IoT Interfaces for Everyday People

Meghan Clark

Intel/NSF CPS-Security Final PI Meeting

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mclarkk@berkeley.edu

Consumer IoT is coming.

Over 40 billion IoT devices by 2021

https://www.juniperresearch.com/press/press-releases/%E2%80%98internet-of-things%E2%80%99-connected-devices-to-triple-b

Consumer IoT is coming.

But how will we interact with it?

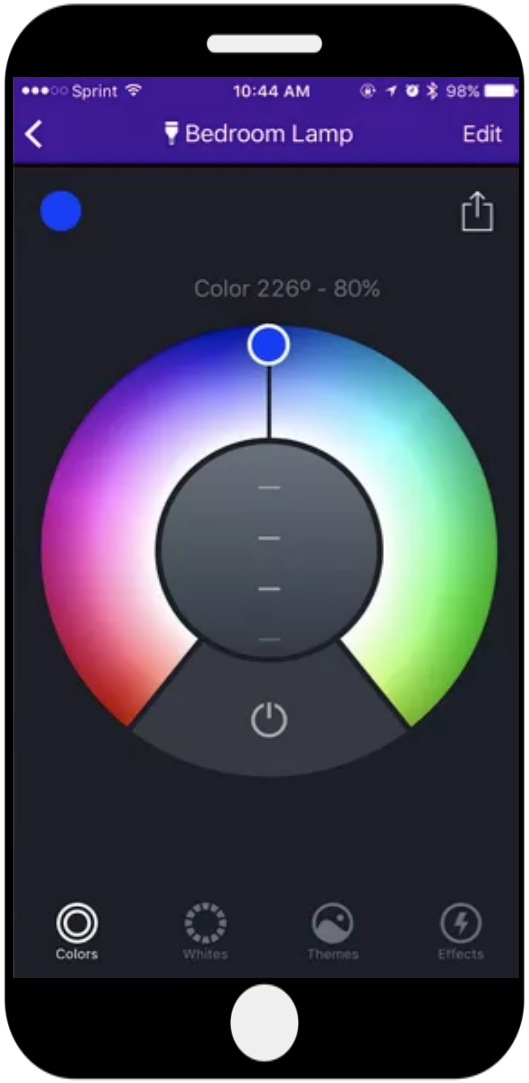
OFF

LUTRON

LUTRON

AT&T
12:52 PM
My Home
Entry Light
Right Now
Recently
SmartApps
ON
Tap ▼
70%
Button 1 Tap
Button 2 Tap
Button 3 Tap
Button 4 Tap
Button 5 Hold
Button 6 Hold
Button 7 Tap
Button 8 Tap
Button 9 Tap
Button 10 Tap
Button 11 Tap
Button 12 Tap
70 %
HomeSeer Technologies Firmware V5.9
Configure

BT 4G
15:01
79%


Sprint
10:44 AM
98%
Bedroom Lamp
Edit
Color 226º - 80%
Colors
Whites
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Effects

hue
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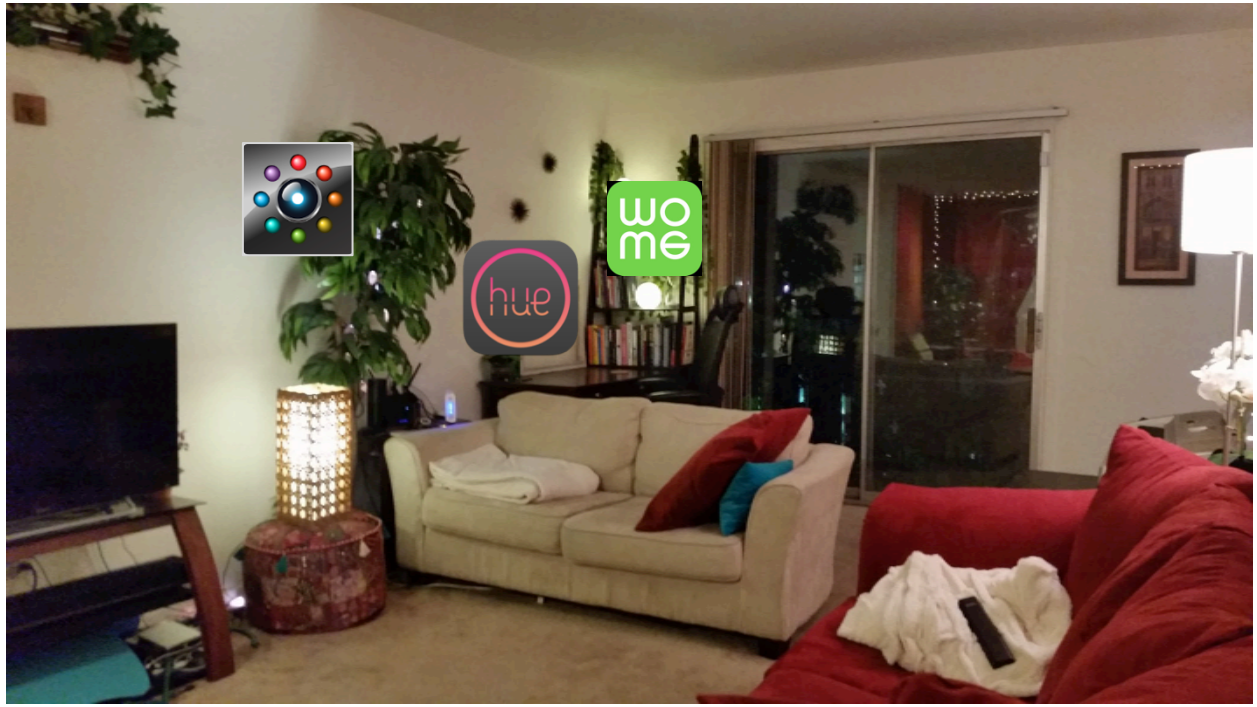
WOMe
WOMe
hue


