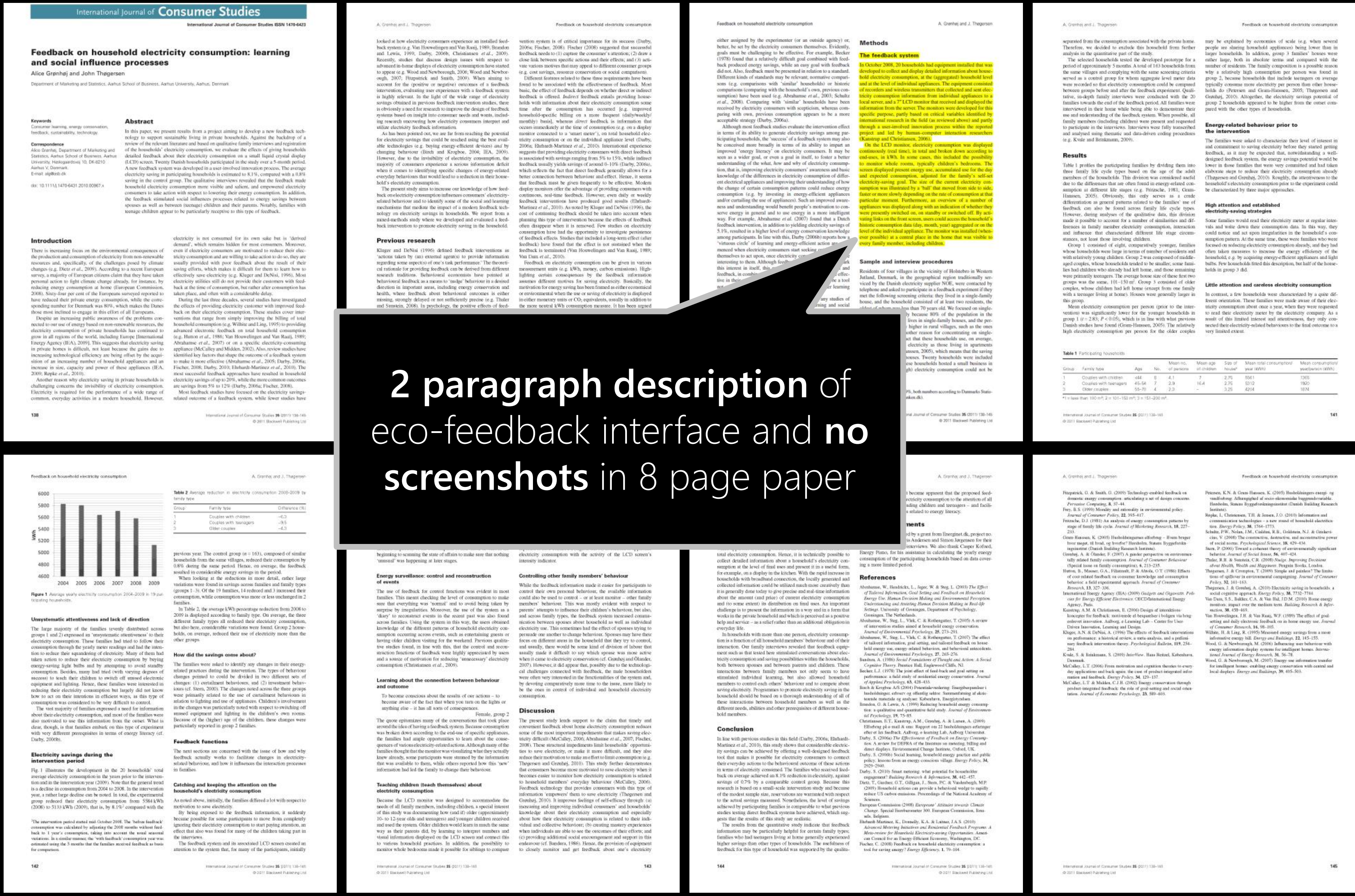
Brandon *et al.*, **Reducing Household Energy Consumption: A Qualitative & Quantitative Field Study**, *Environmental Psychology 1999*

Well, but that was **1999**.

Fair enough!

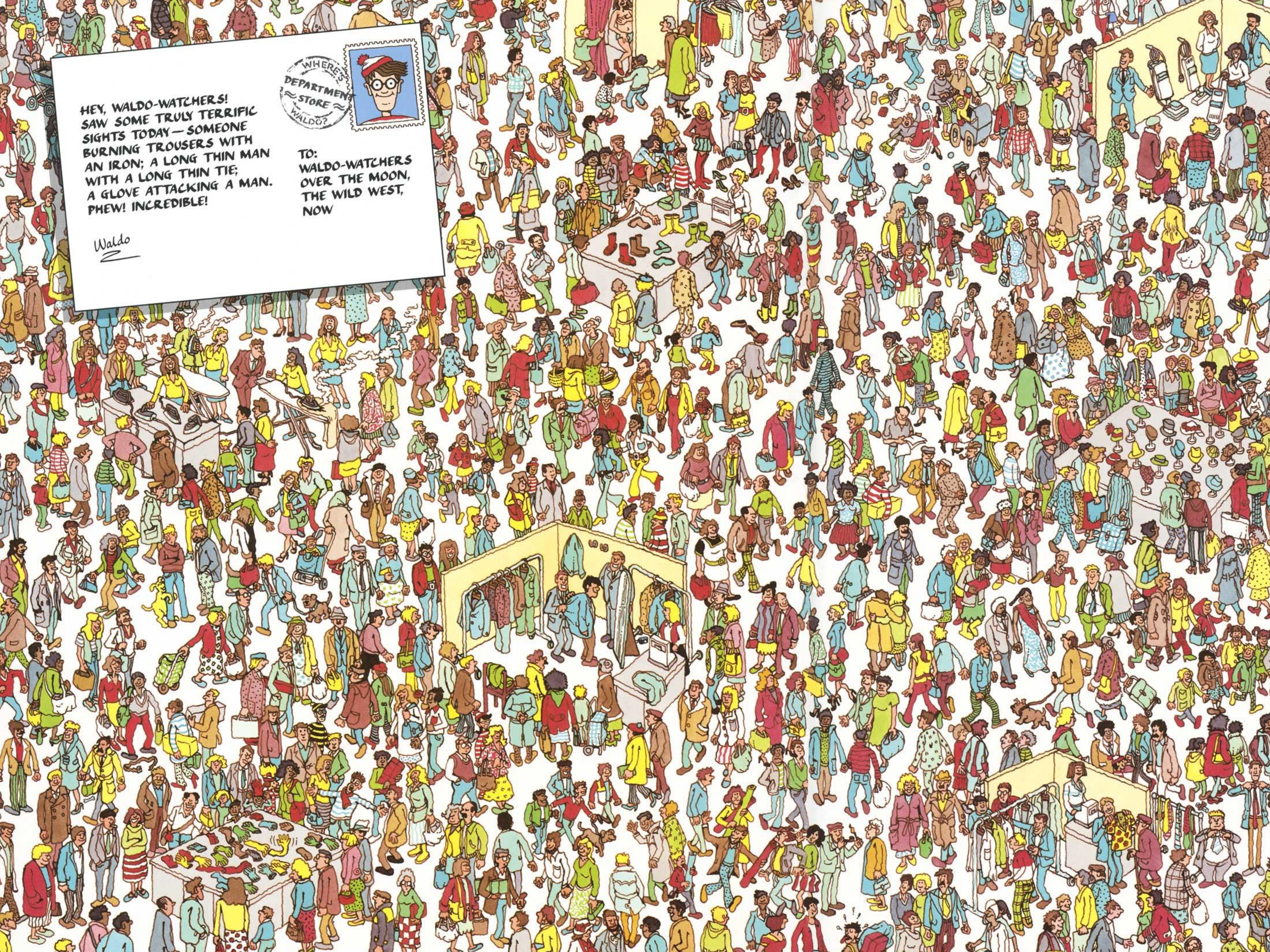


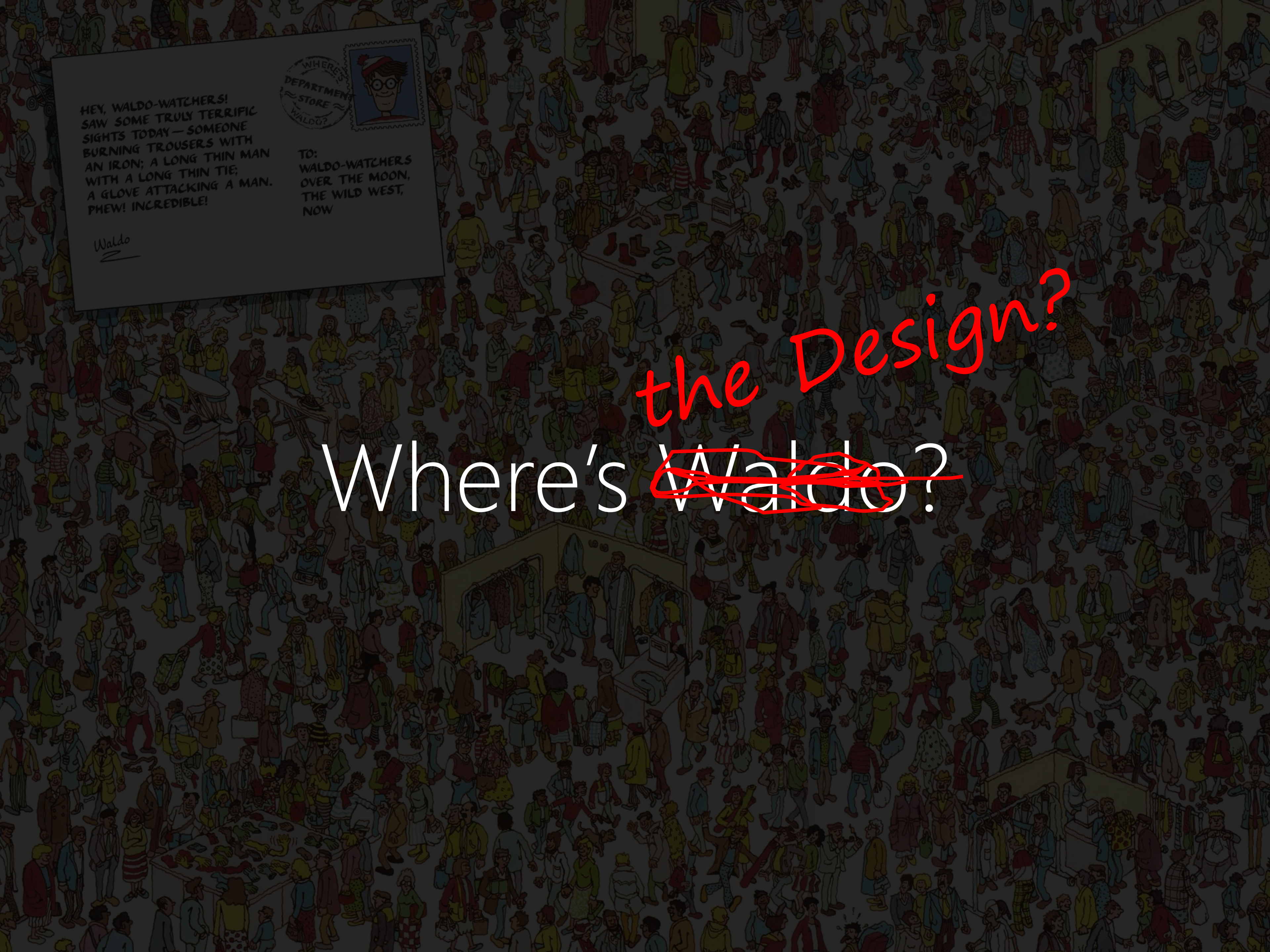
Grønhøj & Thøgersen, **Feedback on Household Electricity Consumption: Learning & Social Influence Processes**, *IJCS2011*



2 paragraph description of eco-feedback interface and **no screenshots** in 8 page paper

Grønhøj & Thøgersen, **Feedback on Household Electricity Consumption: Learning & Social Influence Processes**, *IJCS2011*


HEY, WALDO-WATCHERS!
SAW SOME TRULY TERRIFIC SIGHTS TODAY — SOMEONE BURNING TROUSERS WITH AN IRON; A LONG THIN MAN WITH A LONG THIN TIE; A GLOVE ATTACKING A MAN. PHEW! INCREDIBLE!
Waldo
WHERE'S DEPARTMENT STORE WALDO?
TO:
WALDO-WATCHERS
OVER THE MOON,
THE WILD WEST,
NOW

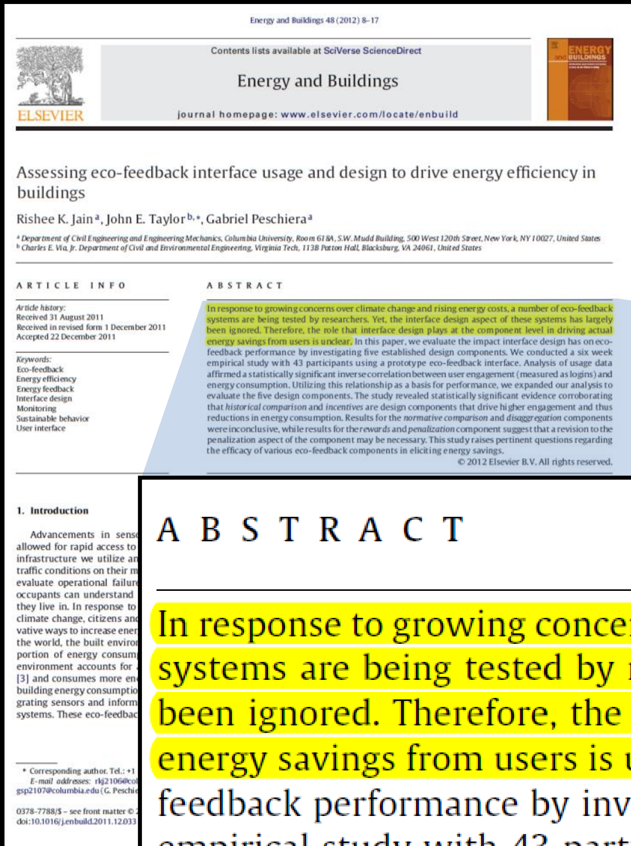

HEY, WALDO-WATCHERS!
SAW SOME TRULY TERRIFIC SIGHTS TODAY—SOMEONE BURNING TROUSERS WITH AN IRON; A LONG THIN MAN WITH A LONG THIN TIE; A GLOVE ATTACKING A MAN. PHEW! INCREDIBLE!
Waldo
WHERE'S DEPARTMENT STORE WALDO?
TO: WALDO-WATCHERS OVER THE MOON, THE WILD WEST, NOW
the Design?
Where's ~~Waldo~~?