WOMe
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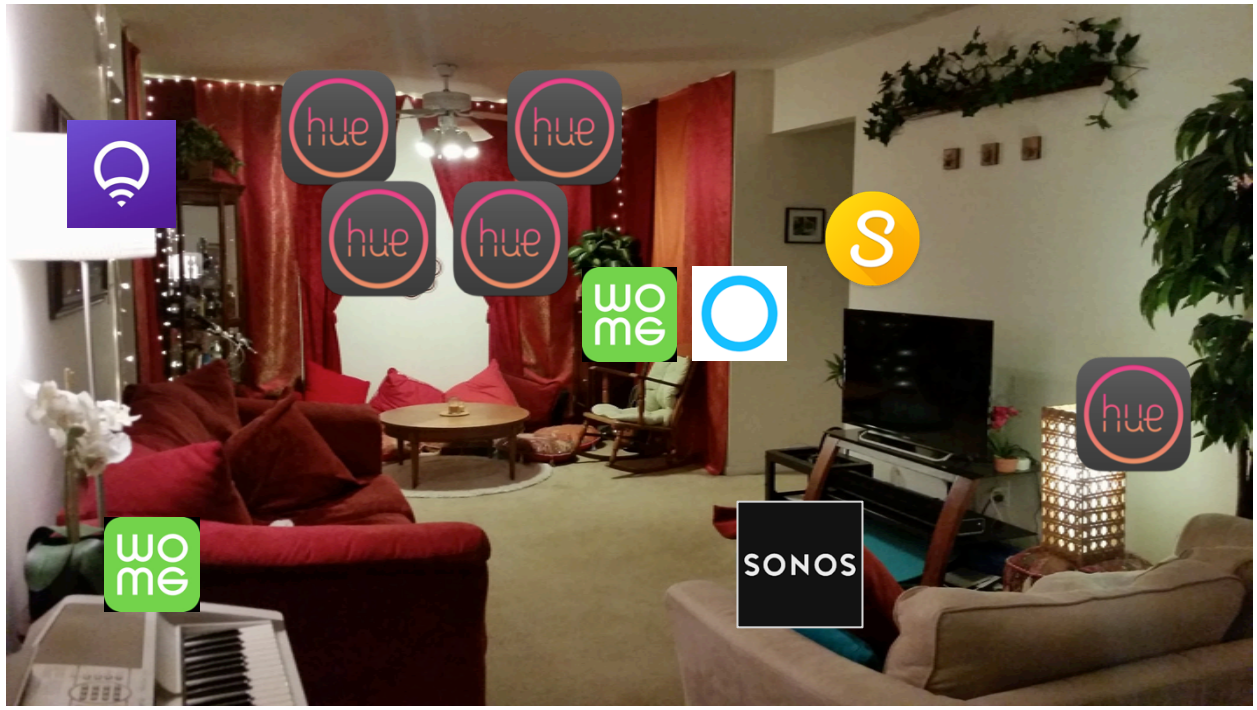
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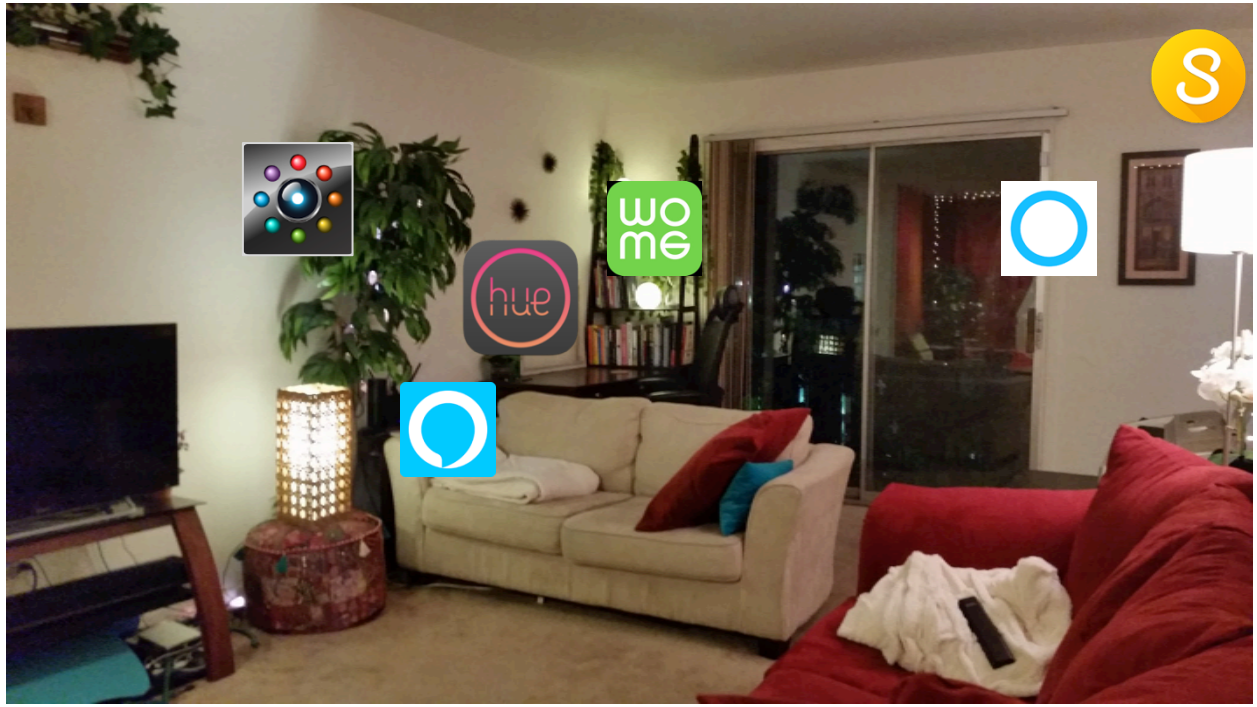
SONOS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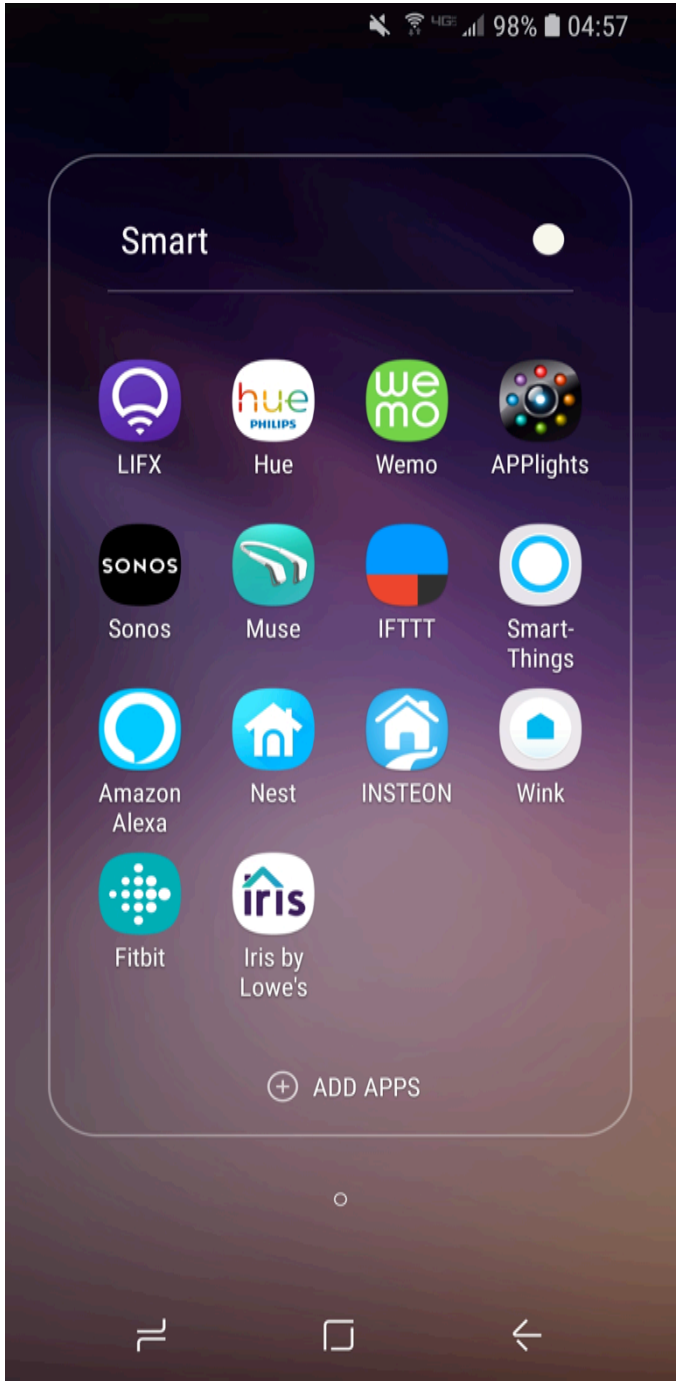
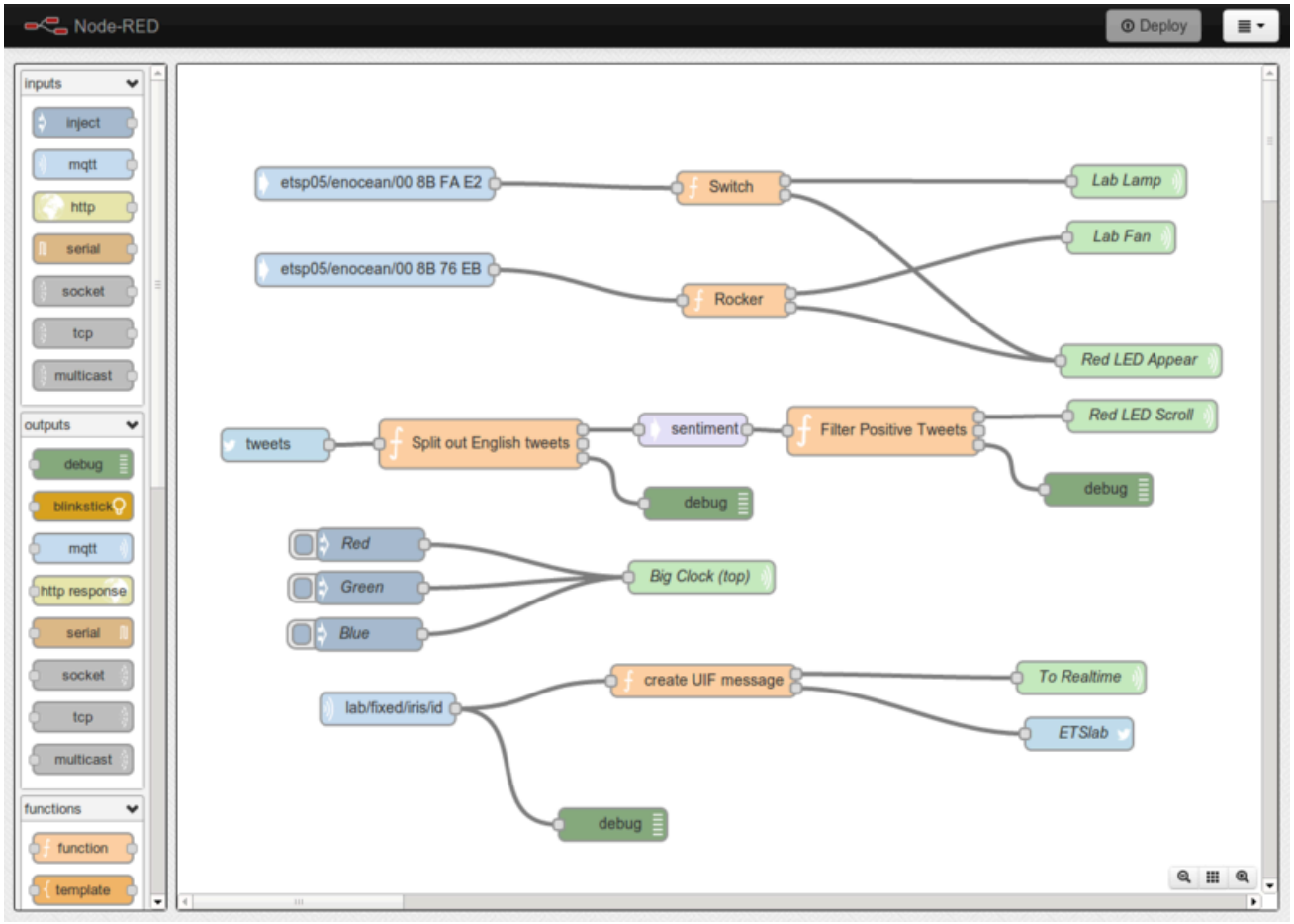

98% 04:57
Smart
LIFX
Hue
Wemo
APPlights
Sonos
Muse
IFTTT
Smart-Things
Amazon Alexa
Nest
INSTEON
Wink
Fitbit
Iris by Lowe's
ADD APPS

95% 05:19
Lab 11
FAVORITES
ON
Branden's Light
OFF
Josh's Desk Light
CLOSED
Kitchen Door
ON
Kitchen light
Meghan Clark's Android
ON
Meghan's Desk Light
ON
Noah's Light
ON
Pat's Desk Light
Dashboard
My Home
Automation
Marketplace


Node-RED
Deploy
inputs
inject
mqtt
http
serial
socket
tcp
multicast
outputs
debug
blinkstick
mqtt
http response
serial
socket
tcp
multicast
functions
function
template
etsp05/enocean/00 8B FA E2
Switch
Lab Lamp
Lab Fan
etsp05/enocean/00 8B 76 EB
Rocker
Red LED Appear
tweets
Split out English tweets
sentiment
Filter Positive Tweets
Red LED Scroll
debug
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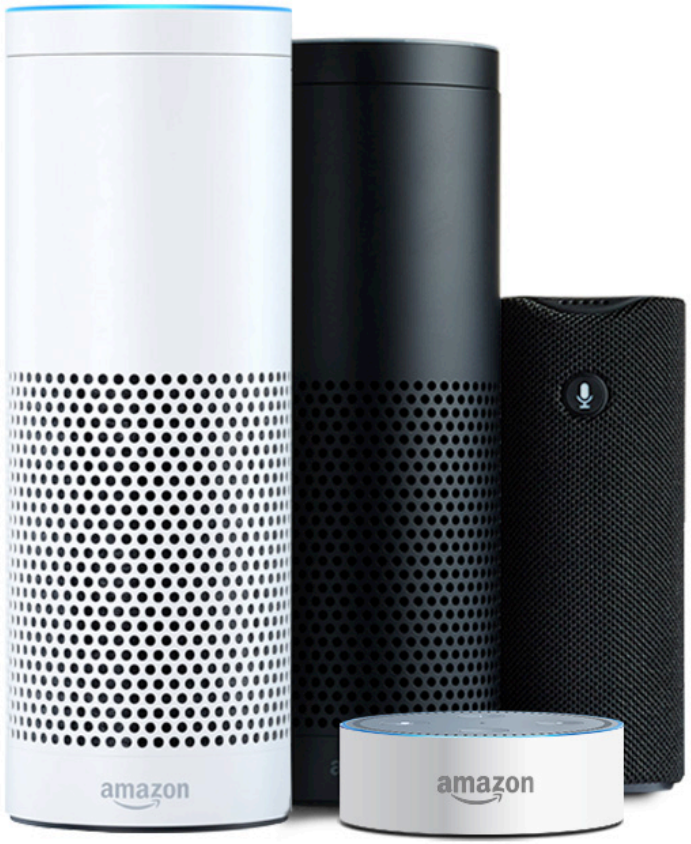
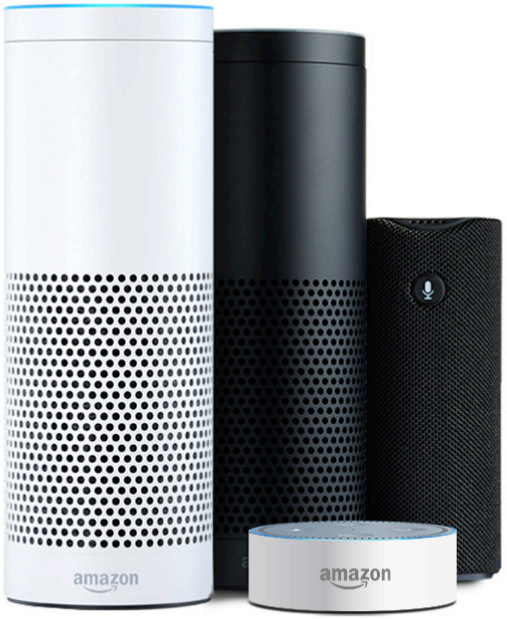
Red
Green
Blue
Big Clock (top)
lab/fixed/iris/id
create UIF message
To Realtime
ETSlab
debug


amazon
amazon

wink
Climate
Smoke Alarm
Locks
Lights & Power
Garage Door
Add a Product
Home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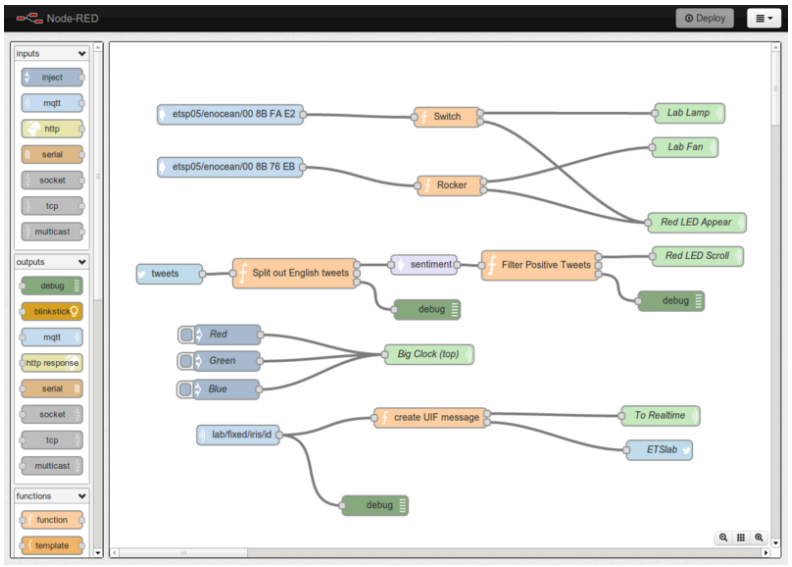
Node-RED
Deploy
inputs
inject
mqtt
http
serial
socket
tcp
multicast
outputs
debug
blinkstick
mqtt
http response
serial
socket
tcp
multicast
functions
function
template
etsp05/enocean/00 8B FA E2
Switch
Lab Lamp
Lab Fan
etsp05/enocean/00 8B 76 EB
Rocker
Red LED Appear
tweets
Split out English tweets
sentiment
Filter Positive Tweets
Red LED Scroll
debug
debug
Red
Green
Blue
Big Clock (top)
lab/fixed/iris/id
create UIF message
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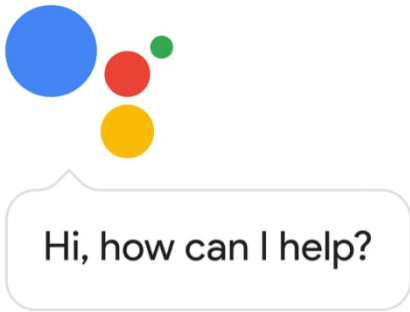
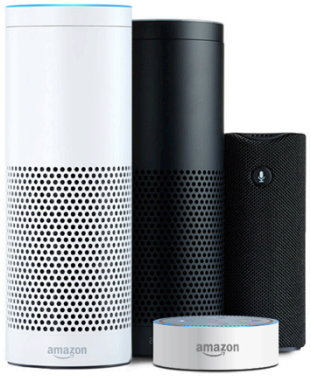
debug


Hi, how can I help?

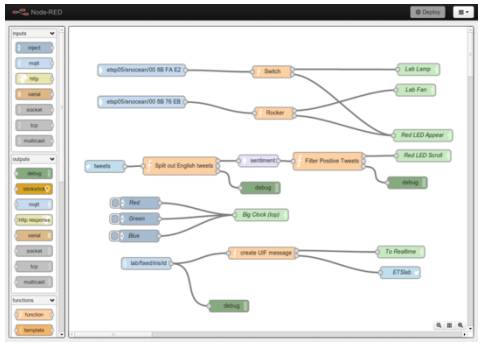
Little has been done to explore the trade-offs between these representations.

Devices??



Agents??

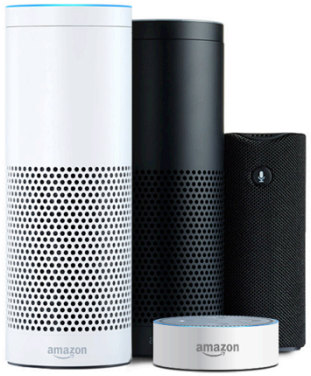
Data??



Hi, how can I help?

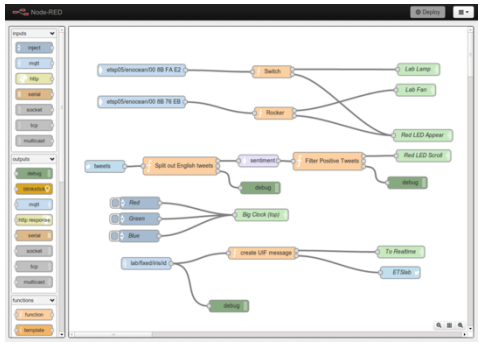
What if certain representations discourage users from thinking of classes of interactions?

Devices??



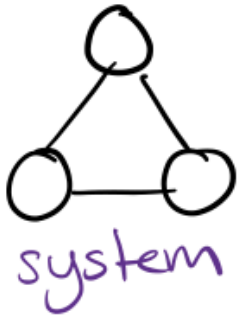
Agents??

Data??



Hi, how can I help?

What are mental models and how are they formed?



Norman, Don. *The design of everyday things: Revised and expanded edition*. Basic Books (AZ), 2013.

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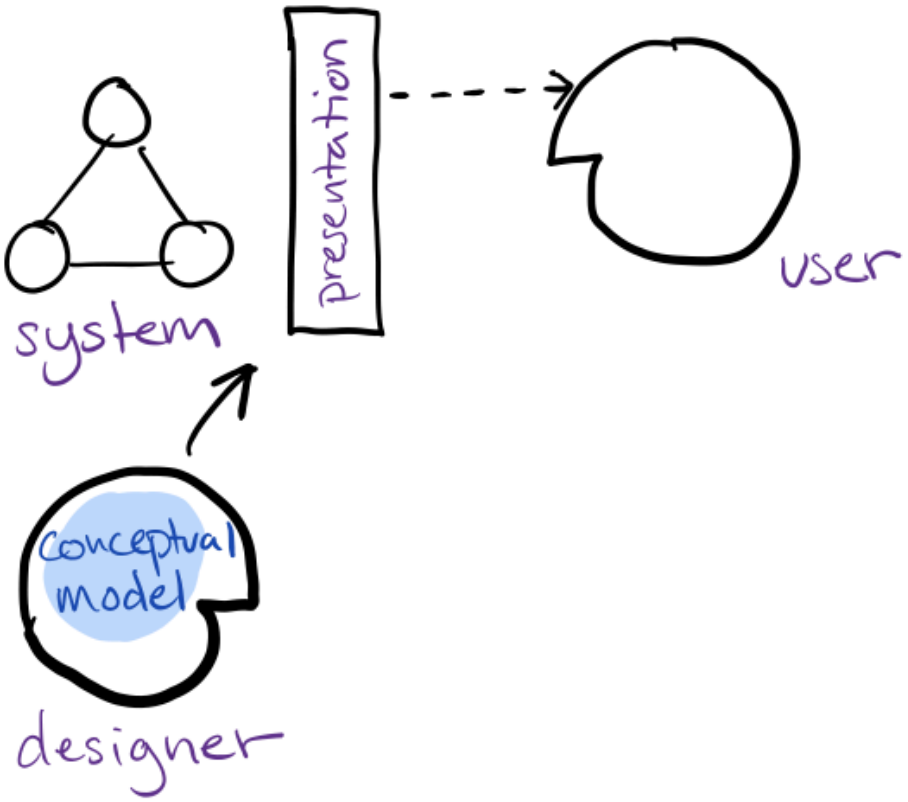

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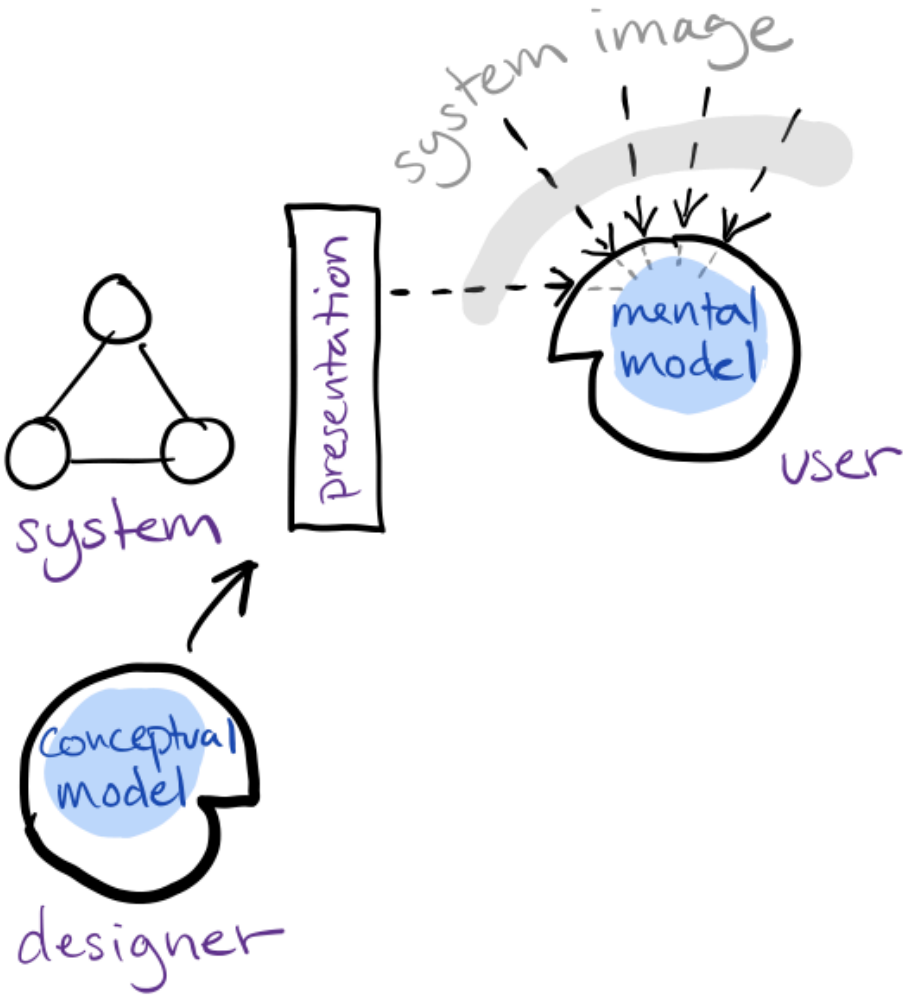