So, clearly a **disciplinary divide…**

psychologists
designers
engineers
economists
building scientists
others?

This oversight seems to reflect a lack of recognition about the critical role that **particular design choices play in affecting behavior.**

This unduly narrows and curbs potentially rich research directions


Energy and Buildings 48 (2012) 8–17

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Assessing eco-feedback interface usage and design to drive energy efficiency in buildings

Rishee K. Jain[a], John E. Taylor[b,*], Gabriel Peschiera[a]

ARTICLE INFO

Article history:
Received 31 August 2011
Received in revised form 1 December 2011
Accepted 22 December 2011

Keywords:
Eco-feedback
Energy efficiency
Energy feedback
Interface design
Monitoring
Sustainable behavior
User interface

1. Introduction

ABSTRACT

In response to growing concerns over climate change and rising energy costs, a number of eco-feedback systems are being tested by researchers. Yet, the interface design aspect of these systems has largely been ignored. Therefore, the role that interface design plays at the component level in driving actual energy savings from users is unclear. In this paper, we evaluate the impact interface design has on eco-feedback performance by investigating five established design components. We conducted a six week empirical study with 43 participants using a prototype eco-feedback interface. Analysis of usage data affirmed a statistically significant inverse correlation between user engagement (measured as logins) and energy consumption. Utilizing this relationship as a basis for performance, we expanded our analysis to evaluate the five design components. The study revealed statistically significant evidence corroborating that *historical comparison* and *incentives* are design components that drive higher engagement and thus reductions in energy consumption. Results for the *normative comparison* and *disaggregation* components were inconclusive, while results for the *rewards* and *penalization* component suggest that a revision to the penalization aspect of the component may be necessary. This study raises pertinent questions regarding the efficacy of various eco-feedback components in eliciting energy savings.

Jain *et al.*, **Assessing Eco-Feedback Interface Usage and Design to Drive Energy Efficiency in Buildings**, *Energy and Buildings 2012*

This is a big problem

Perhaps because of the design de-emphasis, **very few papers discuss the design process** that led to the ultimate design artifact that was created and studied

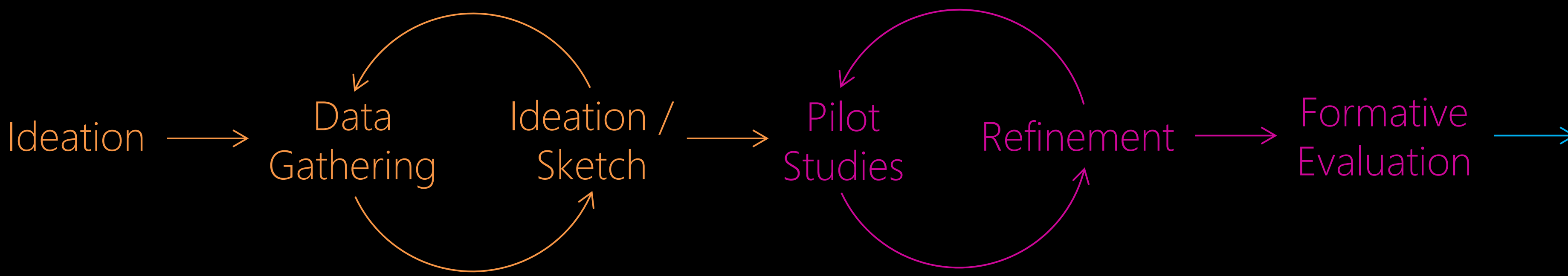
Placing a focus on the **design process** will allow for reusable methodology and more principled approaches to the practice of design—the "science of design"

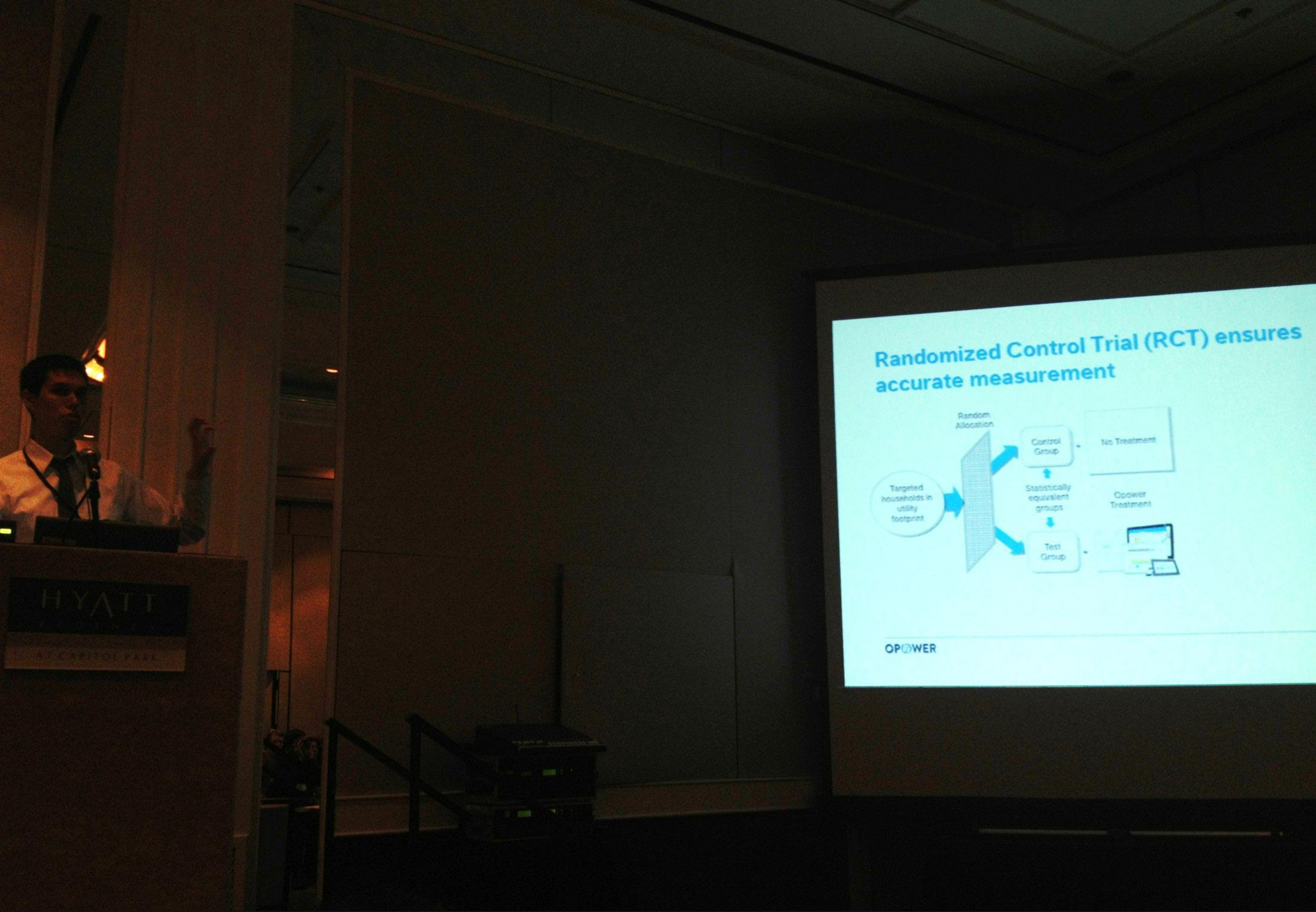
Overarching Question

How can we structure and support the design process to create and identify the most promising (and potentially most influential) aspects of an eco-feedback design robustly and in a cost-efficient manner?

In particular, before expending time, effort, and money on a randomized control trial (RCT)

An **Eco-Feedback** Iterative Design



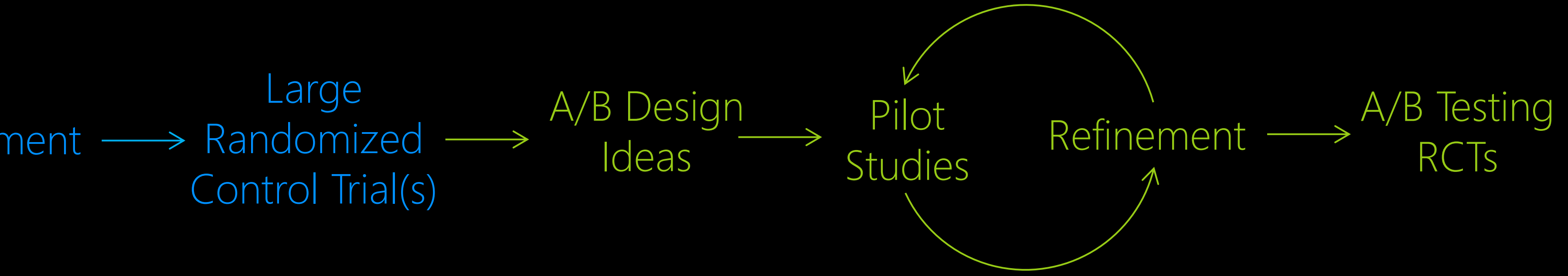


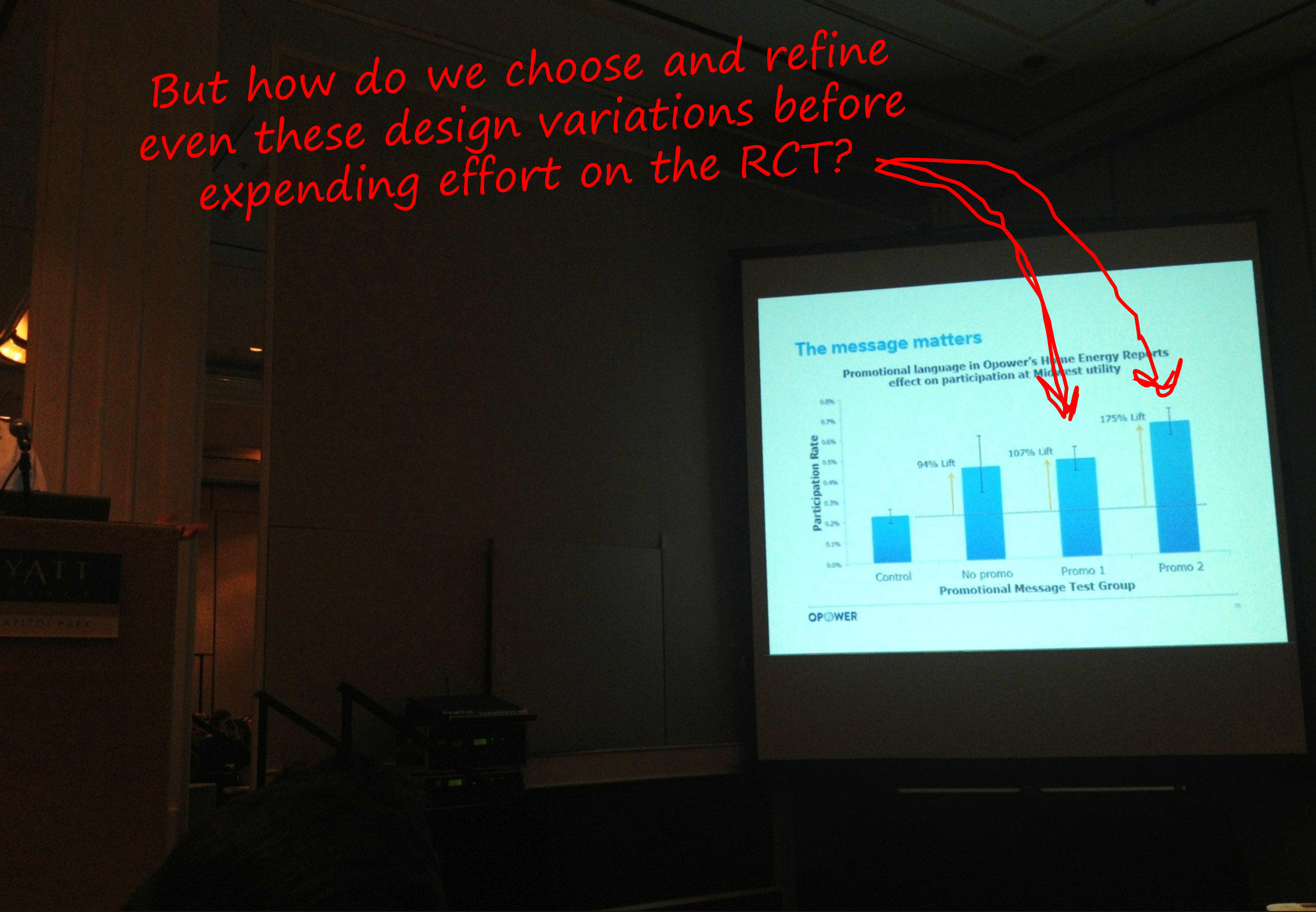
Gunel, A. **The Halo Effect: Using Behavior to Upgrade Technology,** *BECC2012*