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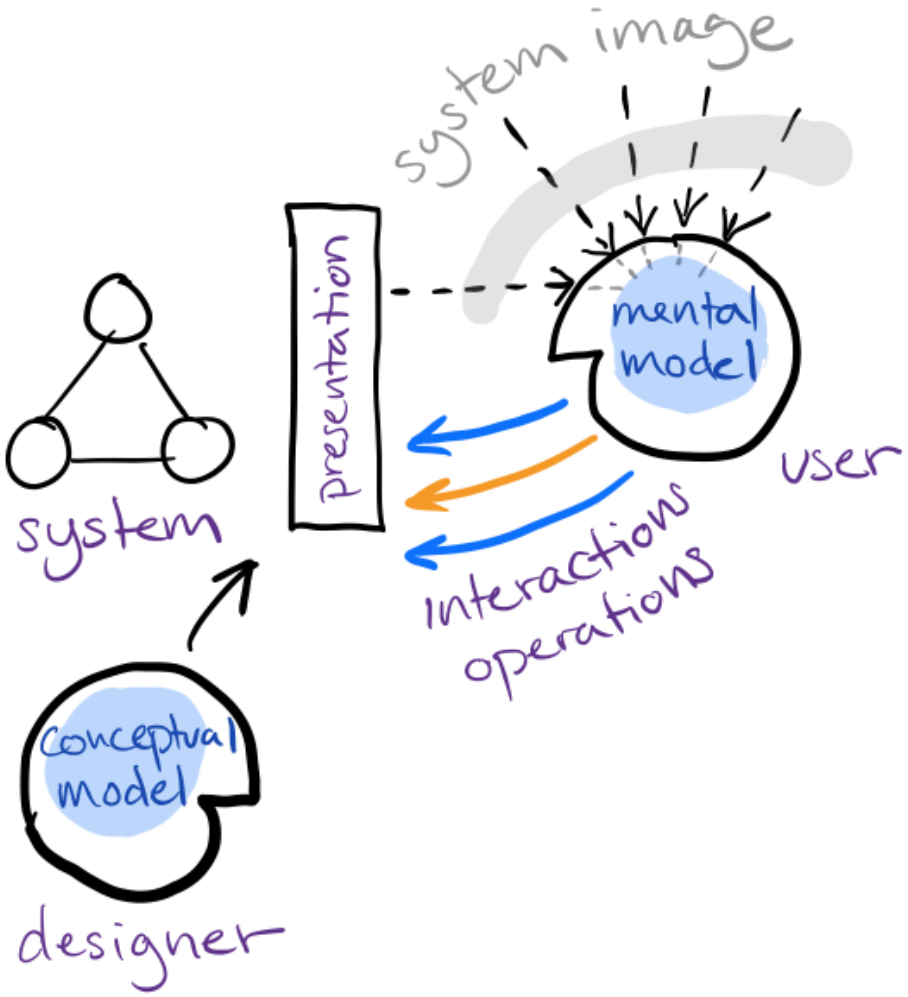
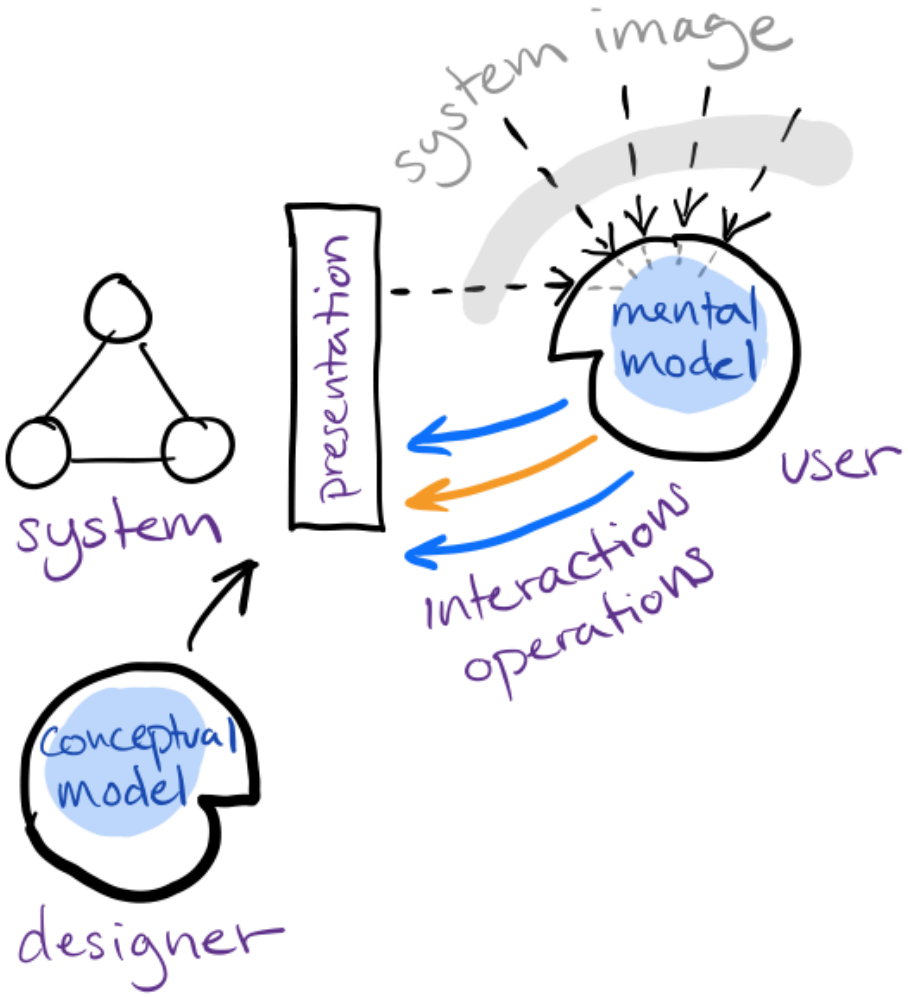


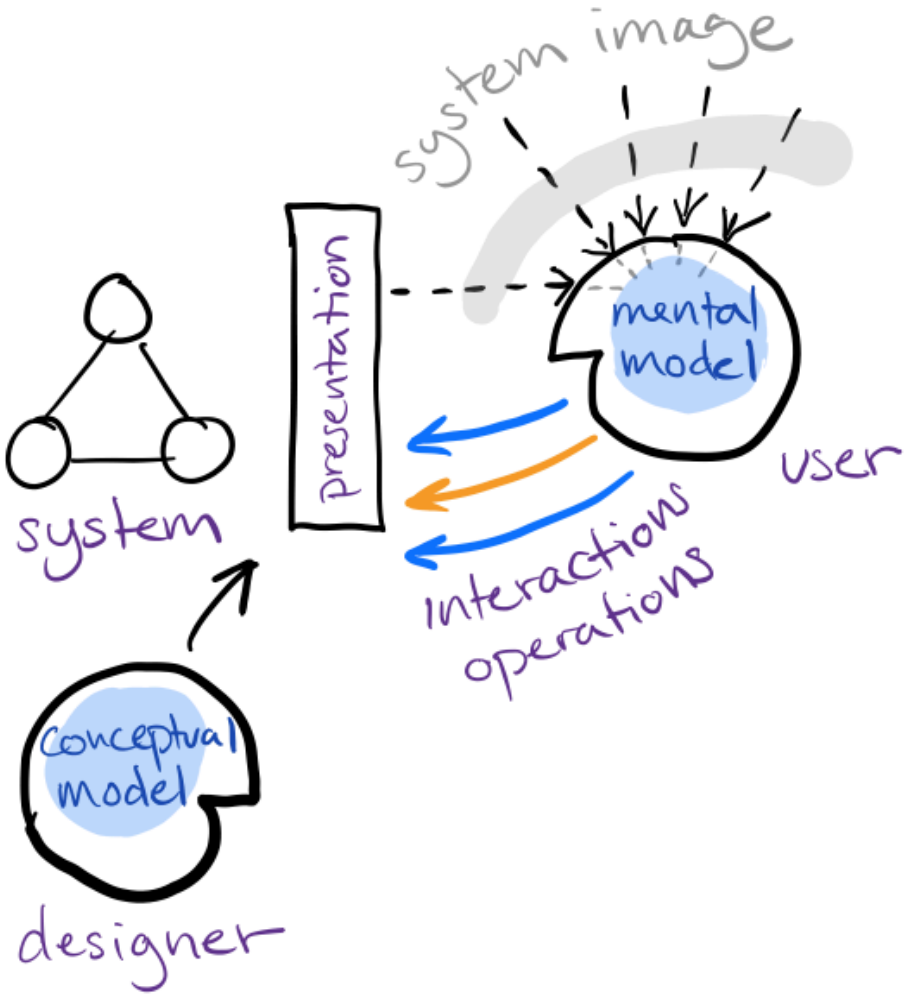
What are mental models and how are they formed?

In this talk, like Norman, I use *conceptual model* and *mental model* to refer to separate ideas.



What are mental models and how are they formed?

Initial exposure to conceptual models may prime user' mental models.



We should incorporate priming into the design process

Works that assume “natural” mental models for IoT technologies:

- iCAP: Interactive Prototyping of Context-aware Applications [1]
- Practical Trigger-Action Programming in the Smart Home [2]
- CAMP Magnetic Poetry [3]
    - Tried to avoid biasing users by providing scenarios in comic form

Unlike prior work, we assume that:

- All scenario descriptions and interfaces express conceptual models that will prime users
- Priming is not inherently bad
- We should incorporate priming in our system design to learn how to intelligently shape user interactions and align them with system capabilities

[1] Anind K. Dey, Timothy Sohn, Sara Streng, and Justin Kodama. 2006. iCAP: Interactive prototyping of context-aware applications. In International Conference on Pervasive Computing. https://doi.org/10.1007/11748625_16

[2] Khai N Truong, Elaine M Huang, and Gregory D Abowd. 2004. CAMP: A Magnetic Poetry Interface for End-User Programming of Capture Applications for the Home. In International Conference on Ubiquitous Computing.

[3] Blase Ur, Elyse Mcmanus, Melwyn Pak, Yong Ho, and Michael L Littman. 2014. Practical Trigger-Action Programming in the Smart Home. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 803–812. https://doi.org/10.1145/2556288.2557420

In this work, we examine the following three questions:

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- To what degree do different abstractions prime end-user mental models?

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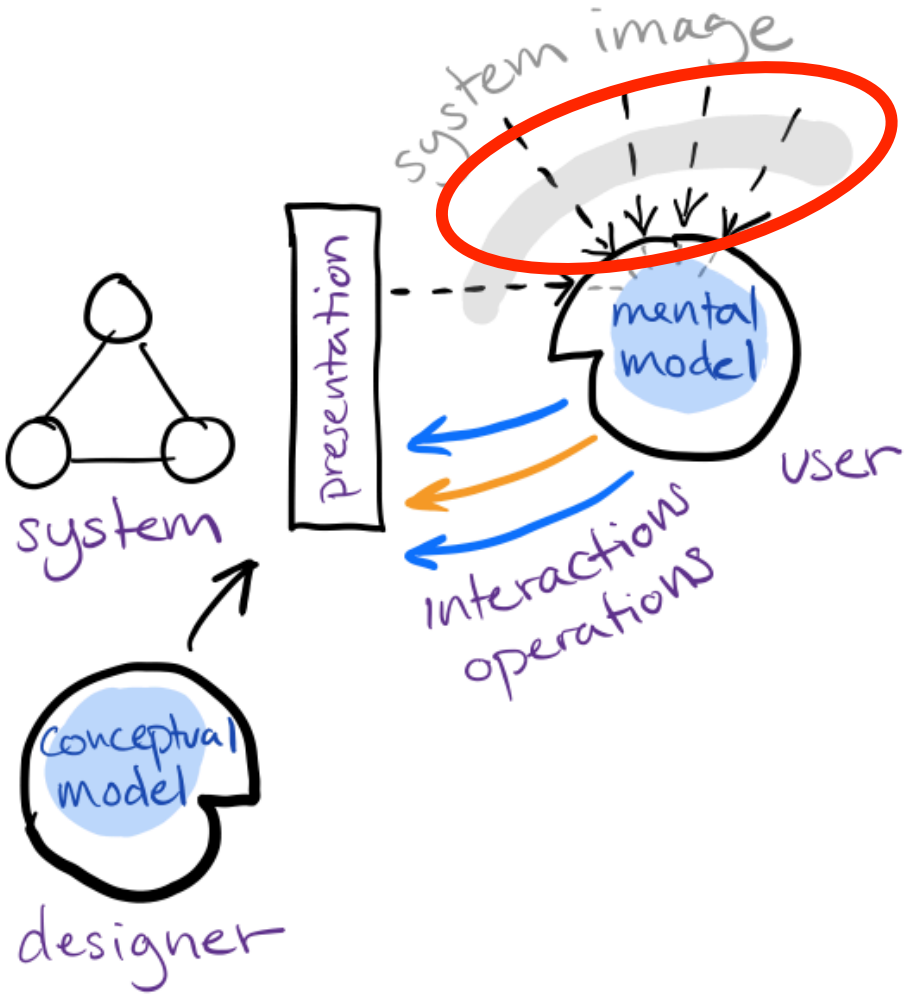
- What are the specific effects and trade-offs of common conceptual models?

In this work, we examine the following three questions:

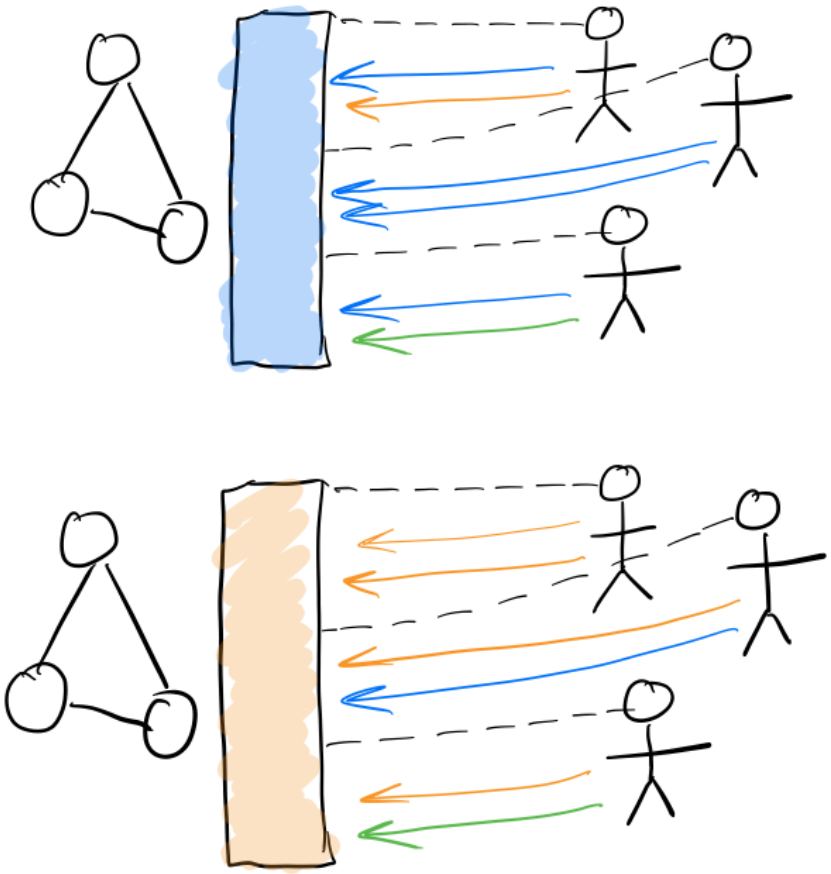
- To what degree do different abstractions prime end-user mental models?
- What are the specific effects and trade-offs of common conceptual models?
- Do different populations respond differently to conceptual models?