Design Process

→ Formative Evaluation → Refinement → Small Field Deployment(s) ⟲ Refinement → Large Randomized Control Trial(s) → A/B

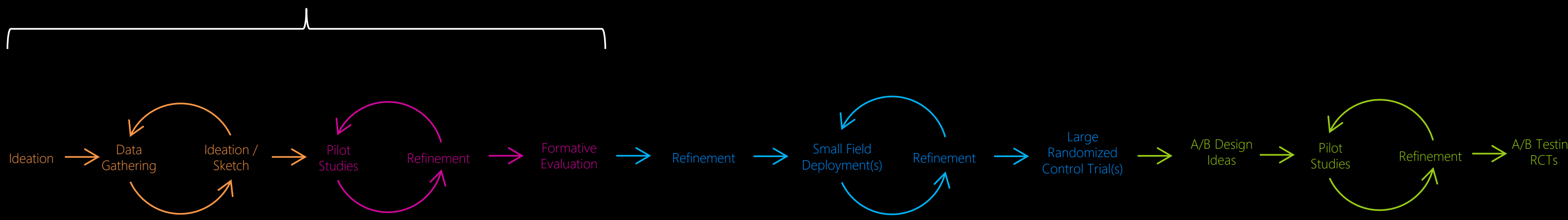
A/B Testing is Ultimate Playground



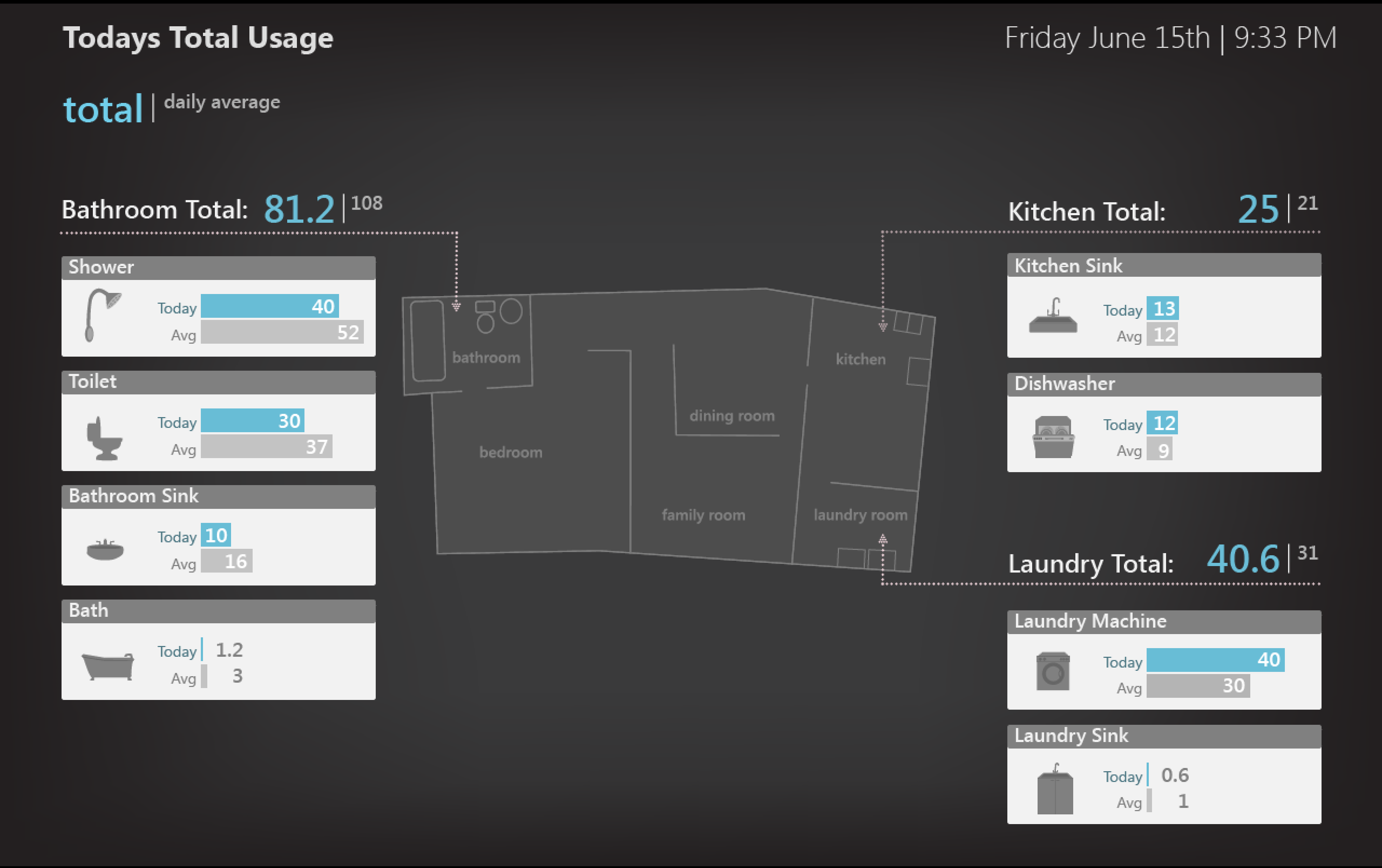


Gunel, A. **The Halo Effect: Using Behavior to Upgrade Technology**,*BECC2012*

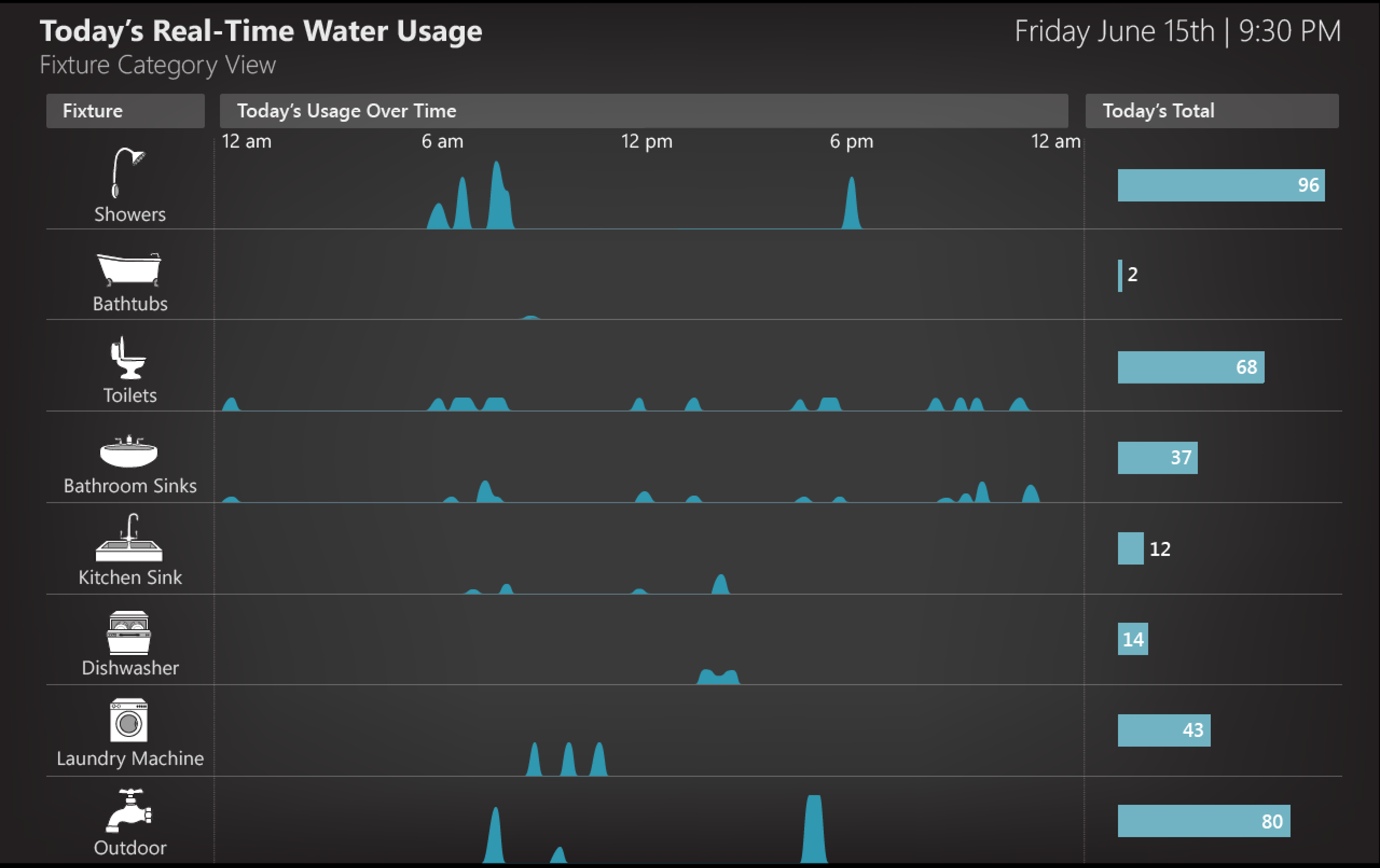
Evaluating early design ideas to prepare for field deployments

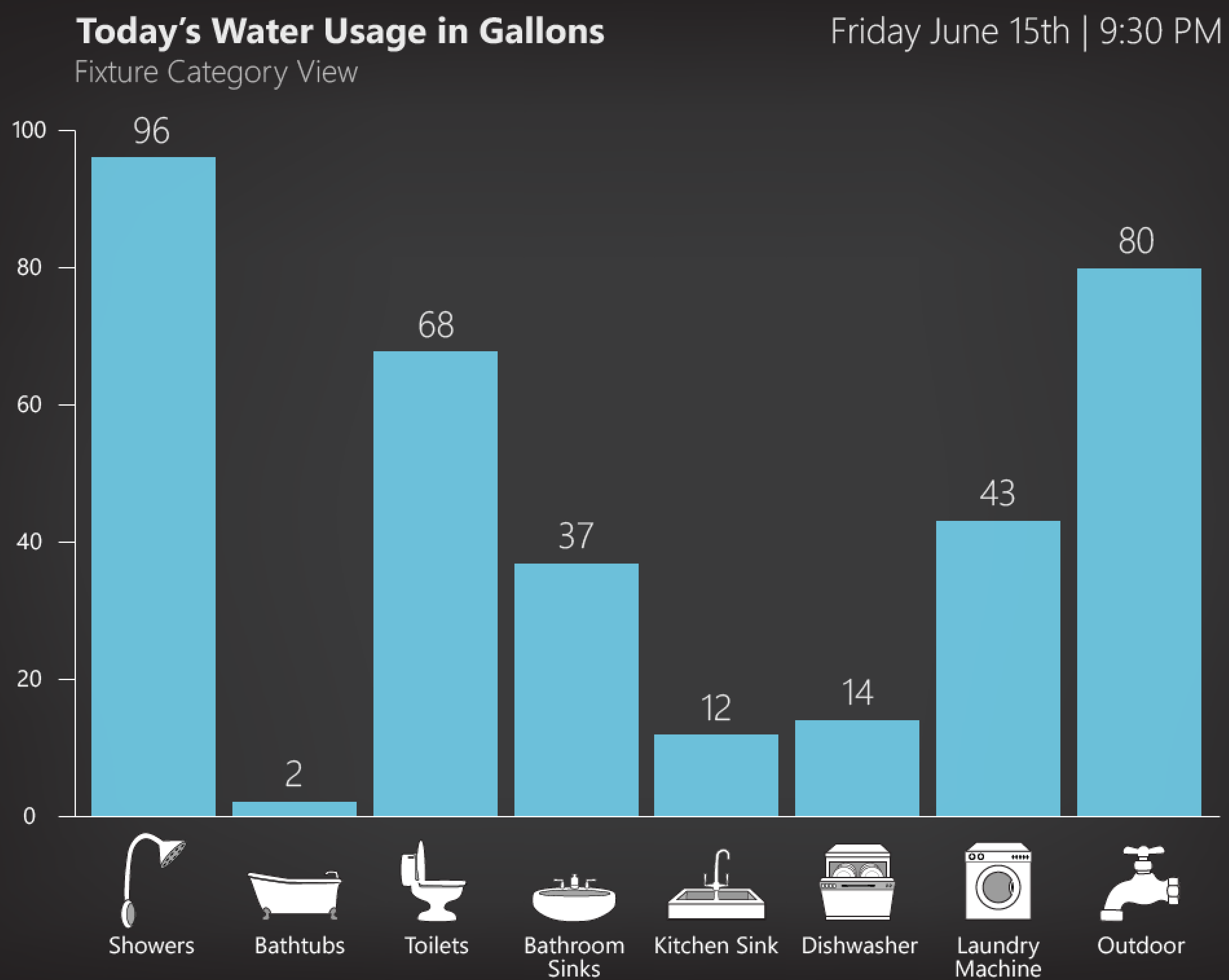


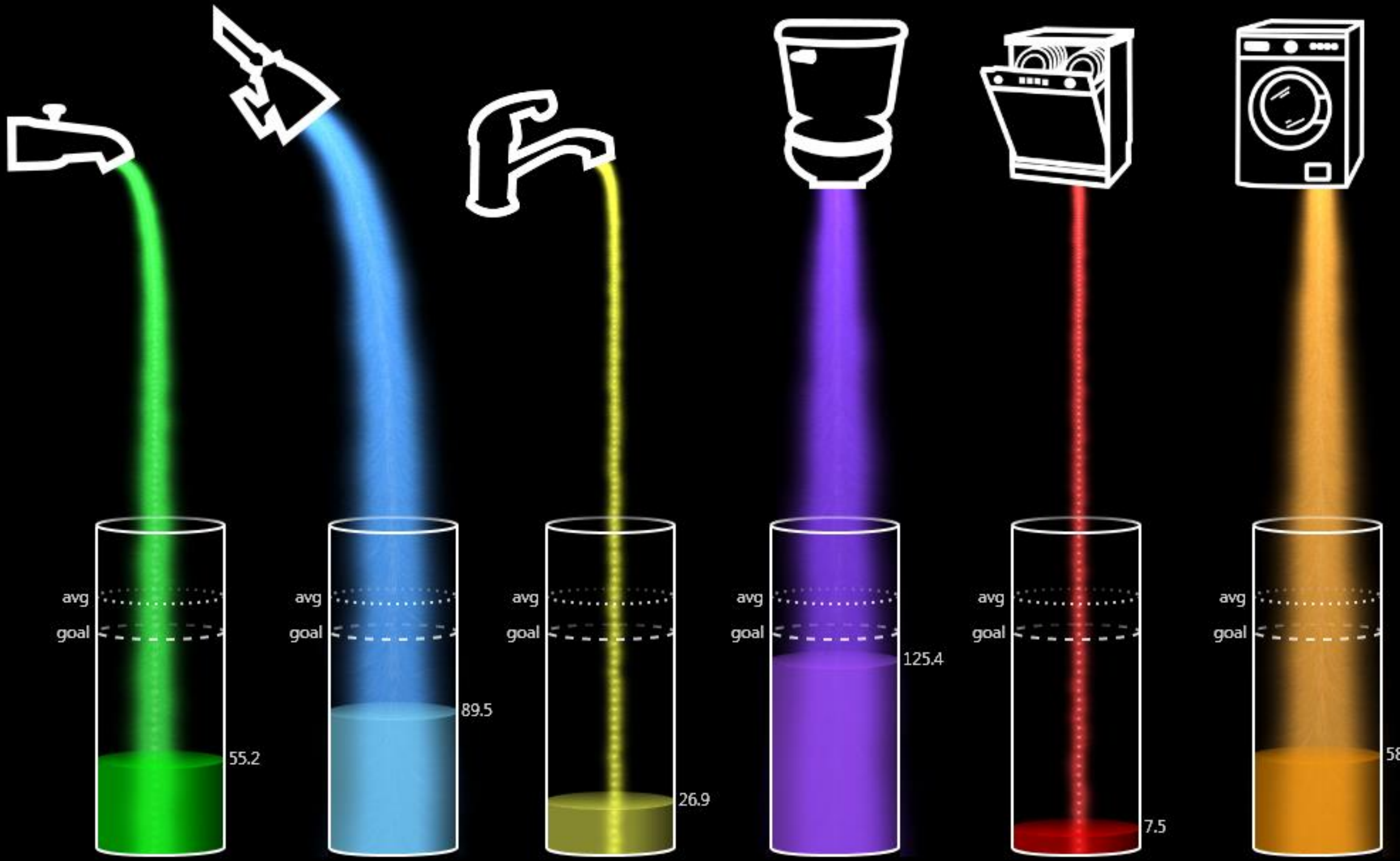
Froehlich *et al.*, **The Design & Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data**, *CHI2012*



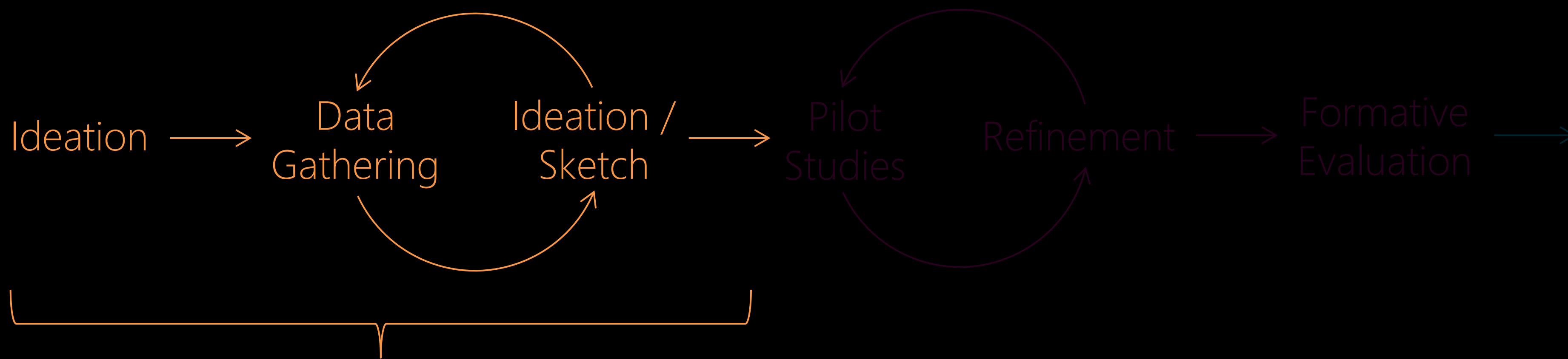
Todays Total Usage
Friday June 15th | 9:33 PM
total | daily average
Bathroom Total: 81.2 | 108
Shower
Today 40
Avg 52
Toilet
Today 30
Avg 37
Bathroom Sink
Today 10
Avg 16
Bath
Today 1.2
Avg 3
bathroom
bedroom
dining room
family room
kitchen
laundry room
Kitchen Total: 25 | 21
Kitchen Sink
Today 13
Avg 12
Dishwasher
Today 12
Avg 9
Laundry Total: 40.6 | 31
Laundry Machine
Today 40
Avg 30
Laundry Sink
Today 0.6
Avg 1


Today's Real-Time Water Usage
Fixture Category View
Friday June 15th | 9:30 PM
Fixture
Today's Usage Over Time
Today's Total
12 am
6 am
12 pm
6 pm
12 am
Showers
96
Bathtubs
2
Toilets
68
Bathroom Sinks
37
Kitchen Sink
12
Dishwasher
14
Laundry Machine
43
Outdoor
80


Today's Water Usage in Gallons
Fixture Category View
Friday June 15th | 9:30 PM
100
80
60
40
20
0
96
2
68
37
12
14
43
80
Showers
Bathtubs
Toilets
Bathroom Sinks
Kitchen Sink
Dishwasher
Laundry Machine
Outdoor


avg
goal
55.2
avg
goal
89.5
avg
goal
26.9
avg
goal
125.4
avg
goal
7.5
avg
goal
58.

An **Eco-Feedback** Iterative Design Process

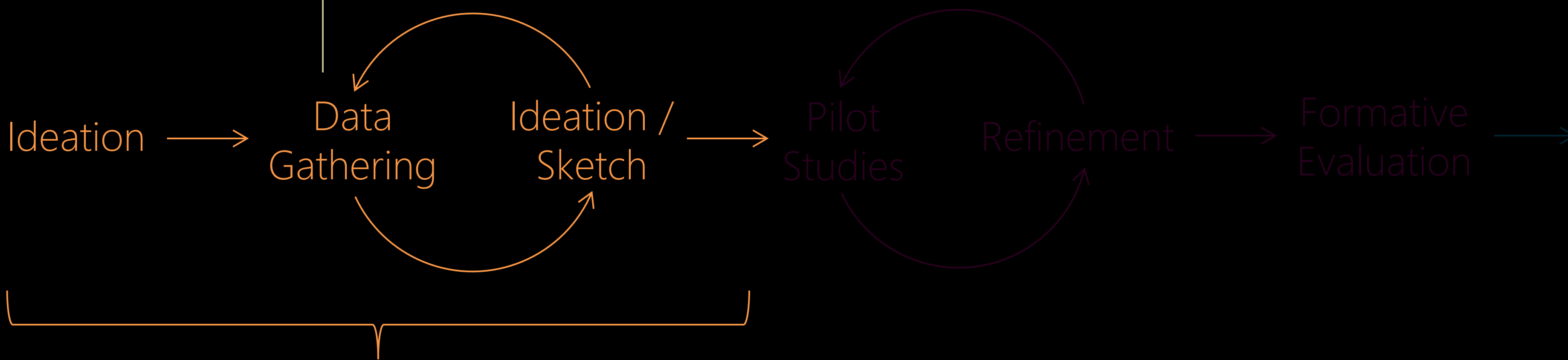


Goal: gather formative data and use as basis to create a set of early, promising designs

Inquiry Methods: ethnography, interviews, surveys, literature reviews

An **Eco-Feedback** Iterative Design Process

Informal interviews with water experts (e.g., SPU, Amy Vickers)
Literature review of water resource management, environmental psychology
Our own online survey of water usage attitudes & knowledge (N=656 respondents)



Goal: gather formative data and use as basis to create a set of early, promising designs

Inquiry Methods: ethnography, interviews, surveys, literature reviews

Respondents (N=651) dramatically **underestimated** the amount of water used in common everyday activities.

	underestimate
toilet :	by 15%
shower :	by 30%
bath :	by 55%
low-flow shower :	by 60%
outdoor yard watering :	by 83% to 95%

[Froehlich, UW PhD Dissertation, 2011]

Challenge: how can we use gathered data to inform our designs?

Eco-Feedback Design Space

Information Access

- **update frequency**: real-time — monthly or less — user poll
- **spatial proximity to behavior**: co-located — remote
- **attentional demand**: glanceable — high attention
- **effort to access**: low — high

Interactivity

- **degree of interactivity**: none — high
- **interface customizability**: none — high
- **user additions**: user annotations — user corrections

Display Medium

- **manifestation**: webpage — mobile phone app — wearable interface — custom display — in-home display
- **ambience**: not-ambient — ambient
- **size**: small — large

Actionability/Utility

- **degree of actionability**: low — high
- **decision support**: suggests actions — suggests purchase decisions — anomaly alerts
- **personal-ization**: no personalization — highly personalized
- **information intent**: Informs one action — informs many actions
- **automation/ control**: no control — system controls resource use

Data Representation

- **aesthetic**: pragmatic — artistic
- **time window**: <hour — >year
- **temporal grouping**: ≤sec — by hour — by day — by week — by month — ≥year
- **data granularity**: coarse-grain — fine-grain
- **visual complexity**: simple — complex
- **primary visual encoding**: textual — graphical
- **measurement unit**: resource — cost — environmental impact — activity — time — metaphor
- **primary view**: temporal — spatial — categorical
- **data grouping**: by resource — by person — by time — by space — by activity — by consumption category

Motivational/Persuasive Strategies

persuasive tactics from psychology and applied social psychology disciplines:

- persuasive design
- persuasive technology
- behavioral science/economics
- environmental psychology
- game design
- social marketing
- health behavior change

persuasive tactics include:

rewards	goal-setting
punishment	narrative
public commitment	likeability
written commitment	reputation
loss aversion	competition
kairos	social proof
encouragement	authority
descriptive norms	emotional appeals
scarcity principle	door-in-face
framing	unlock features
anchoring bias	endowment effect
defaults	collection building

Comparison

- **comparison target**: self — social — goal
- **comparison by time**: past — projected
- **social-comp. target**: geographically proximal — demographically similar — selected social network
- **goal-setting strategy**: self-set — system-set — externally-set
- **difficulty to reach comparison target**: easy — hard

comparison variables
- ☐ time window
- ☐ time granularity
- ☐ data grouping
- ☐ data granularity
- ☐ measurement unit

statistic
- ○ raw value
- ○ average
- ○ median
- ○ mode
- ○ other

computation
- @ this time [yest, last wk, mo, yr]
- [hrly, daily, wkly, monthly, yrly]
- over past [X] days
- this day type [weekday, weekend]
- this day of week (e.g., mondays)