How can we compare conceptual models and their effects?

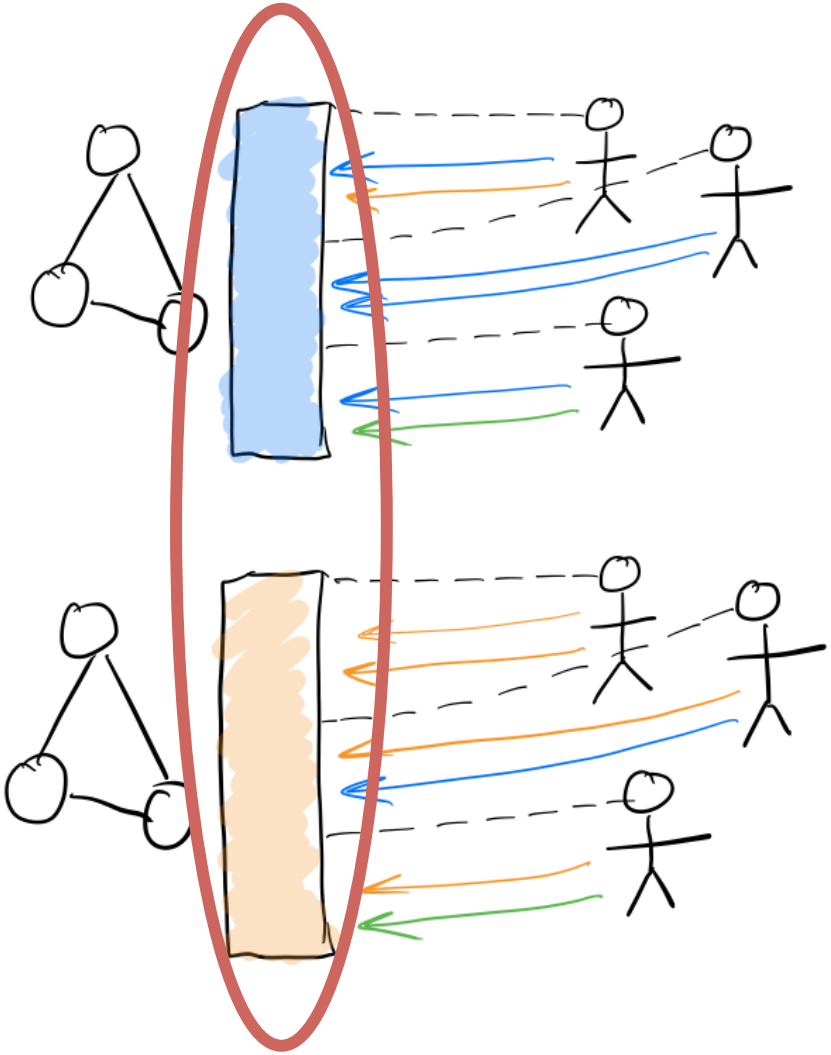
How do we control for individual differences in prior experiences?



How do we control for individual differences in prior experiences?



How do we compare conceptual models?



We examine four *abstractions* along two *dimensions*, for a total of four conceptual models.

Personification

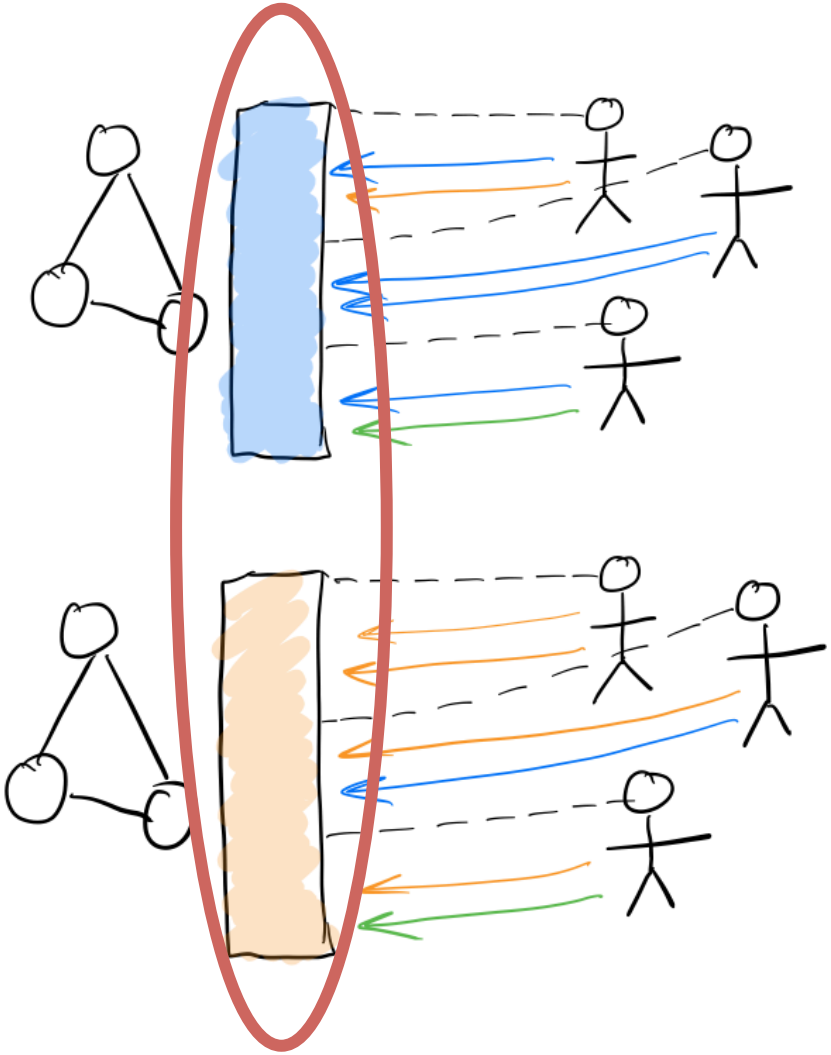
Unmediated | Agent-mediated

Capabilities

Devices

Data

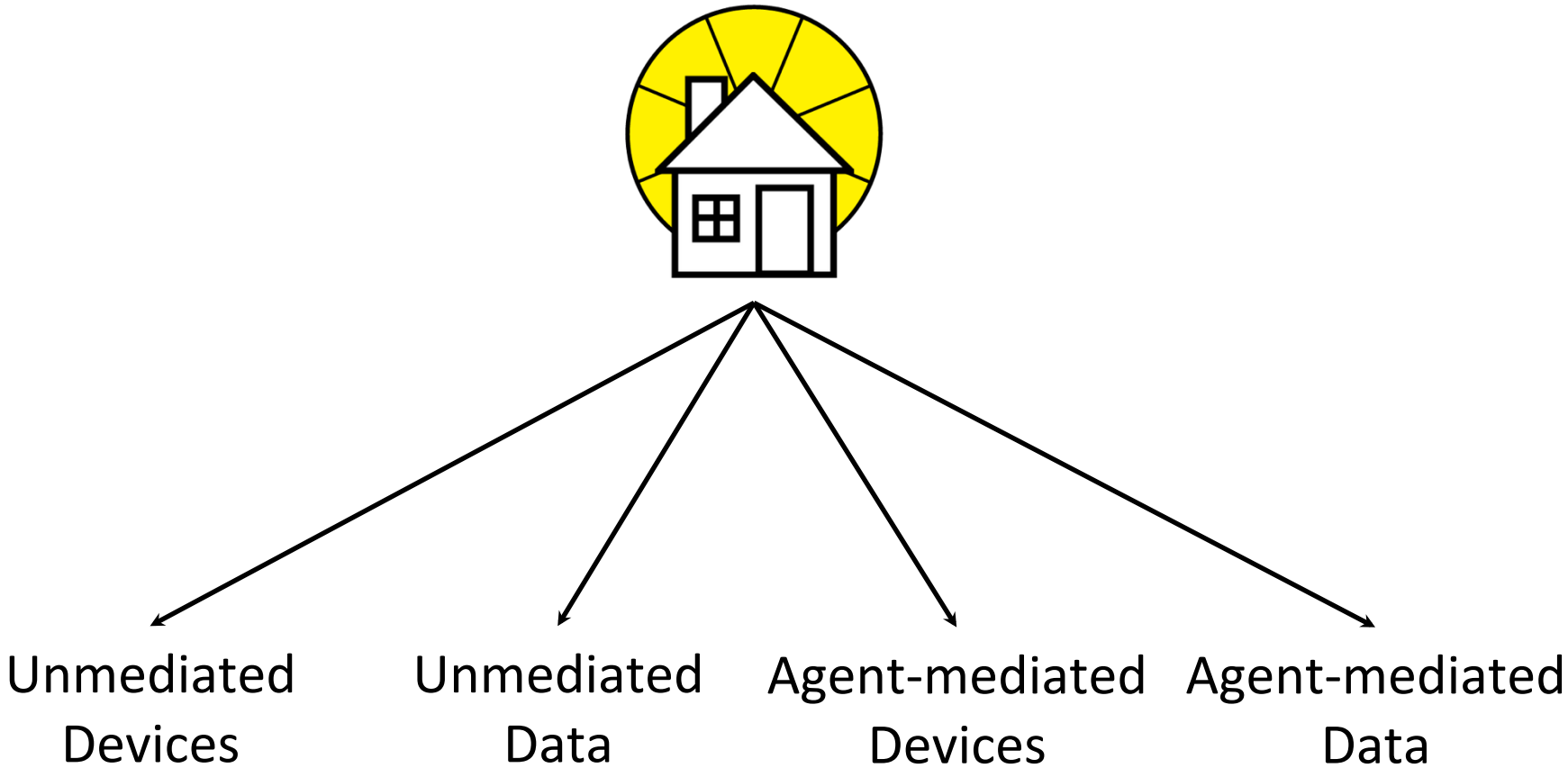
Now we can compare conceptual models.



How do we compare user responses to different abstractions?