Social Aspects

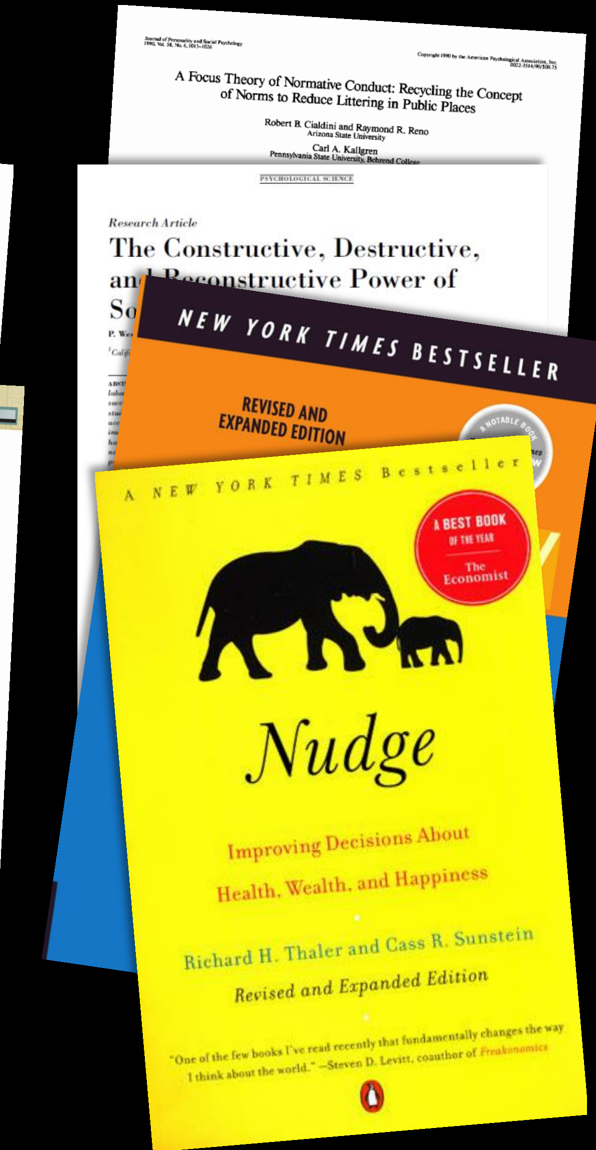
- **target**: person — household — community — state — country
- **private/ public**: private — public
- **data sharing**: none — everyone
- **social-comparison**: available — (see Comparison) — unavailable

[Froehlich et al., HCIC2009; CHI2010; UW PhD Dissertation 2011]

My own experiences

Existing frameworks

(*e.g.*, persuasive tech, health informatics, other eco-feedback work, and infovis)



Psychology

(*e.g.*, environmental psychology, social psychology, behavioral economics)

INPUTS (SENSING)

- automated ~~vs~~ vs self-report
- Data granularity
- user annotations
- user corrections
-

how do these things fit into design space?

When I talk about the prius I talk about
- immediate
- simple
- educates
- constrained environment
- reason to care
- informs only one action

MODELS

what motivates us?

- Explicit encoding of behavior change theories
- Personalization
  - ↳ does system adapt to person based on sensed data or demographics
- Designer's agenda? ← to inform, to teach to change behavior
- Does person have reason to care

SOCIAL ASPECTS

- Design for person vs. design for household
- Social sharing of information over internet
- public or private display
- comparison to others ★
-

some overlap

INFORMATION ACCESS

independent — attached

- Update frequency
- push/pull
- Degree of interactivity
- Spatial proximity to behavior
- Approachability or learnability
  - ↳ how easy is interface to immediately understand

maybe this goes in data representation?

- Attentional Need
  - glanceability
- ambient vs. non-ambient
- availability (highly available) ← effort to access

DATA REPRESENTATION

- views of data - historical view, by day, by room or fixture
- Grouping / Clustering by time of day or by room or by fixture
- visual encoding of sensed data
  - ↳ textual, chart, iconic, abstract
- simple ⟷ complex
- Scale
- value type: relative/absolute
- aesthetic
  - ↑ Kosara, presents spectrum of aesthetic

some overlap

some overlap

★ COMPARISON

- comparison to self
- comparison to others
- comparison to projected self
- comparison to a goal

MEDIUM

- display medium: screen, orb, mobile, desktop, watch
- ambient vs. non-ambient (maybe this goes in Information Access)
- display size

Actionability

also, related is "utility" how much utility does user gain from tool

- degree of actionability
- maybe this is called perceptual affordance?
  - ↑ the thing I talked about @ BECC 2010
- Decision support

maybe call this: motivational strategies? or behavioral science toolbox

comparison might actually fit in here

PERSUASIVE TOOLBOX

- Projected future
  - ↳ project a trend to foreshadow where they will end up
- loss aversion
- progress
- goal-setting
- see word doc for more
- anticipation
- negative vs. positive feedback

- where would customizability go?
- What about perceived levels of trust?
- unintended positive reinforcement w/ visualizations
- role of information vs. role of persuasion

★ could also have group called Comparison & have comparison to others & comparison to self

★★ might have a few more specific things for home resource consumption feedback like "fits fit into the home"


information
agenda
inputs
(models +
theories)
personalization
persuasive
toolbox.
ambient
vs non ambient
medium
medium
data
representation
social
aspects

inputs (sensing)
support for user annotations
support for user corrections
social aspects
data representation
visual encoding
information agenda
inputs (modeled theories)
medium
medium
update frequency
push/pull
user effort
location
persuasive tactics

Eco-Feedback Design Space

Information Access

- **update frequency**: real-time — monthly or less — user poll
- **spatial proximity to behavior**: co-located — remote
- **attentional demand**: glanceable — high attention
- **effort to access**: low — high

Interactivity

- **degree of interactivity**: none — high
- **interface customizability**: none — high
- **user additions**: user annotations — user corrections

Display Medium

- **manifestation**: webpage — mobile phone app — wearable interface — custom display — in-home display
- **ambience**: not-ambient — ambient
- **size**: small — large

Actionability/Utility

- **degree of actionability**: low — high
- **decision support**: suggests actions — suggests purchase decisions — anomaly alerts
- **personal-ization**: no personalization — highly personalized
- **information intent**: Informs one action — informs many actions
- **automation/ control**: no control — system controls resource use

Data Representation

- **aesthetic**: pragmatic — artistic
- **time window**: <hour — >year
- **temporal grouping**: ≤sec — by hour — by day — by week — by month — ≥year
- **data granularity**: coarse-grain — fine-grain
- **visual complexity**: simple — complex
- **primary visual encoding**: textual — graphical
- **measurement unit**: resource — cost — environmental impact — activity — time — metaphor
- **primary view**: temporal — spatial — categorical
- **data grouping**: by resource — by person — by time — by space — by activity — by consumption category

Motivational/Persuasive Strategies

persuasive tactics from psychology and applied social psychology disciplines:

- persuasive design
- persuasive technology
- behavioral science/economics
- environmental psychology
- game design
- social marketing
- health behavior change

persuasive tactics include:

rewards	goal-setting
punishment	narrative
public commitment	likeability
written commitment	reputation
loss aversion	competition
kairos	social proof
encouragement	authority
descriptive norms	emotional appeals
scarcity principle	door-in-face
framing	unlock features
anchoring bias	endowment effect
defaults	collection building

Comparison

- **comparison target**: self — social — goal
- **comparison by time**: past — projected
- **social-comp. target**: geographically proximal — demographically similar — selected social network
- **goal-setting strategy**: self-set — system-set — externally-set
- **difficulty to reach comparison target**: easy — hard

comparison variables
- ☐ time window
- ☐ time granularity
- ☐ data grouping
- ☐ data granularity
- ☐ measurement unit

statistic
- ○ raw value
- ○ average
- ○ median
- ○ mode
- ○ other

computation
- @ this time [yest, last wk, mo, yr]
- [hrly, daily, wkly, monthly, yrly]
- over past [X] days
- this day type [weekday, weekend]
- this day of week (e.g., mondays)

Social Aspects

- **target**: person — household — community — state — country
- **private/ public**: private — public
- **data sharing**: none — everyone
- **social-comparison**: available — (see Comparison) — unavailable

[Froehlich et al., HCIC2009; CHI2010; UW PhD Dissertation 2011]


data representation
information access
inputs
display medium
the eco-feedback design space
behavioral models
comparison
social
actionability
motivational strategies

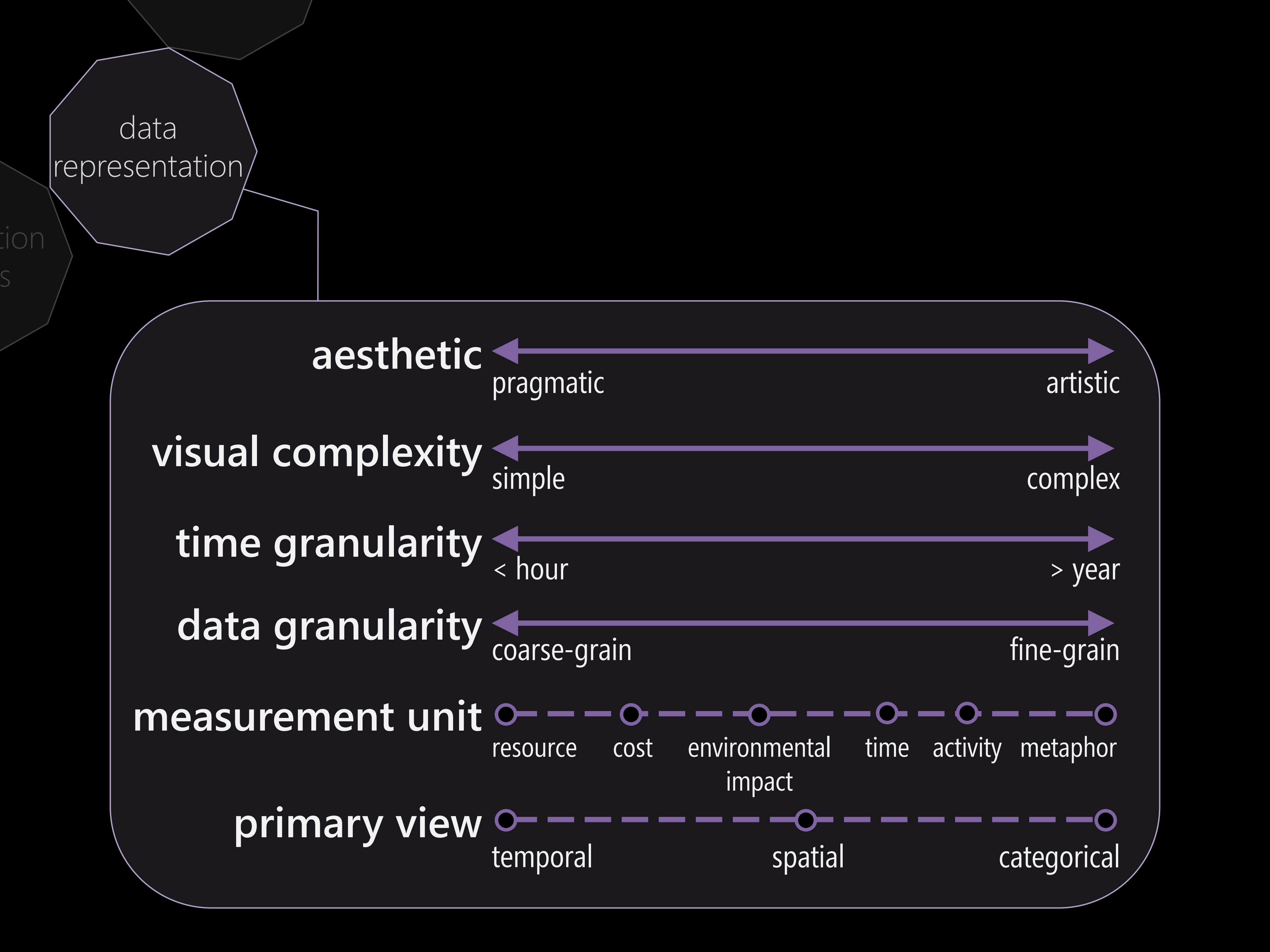
the eco-feedback design space
data representation
information access
display medium
comparison
actionability
motivational strategies
social
behavioral models
inputs