THE STUDY

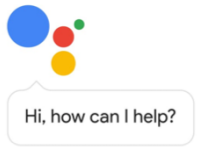
We deployed four questionnaires to Mechanical Turk



Unmediated Devices

Unmediated Data

Agent-mediated Devices



Agent-mediated Data

List of smart home devices

List of smart home data streams

Write for five minutes about what applications you want

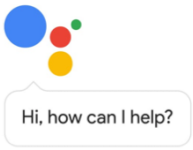
Pick gender and name for “smart home AI”

List of smart home devices

List of smart home data streams

“Okay, <AI name>…”

We had 1,535 respondants in total

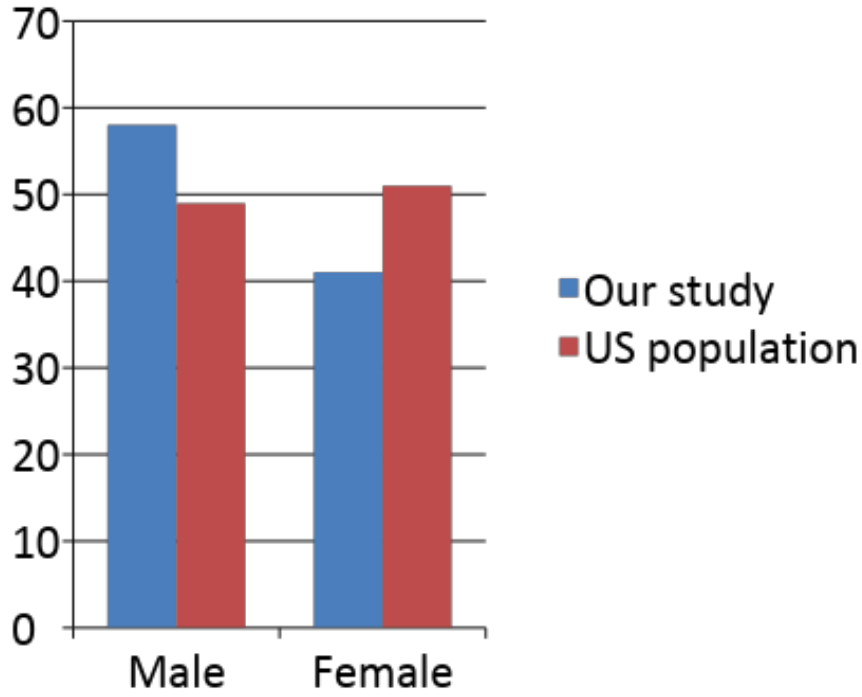
	Conceptual model	Responses
	Unmediated Devices	313
	Unmediated Data	302
	Agent-mediated Devices	442
	Agent-mediated Data	478

Our subjects are representative of who we want to study

- Age, gender, and education similar to U.S. pop
- Overall non-technical, an improvement over past studies

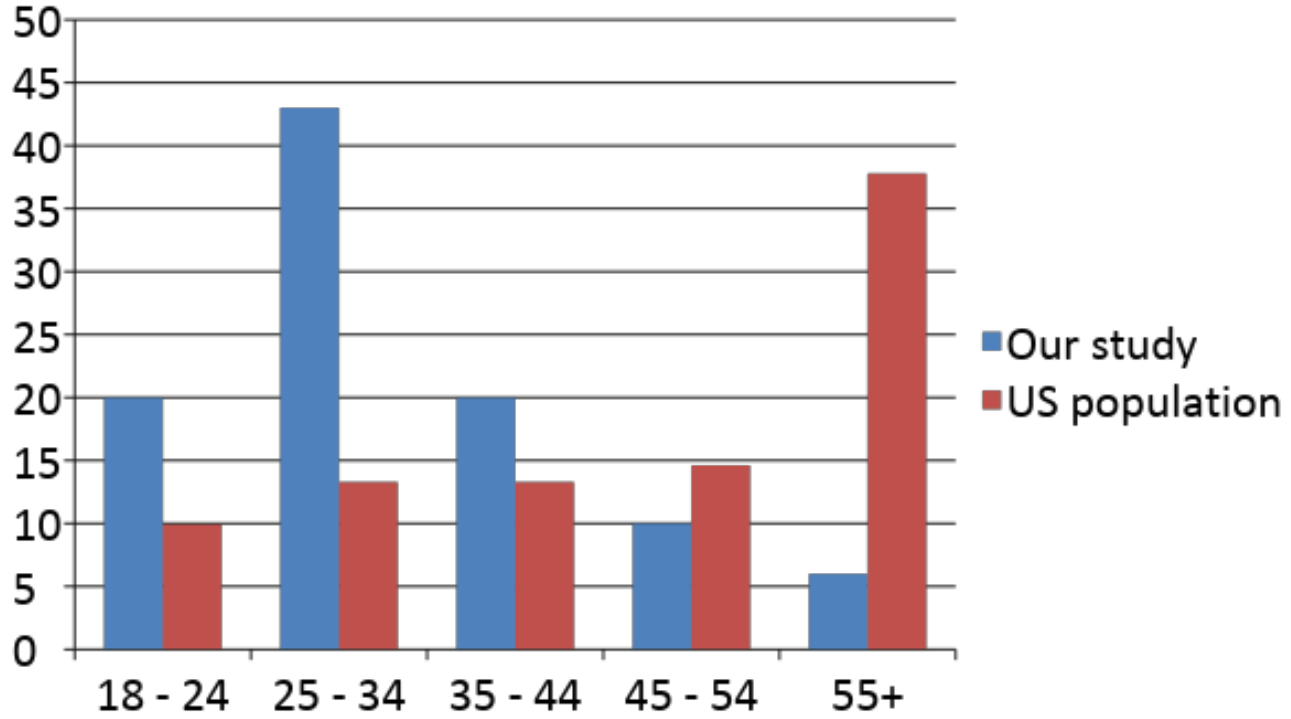
	Our study
Not a computer worker	91%
CS exposure low/none	76%
Never heard of IoT	66%

Are our subjects representative of who we want to study?



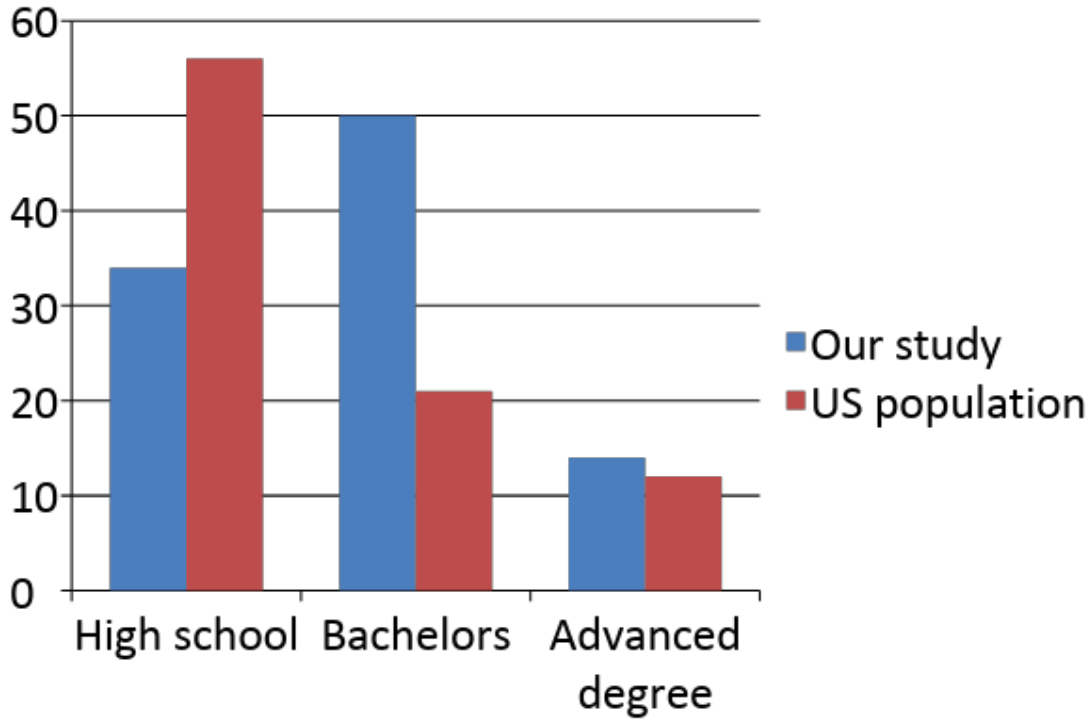
Our study population is slightly more male than the US population

Are our subjects representative of who we want to study?



Our study population skews younger than the US population

Are our subjects representative of who we want to study?



Our study population skews more educated than the US population

Are our subjects representative of who we want to study?

	Our study
Not a computer worker	91%
CS exposure low/none	76%
Never heard of IoT	66%

Our study population is overall non-technical

What do we do with this dataset?

ANALYSIS

How do we analyze the dataset?

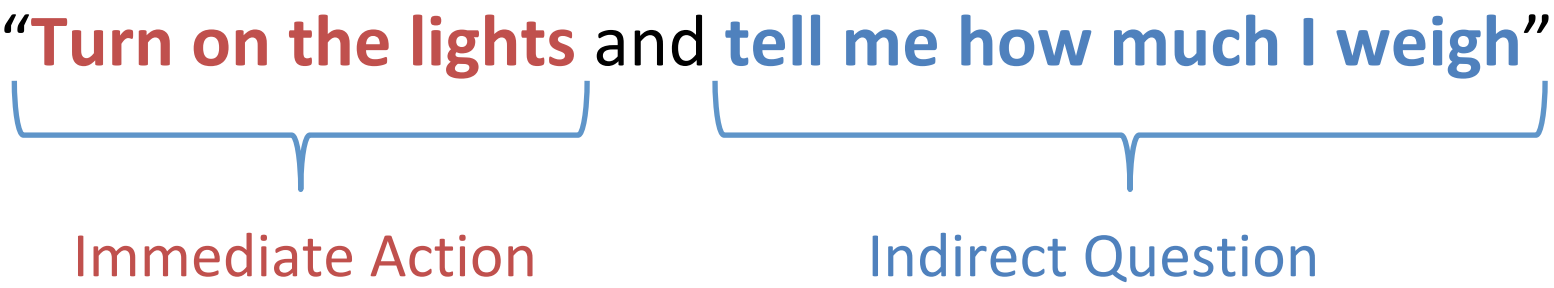
- Qualitative differences

How do we analyze the dataset?

- Qualitative differences
- Characteristic words

How do we analyze the dataset?

- Qualitative differences
- Characteristic words
- User operations profile



User operation schema

- Immediate interactions
  - Immediate actions (“Turn on the lights”)
  - Direct questions (“What is my weight?”)
  - Indirect questions (“Tell me my weight”)
- Conditional interactions
  - Conditional actions (“When I come home turn on the light”)
  - Notifications (“Let me know when my children get home”)

How did the four prompts affect subjects?

THE FINDINGS

Priming had an effect

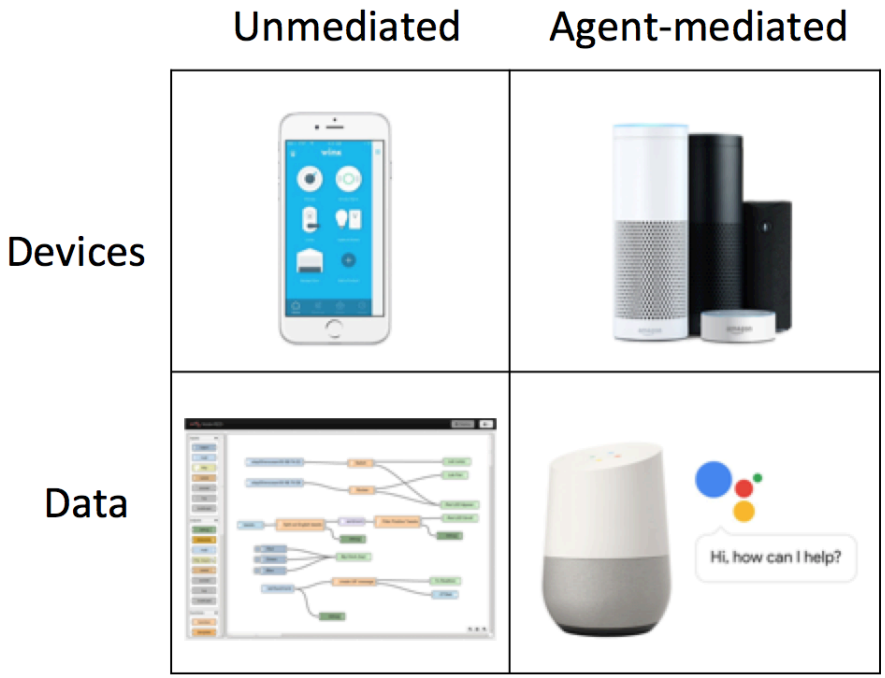
Unmediated Devices
"I would definitely want the smart watch to control the majority of the devices and controls in the house. I would definitely look for the smart door lock and smart thermostat."

Unmediated Data
"I would want an interface between my security system, smoke alarms, CO alarms, and cell phone. I would also want to be able to control the climate control systems (A/C and heat) from my cell phone, and monitor the temperature."