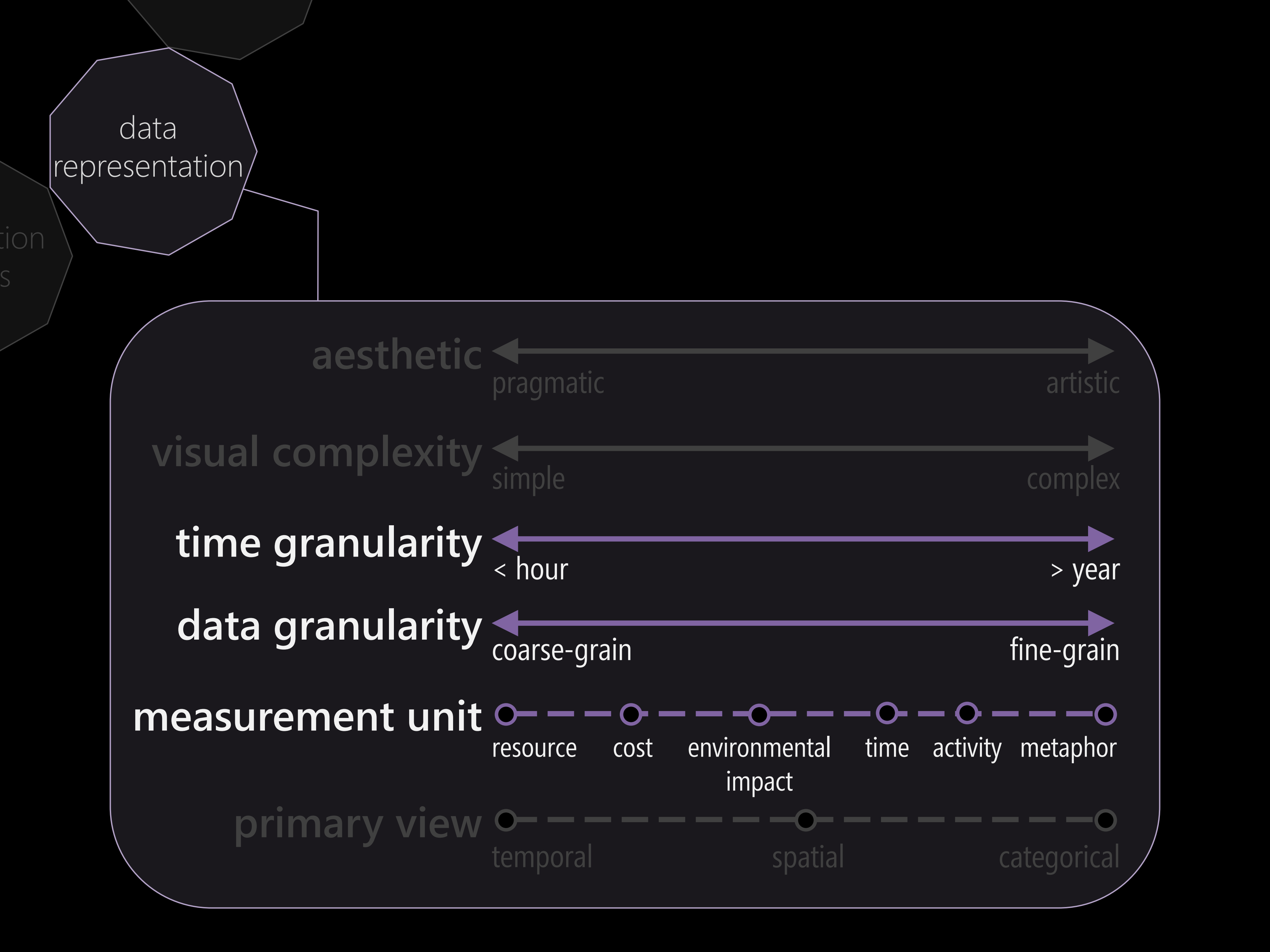

data representation
information access
display medium
inputs
the eco-feedback design space
behavioral models
comparison
social
actionability
motivational strategies


data representation
information access
inputs
display medium
the
eco-feedback
design space
behavioral models
comparison
social
actionability
motivational strategies


data
representation
information
access
inputs
display
medium
the
eco-feedback
design space
behavioral
models
comparison
social
actionability
motivational
strategies


data representation
information access
display medium
comparison
actionability
motivational strategies
social
behavioral models
inputs
the eco-feedback design space

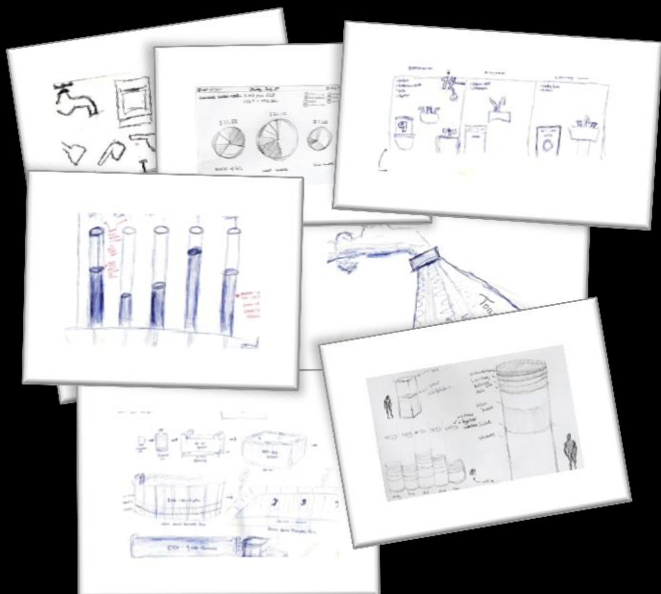

data representation
tion
s
aesthetic
pragmatic
artistic
visual complexity
simple
complex
time granularity
< hour
> year
data granularity
coarse-grain
fine-grain
measurement unit
resource
cost
environmental impact
time
activity
metaphor
primary view
temporal
spatial
categorical



data representation
tion
s
aesthetic
pragmatic
artistic
visual complexity
simple
complex
time granularity
< hour
> year
data granularity
coarse-grain
fine-grain
measurement unit
resource
cost
environmental impact
time
activity
metaphor
primary view
temporal
spatial
categorical

Data Granularity

Prototype and Evaluate Across a Fidelity Spectrum

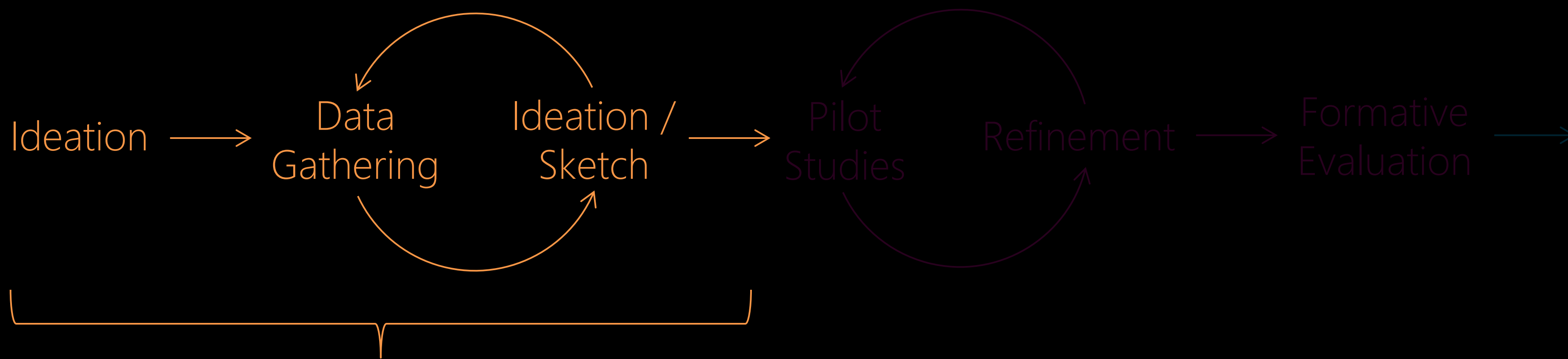


Sketch

Lo-to-Mid Fidelity Mockup

Higher Fidelity Mockup

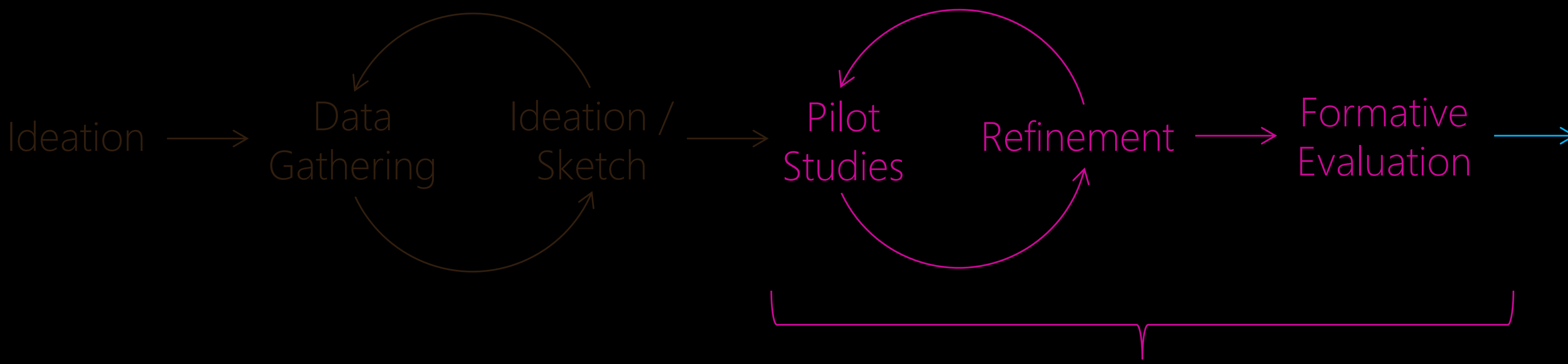
An **Eco-Feedback** Iterative Design Process



Goal: gather formative data and use as basis to create a set of early, promising designs

Inquiry Methods: ethnography, interviews, surveys, literature reviews

An **Eco-Feedback** Iterative Design Process



Goal: test early design ideas, improve promising ideas, improve usability / aesthetic

Evaluation Methods: online interactive surveys, design probe-based interviews, lab studies

Challenge: the ultimate goal is to create a design that informs and, possibly, motivates behavior. The former is easier to evaluate with these methods than the latter.

Online Survey

Water Feedback Evaluation Survey

Consent Form

0%

Hi, my name is Jon Froehlich and I'm a graduate student at the University of Washington. The survey you are about to take is for my PhD dissertation on water usage information systems. Your responses will help inform the design of future water conservation programs.

I appreciate you taking the time to fill out this survey,

Jon E. Froehlich
PhD Candidate
University of Washington

RESEARCHERS' STATEMENT
We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear by emailing jfroehli@uw.edu. After reading this form, you can decide if you want to be in the study or not. This process is called "informed consent." You can print a copy of this form for your records.

PURPOSE OF THE STUDY
We are studying how computer displays (interfaces) can help inform people about their energy, water, and gas usage in the home.

STUDY PROCEDURES
To participate in this study, you simply need to fill out the forthcoming online survey. Please try to answer each question carefully and honestly. The survey should take between 20-35 minutes to complete. At the end of the survey, we will ask you for your email address. You do not need to provide this information. Those respondents that do supply their email addresses will be entered in a raffle to win a **$100 gift certificate** to Amazon.com. We will not use your email for any other purpose or give out you email address to anyone for any reason.

amazon.com $100

RISKS, STRESS, OR DISCOMFORT
We do not expect any risks, stresses, or discomforts as a result of this research.

BENEFITS OF THE STUDY
Although you may not directly benefit from this study, we hope that the findings of this study will help to develop new technology that will help the environment.

OTHER INFORMATION
Taking part in this study is voluntary. You can stop filling out the survey at any time. Information about you is anonymous. The information you provide is not linked to your name.

SUBJECT'S STATEMENT
This study has been explained to me. I volunteer to take part in this research. If I have questions later about the research, I can email one of the researchers listed above. If I have questions about my rights as a research subject, I can call the University of Washington Human Subjects Division at (206) 543-0098.

The survey should take between **20-35 minutes** to fill out. If you would like to go back to a previous page once you start the survey, please **do not hit the "back" button on your browser**. Instead, use the "back" button located at the bottom of each survey page.

By clicking 'Yes' below, you consent to take part in this study. *

Yes

Recruitment

- Online postings and word-of-mouth

Survey Design

- 63 questions (10 optional)
- Question and answer order randomized when possible

Collected Data

- 712 completed surveys (651 from US or Canada)
- Nearly 6,000 qualitative responses

Water Feedback Evaluation Survey

Introduction

6%

Most people receive information on their water usage from a monthly or bi-monthly bill. We are working on a new type of system that can **immediately show people how much water they are using** at each fixture in their home. This information could be viewed, for example, on a mobile phone, on a laptop, a digital picture frame, or on an in-home touchscreen display.

In this survey, we'll explore different ways of visually displaying water usage information. Unless otherwise noted, each design is based on an average North American household of four people with two adults and two teenagers.

First, though, we need to ask some demographic questions.

Back Next

6%

Water Feedback Evaluation ×

edu.surveygizmo.com/s3/632637/CHI2012-WaterFeedbackSurveyDemo

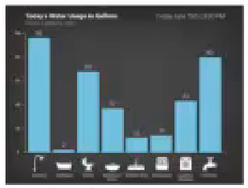
Water Feedback Evaluation Survey

Hot and Cold Breakdown

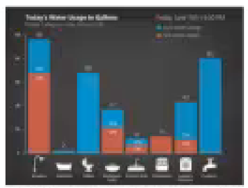
44%

We are also interested in whether people want **information on hot water usage vs. cold water usage**. Display (a) treats all water usage the same (whether hot or cold), while display (b) breaks down water usage by hot water and cold water amounts.

Like before, please mouse over the thumbnails on the left below to see enlarged versions of the display so that you can easily compare the two designs.



(a) Water usage by *fixture type*.



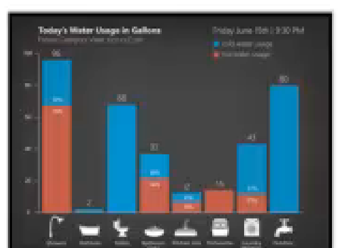
(b) Water usage by fixture type with *hot and cold breakdown*.

Move your mouse cursor over the image thumbnails on the left to see enlarged versions here.