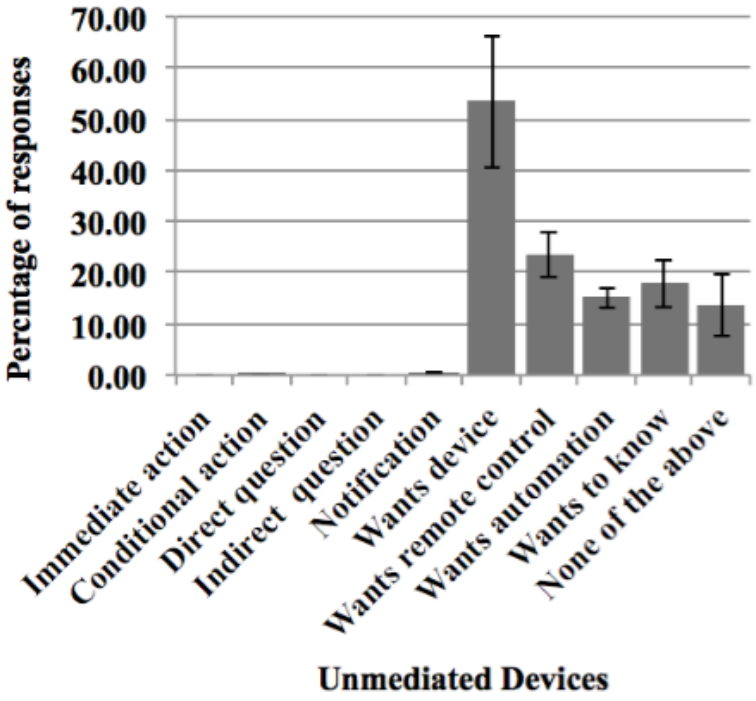
Agent-mediated Devices
"Set the temperature to 70 degrees. Lock the door. Close the blinds. Fetch and read my email. Please wake me up at 9 AM with some pleasant music."

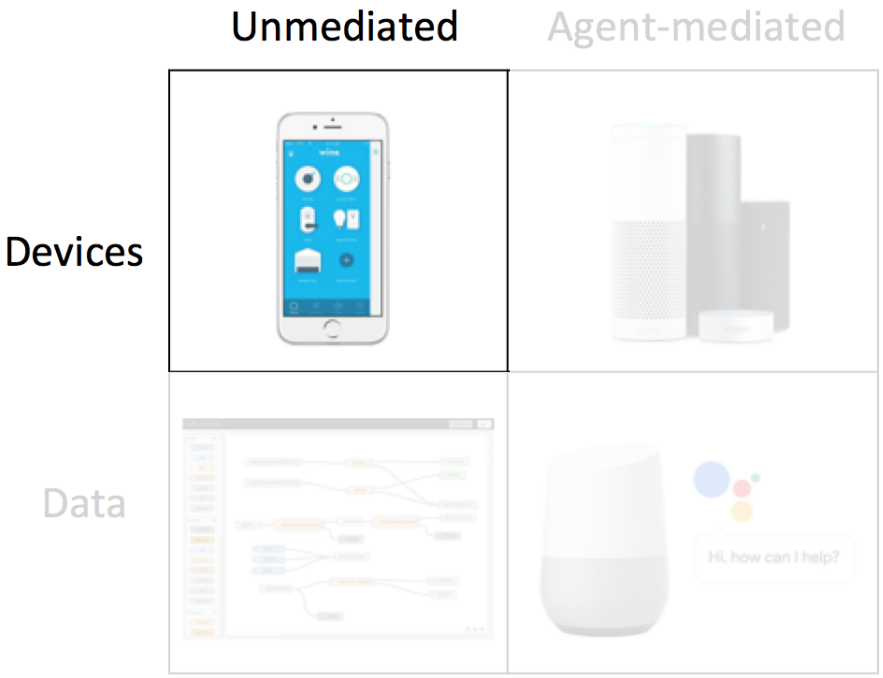
Agent-mediated Data
"Make sure that when I leave the house, all lights, AC, and electronics are turned off and the door is locked. While I am gone, monitor the house, and call my phone if anything strange happens (anyone enters the house, any objects are moved, etc.). Tell me my electricity consumption and gas consumption. How has my sleep been lately?"

What mental models did people form when presented with each conceptual model?



Unmediated Devices ➔ “Islands”

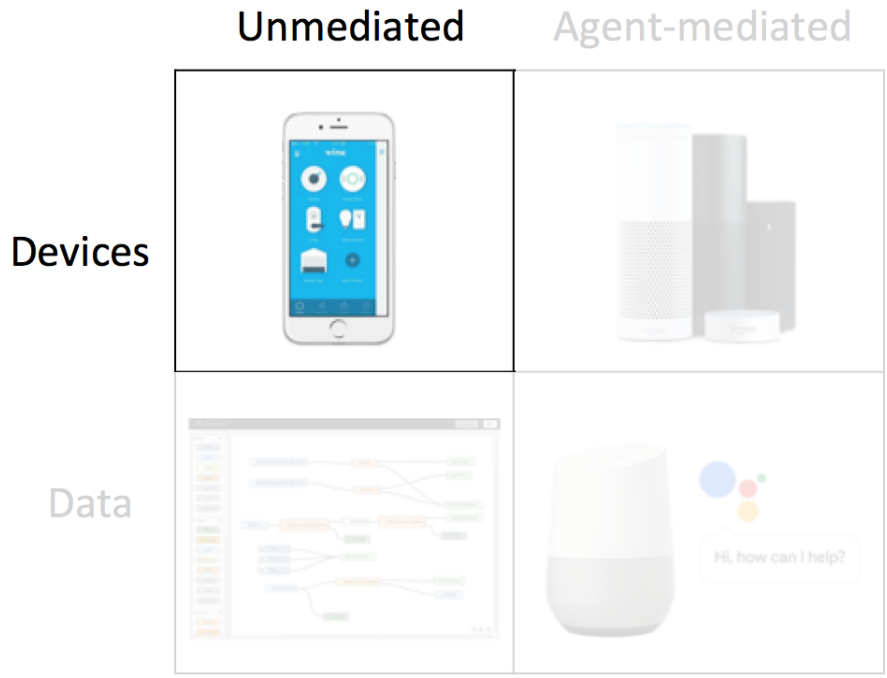




“I would definitely look for the smart door lock and smart thermostat.”

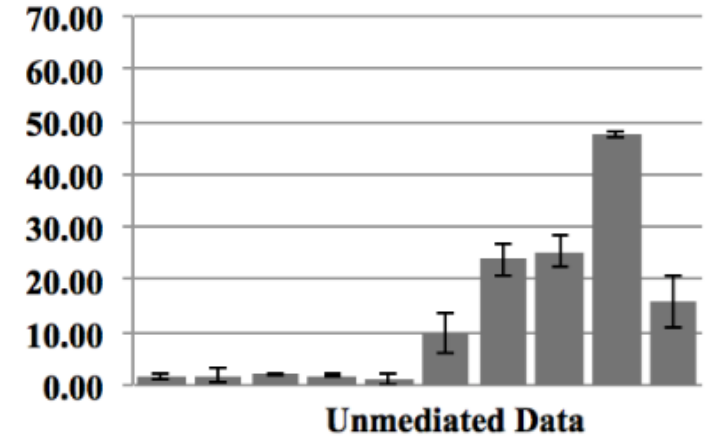
Unmediated Devices ➔ “Islands”

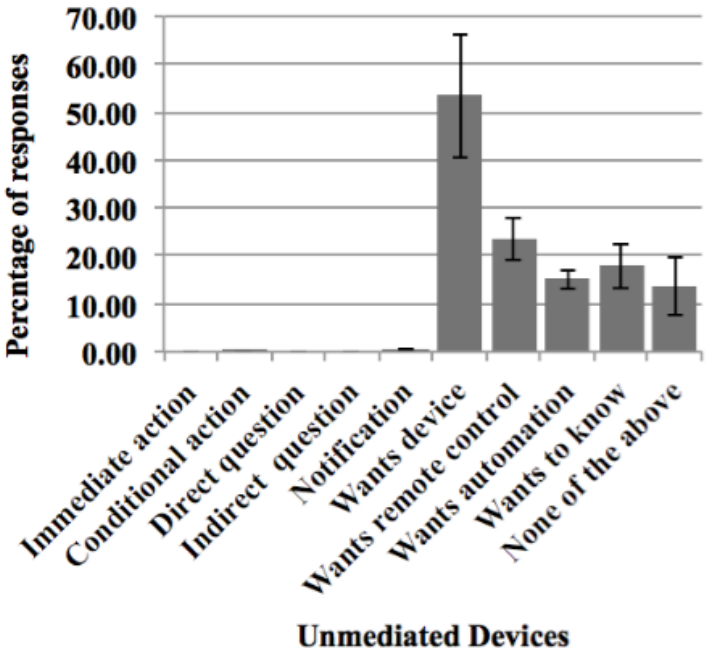
- Wanted devices instead of application
- Manual remote-control
- One-on-one interactions
- “sensor,” “phone,” “device”
- Lack of higher-level applications

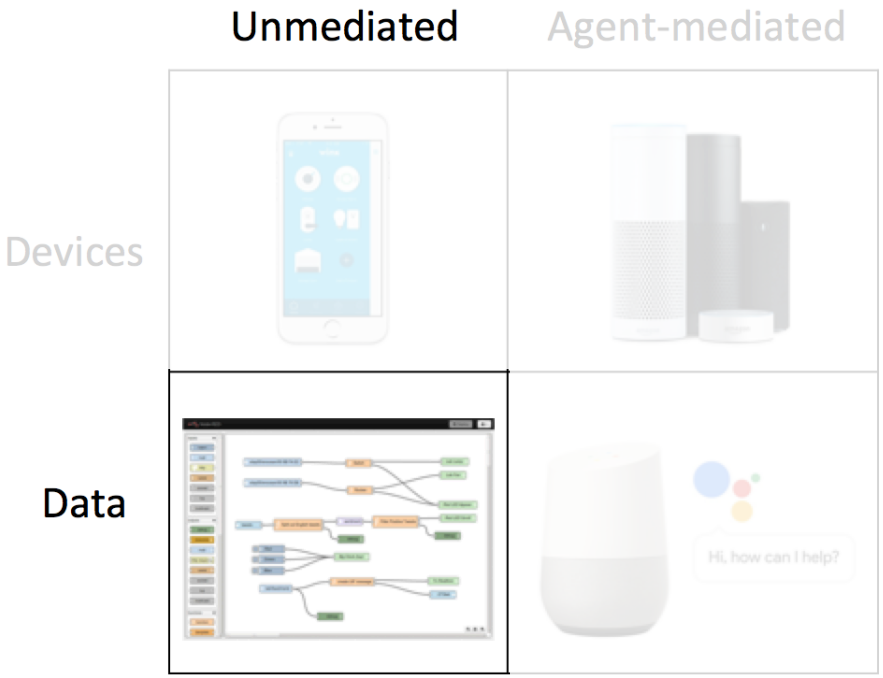


“I would definitely look for the smart door lock and smart thermostat.”