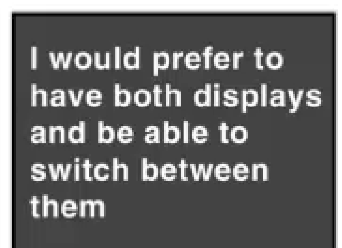
22. Which display do you prefer? *

Click on the image below to make your selection.

Overall water usage by fixture type



Hot and cold water usage for each type of fixture



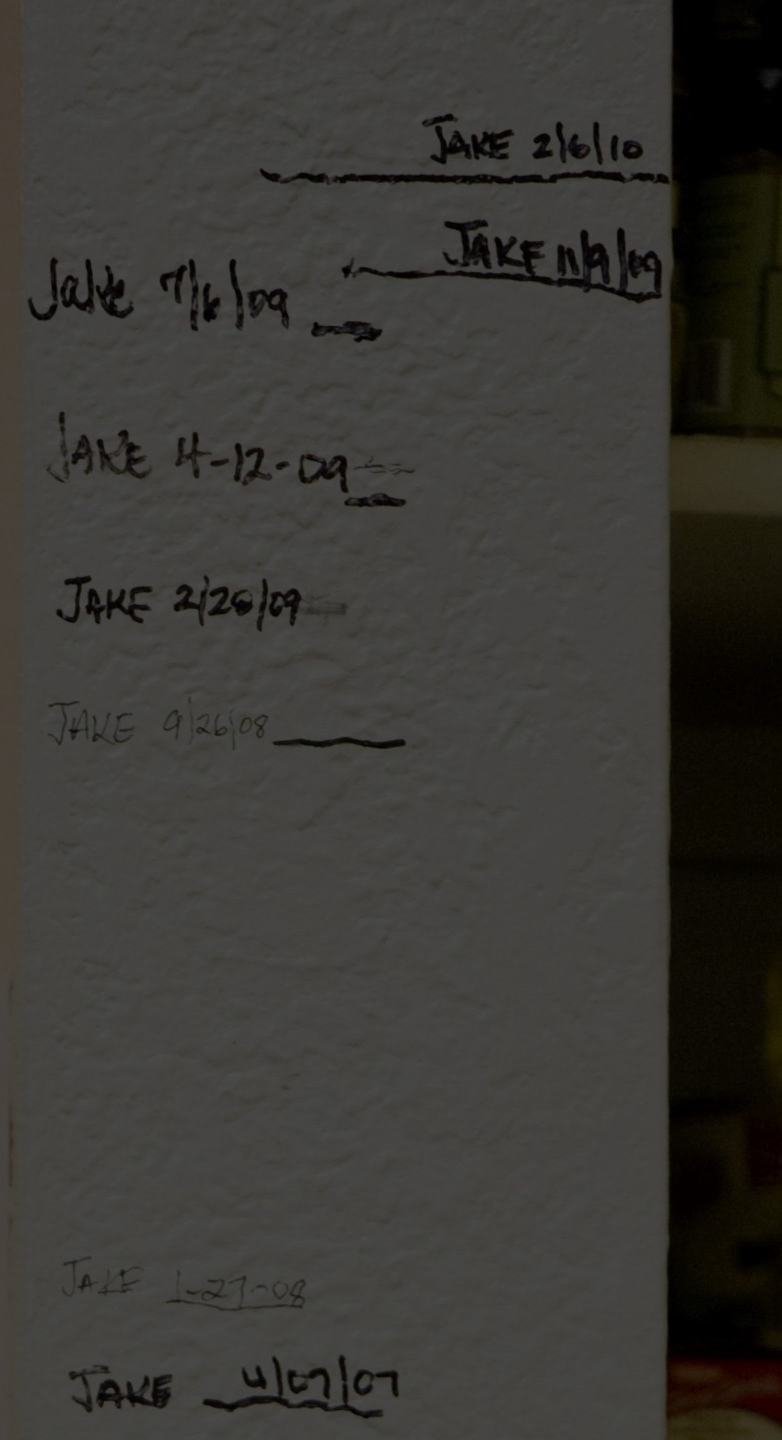
All of the above

Our **online interactive survey** allowed us to study a large N and gather both quantitative and qualitative data


Comparisons were the most uniformly desired pieces of information of all the dimensions

Self-comparison
was most preferred

91%



Our **in-home, design-probe interviews** allowed us to explore how the display was received by families and how (and where) it fit in a domestic setting

In-Home Interviews

Recruitment

- Online postings and word-of-mouth
- Specifically recruited families

Interview Method

- Semi-structured with two researchers
- 90-minutes, 3-phases
- Data coded by two researchers into themes

Participants

- 10 households (20 adults)
- 11 female/9 male
- Diff. socio-economic backgrounds & occupations
- 18 had college degrees

Display Location Preferences

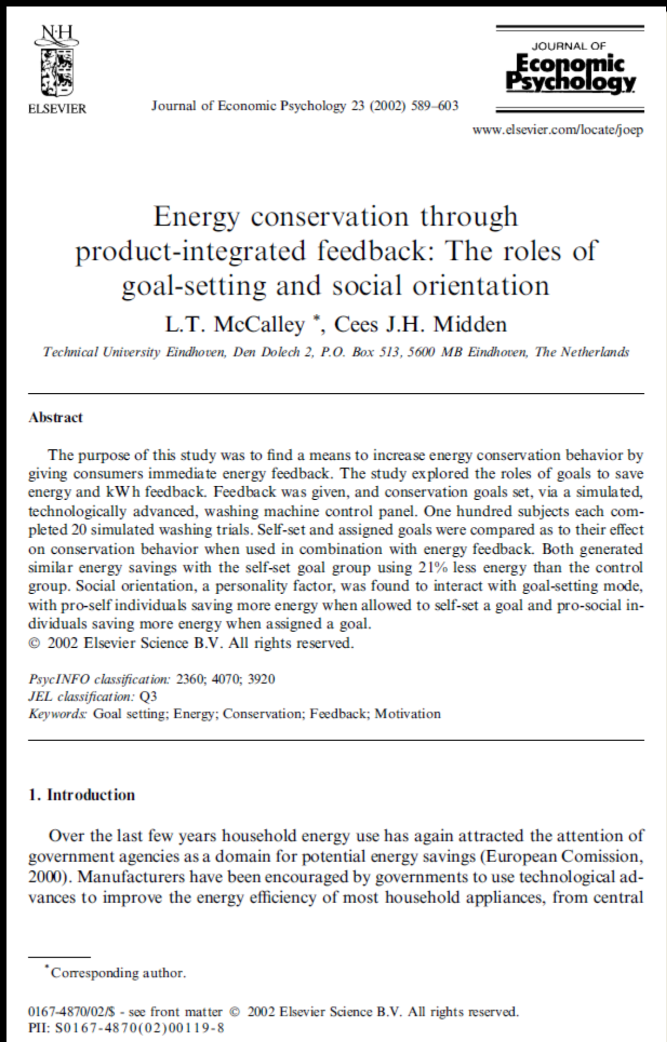
kitchen

near thermostat

high traffic areas

accessible when needed

Behavioral Lab Study



ELSEVIER

Journal of Economic Psychology 23 (2002) 589–603

JOURNAL OF Economic Psychology

www.elsevier.com/locate/joep

Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation

L.T. McCalley *, Cees J.H. Midden

Technical University Eindhoven, Den Dolech 2, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Abstract

The purpose of this study was to find a means to increase energy conservation behavior by giving consumers immediate energy feedback. The study explored the roles of goals to save energy and kWh feedback. Feedback was given, and conservation goals set, via a simulated, technologically advanced, washing machine control panel. One hundred subjects each completed 20 simulated washing trials. Self-set and assigned goals were compared as to their effect on conservation behavior when used in combination with energy feedback. Both generated similar energy savings with the self-set goal group using 21% less energy than the control group. Social orientation, a personality factor, was found to interact with goal-setting mode, with pro-self individuals saving more energy when allowed to self-set a goal and pro-social individuals saving more energy when assigned a goal.

PsycINFO classification: 2360; 4070; 3920
JEL classification: Q3
Keywords: Goal setting; Energy; Conservation; Feedback; Motivation

1. Introduction

Over the last few years household energy use has again attracted the attention of government agencies as a domain for potential energy savings (European Comission, 2000). Manufacturers have been encouraged by governments to use technological advances to improve the energy efficiency of most household appliances, from central

* Corresponding author.

0167-4870/02/$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S0167-4870(02)00119-8

G Model
ENB-3818; No. of Pages 10

ARTICLE IN PRESS

Energy and Buildings xxx (2012) xxx–xxx

ELSEVIER

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

A laboratory test of the efficacy of energy display interface design

Teresa Chiang [a,*], Sukumar Natarajan [a,1], Ian Walker [b,2]

[a] *Department of Architecture and Civil Engineering, University of Bath, Bath BA2 7AY, UK*
[b] *Department of Psychology, University of Bath, Bath BA2 7AY, UK*

ARTICLE INFO

Article history:
Received 17 May 2012
Received in revised form 9 July 2012
Accepted 21 July 2012

Keywords:
In-home displays
Energy use feedback
Display design
Colour
User preferences

ABSTRACT

In-home displays (IHDs) have the potential to change the way energy use feedback is communicated to householders and to induce behavioural change by providing real-time information on energy consumption. How feedback is presented to users and how users understand the meaning of such feedback depends on the design of the display interface. This paper presents a laboratory study to investigate how the user interface of energy displays might be best designed. The work studied people's ability to spot changes in smart meters by comparing three different types of display design to see which was most effective in attracting attention to changing information, and whether the use of colour would also facilitate detecting changes. A computerised spot-the-difference task was undertaken; accuracy rates and response times were the key dependent variables, and qualitative information on participant preferences was gathered in interviews after the computerised task. Results showed that there was a difference between design types presenting the same information: simple numerical displays were superior to pictographic or analogue scale designs in both response time and accuracy. They also showed that the use of colour did not significantly affect performance. In general, participants also subjectively preferred numerical design for their in-home energy displays.

1. Introduction

The UK domestic sector accounts for 30.5% energy use [1] and 17.5% CO_2 emissions in 2010 [2]. The UK government estimates that over 40% of the UK's energy use and CO_2 emissions are caused by individual behaviour [3]. With the progressive tightening of building regulations and the drive to reduce energy use and improve efficiency, the role of occupant behaviour in reducing domestic energy use has come into sharper focus [e.g. 4,5]. It has been suggested that to achieve energy savings through behavioural change, households need to be made aware of the link between their everyday behaviour and energy consumption [6]. This relies on efficient and comprehensive communications about energy use; the information people receive should be readily comprehensible and, ideally, should prompt appropriate action to reduce consumption without requiring too much analysis and interpretation by the user. In the UK, feedback about energy consumption is typically provided through infrequent energy bills, often based on estimates of how much energy has been used rather than real-time data. Householders generally do not have easy access to their energy meters and have a limited understanding of their energy consumption [7]. Bills are not designed from the consumer's perspective, and the way information is presented makes bills difficult to understand [7]. There is therefore a clear need for user-centred design work on how energy use feedback should be presented.

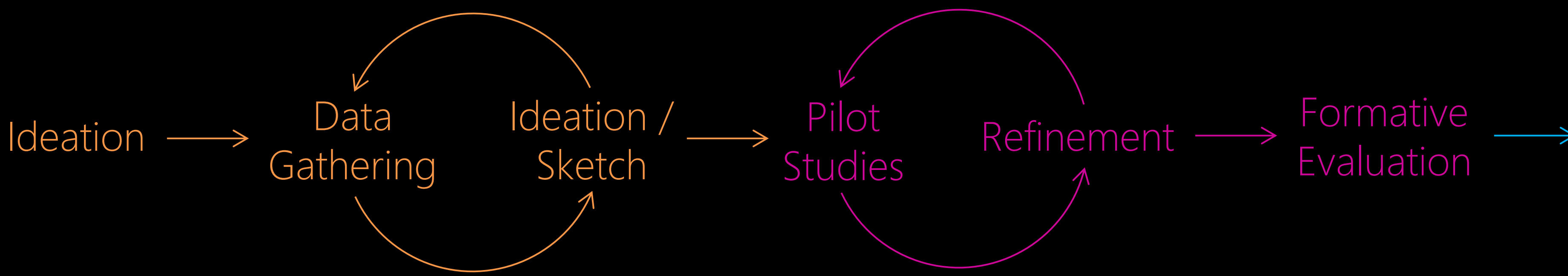
A number of reviews have suggested [8–10] that presenting feedback information by means of real-time monitoring and display technologies has more potential for achieving energy savings than giving information alone. Studies implementing real-time feedback have shown electricity savings in the range of 9–12% [11]. However, it is notable that studies reporting larger savings typically had small sample sizes. For example, Ueno et al. [12] trialled nine Japanese households in a study using a computerised interactive tool with daily feedback and achieved a 9% reduction in electricity consumption. Similarly, Wood and Newborough [5] trialled ten UK households with a display directly attached to stoves, seven of which achieved energy savings of greater than 10%. In contrast, results from the recent Energy Demand Research Project (EDRP, 2007–2010) in the UK, which focused on trialling a range of methods[3] for providing feedback on energy consumption in over

* Corresponding author. Tel.: +44 01225385206; fax: +44 01225386691.
E-mail addresses: t.s.chiang@bath.ac.uk (T. Chiang), s.natarajan@bath.ac.uk (S. Natarajan), i.walker@bath.ac.uk (I. Walker).
[1] Tel.: +44 01225386358; fax: +44 01225386691.
[2] Tel.: +44 01225383908.

[3] The methods (deployed both standalone and in combination) included smart meters, real-time displays, informative billing, written information on energy saving tips, community engagement, incentives to reduce or shift consumption, alarm and "traffic light" messages, meter reading and heating controller.

0378-7788/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2012.07.026

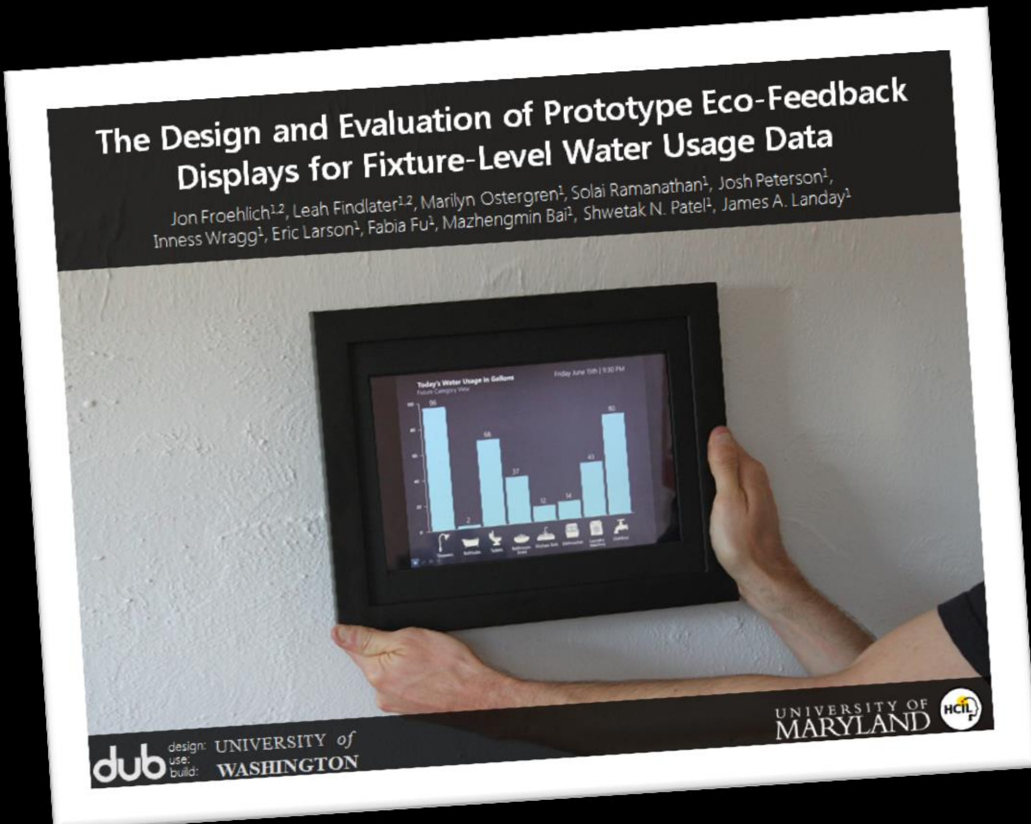
Integrate Findings & Revise Designs

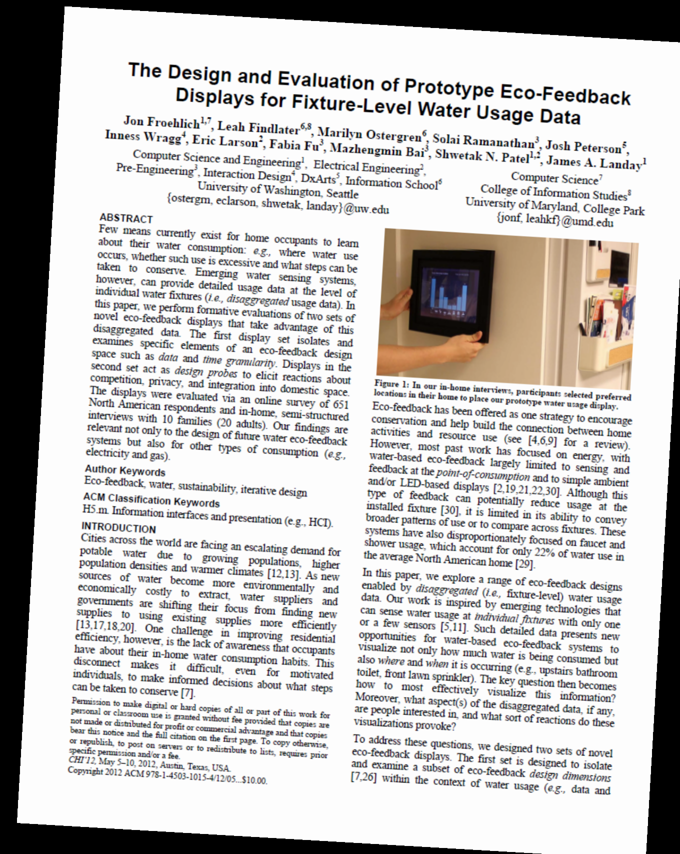


A Call

1. Place more emphasis on describing eco-feedback designs and how design choices may affect behavior in our research papers / white papers

2. Help generate reusable design knowledge by including information not just on the final eco-feedback design but the process used to achieve it





The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data

Jon Froehlich[1,7], Leah Findlater[6,8], Marilyn Ostergren[6], Solai Ramanathan[3], Josh Peterson[5], Inness Wragg[4], Eric Larson[2], Fabia Fu[3], Mazhengmin Bai[3], Shwetak N. Patel[1,2], James A. Landay[1]

Computer Science and Engineering[1], Electrical Engineering[2], Pre-Engineering[3], Interaction Design[4], DxArts[5], Information School[6]
University of Washington, Seattle
{ostergm, eclarson, shwetak, landay}@uw.edu

Computer Science[7]
College of Information Studies[8]
University of Maryland, College Park
{jonf, leahkf}@umd.edu

ABSTRACT

Few means currently exist for home occupants to learn about their water consumption: *e.g.*, where water use occurs, whether such use is excessive and what steps can be taken to conserve. Emerging water sensing systems, however, can provide detailed usage data at the level of individual water fixtures (*i.e., disaggregated* usage data). In this paper, we perform formative evaluations of two sets of novel eco-feedback displays that take advantage of this disaggregated data. The first display set isolates and examines specific elements of an eco-feedback design space such as *data* and *time granularity*. Displays in the second set act as *design probes* to elicit reactions about competition, privacy, and integration into domestic space. The displays were evaluated via an online survey of 651 North American respondents and in-home, semi-structured interviews with 10 families (20 adults). Our findings are relevant not only to the design of future water eco-feedback systems but also for other types of consumption (*e.g.*, electricity and gas).

Author Keywords

Eco-feedback, water, sustainability, iterative design

ACM Classification Keywords

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

INTRODUCTION

Cities across the world are facing an escalating demand for potable water due to growing populations, higher population densities and warmer climates [12,13]. As new sources of water become more environmentally and economically costly to extract, water suppliers and governments are shifting their focus from finding new supplies to using existing supplies more efficiently [13,17,18,20]. One challenge in improving residential efficiency, however, is the lack of awareness that occupants have about their in-home water consumption habits. This disconnect makes it difficult, even for motivated individuals, to make informed decisions about what steps can be taken to conserve [7].

CHI'12, May 5–10, 2012, Austin, Texas, USA.

Figure 1: In our in-home interviews, participants selected preferred locations in their home to place our prototype water usage display.

Eco-feedback has been offered as one strategy to encourage conservation and help build the connection between home activities and resource use (see [4,6,9] for a review). However, most past work has focused on energy, with water-based eco-feedback largely limited to sensing and feedback at the *point-of-consumption* and to simple ambient and/or LED-based displays [2,19,21,22,30]. Although this type of feedback can potentially reduce usage at the installed fixture [30], it is limited in its ability to convey broader patterns of use or to compare across fixtures. These systems have also disproportionately focused on faucet and shower usage, which account for only 22% of water use in the average North American home [29].

In this paper, we explore a range of eco-feedback designs enabled by *disaggregated* (*i.e.*, fixture-level) water usage data. Our work is inspired by emerging technologies that can sense water usage at *individual fixtures* with only one or a few sensors [5,11]. Such detailed data presents new opportunities for water-based eco-feedback systems to visualize not only how much water is being consumed but also *where* and *when* it is occurring (e.g., upstairs bathroom toilet, front lawn sprinkler). The key question then becomes how to most effectively visualize this information? Moreover, what aspect(s) of the disaggregated data, if any, are people interested in, and what sort of reactions do these visualizations provoke?

To address these questions, we designed two sets of novel eco-feedback displays. The first set is designed to isolate and examine a subset of eco-feedback *design dimensions* [7,26] within the context of water usage (*e.g.*, data and

Froehlich *et al.*, **The Design & Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data**, *CHI2012*

Sensing and Feedback of Everyday Activities to Promote Environmental Behaviors

Jon E. Froehlich

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

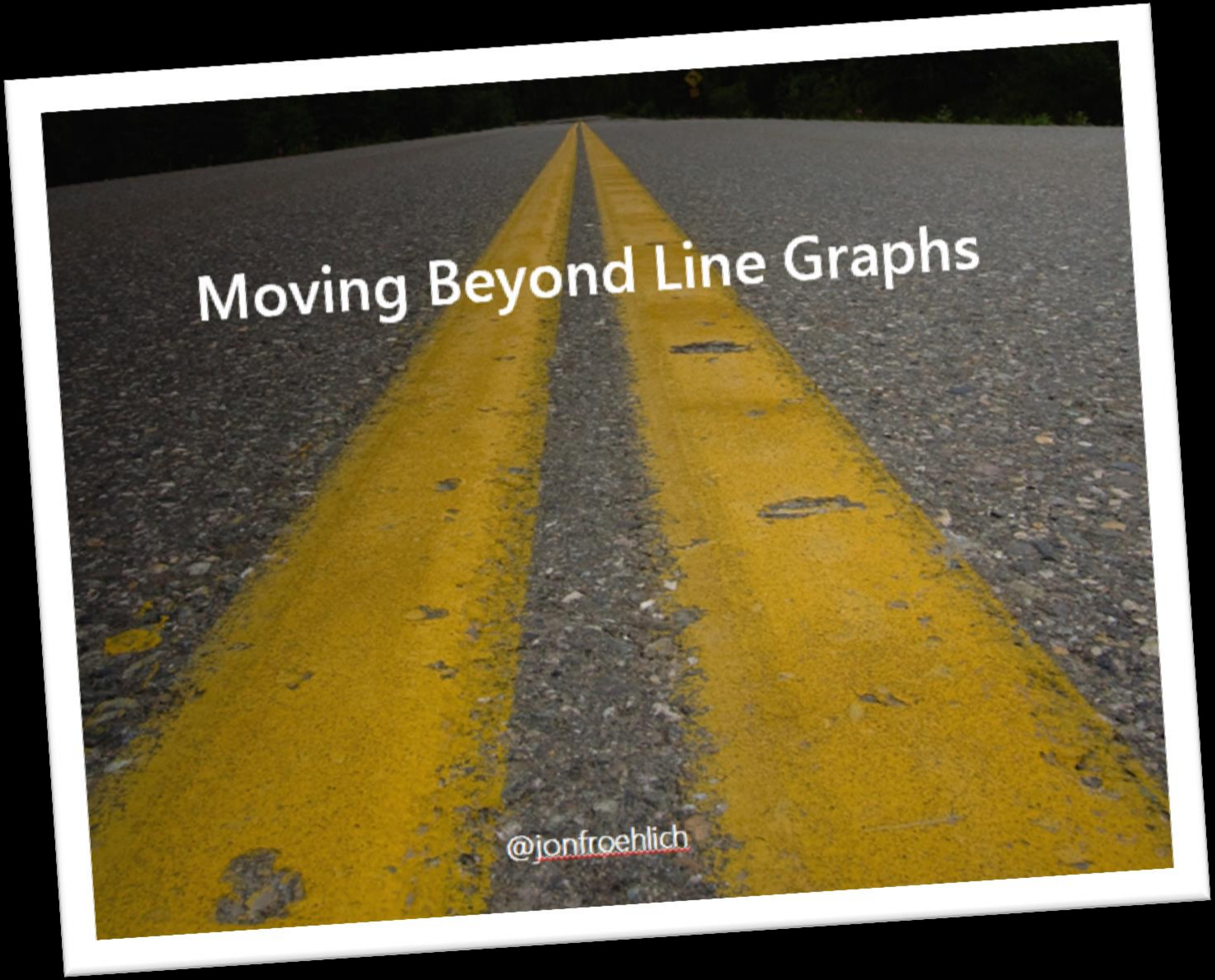
Doctor of Philosophy

University of Washington

2011

Program Authorized to Offer Degree:
Department of Computer Science and Engineering

Jon Froehlich, **Sensing and Feedback of Everyday Activities to Promote Environmental Behaviors**, *PhD Dissertation 2011*


Moving Beyond Line Graphs
@jonfroehlich

Applying **Iterative Design** to the Eco-Feedback Design Process