Unmediated Data ➔ “Watchdog”

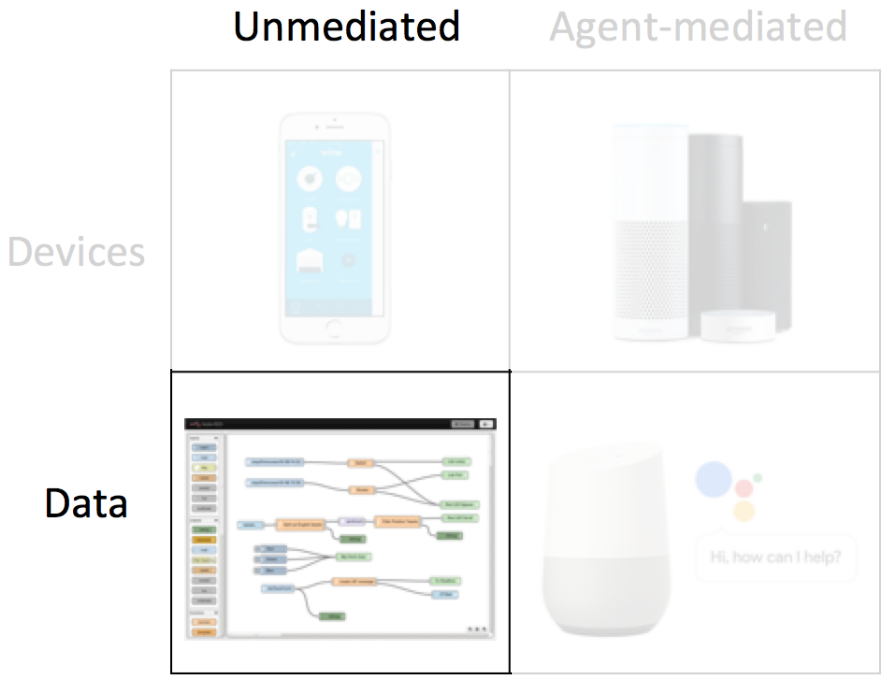






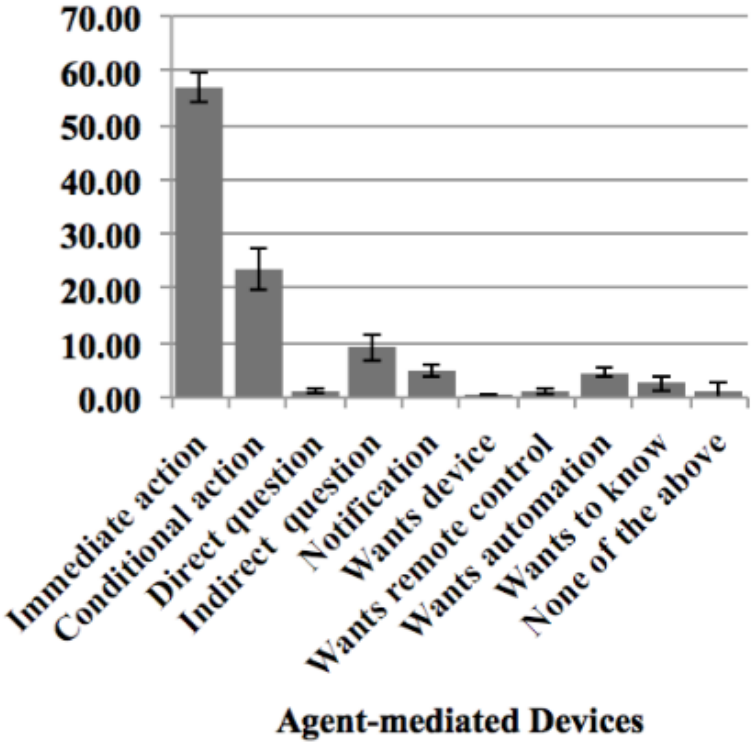
Unmediated Data ➔ “Watchdog”

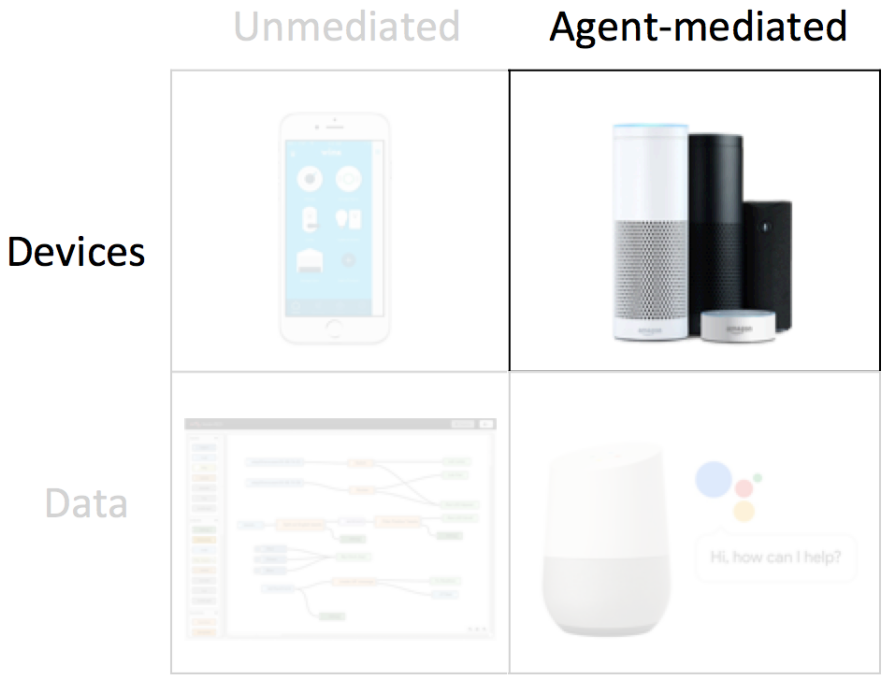
- Majority of sentences were “wants to know”
- Also wanted apps and automation
- “app” and “application”
- “alerts," “know," “see,” and “track”



“It would be nice if I could see my electricity usage in real time, and customizable alerts sent to my phone would be quite helpful.”

Agent-mediated Devices ➔ “Delegate”

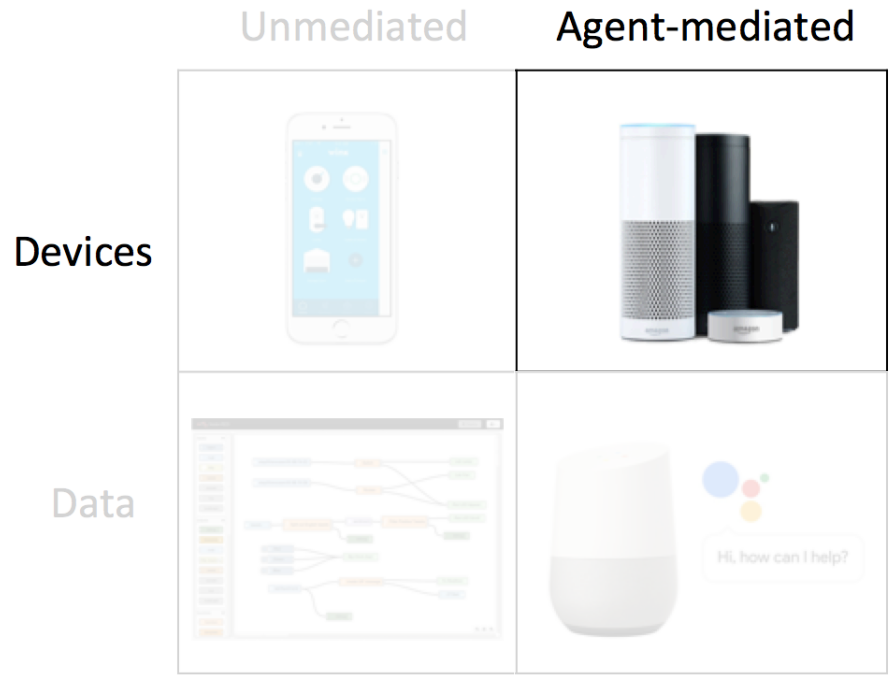




“Turn on the lights.”

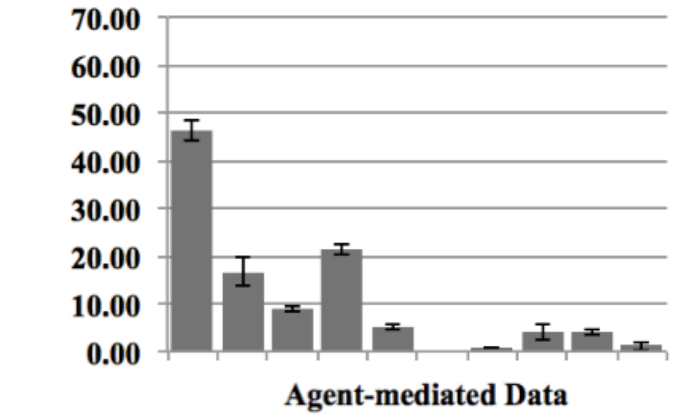
Agent-mediated Devices ➔ “Delegate”

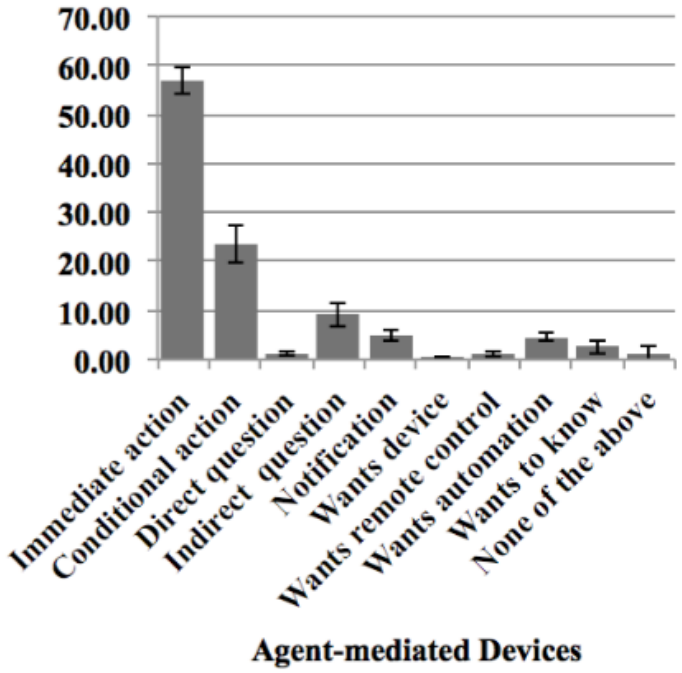
- 57% of sentences were immediate actions
- Nearly a quarter were conditional actions
- “Please” was characteristic of both agent-mediated response sets

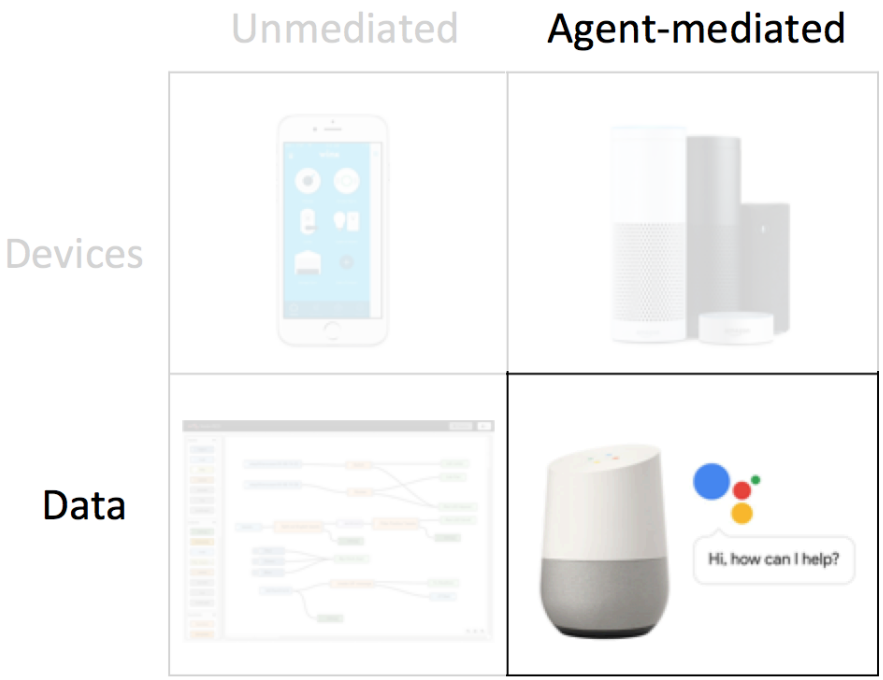


“Turn on the lights.”

Agent-mediated Data ➔ “Assistant”







Did subpopulations show differences?

Populations from the literature:

- Older vs. younger
- Technical vs. non-technical

Our populations:

- 55 and older vs. 34 and younger
- High CS exposure vs. no CS exposure

Subpopulations responded differently

Findings:

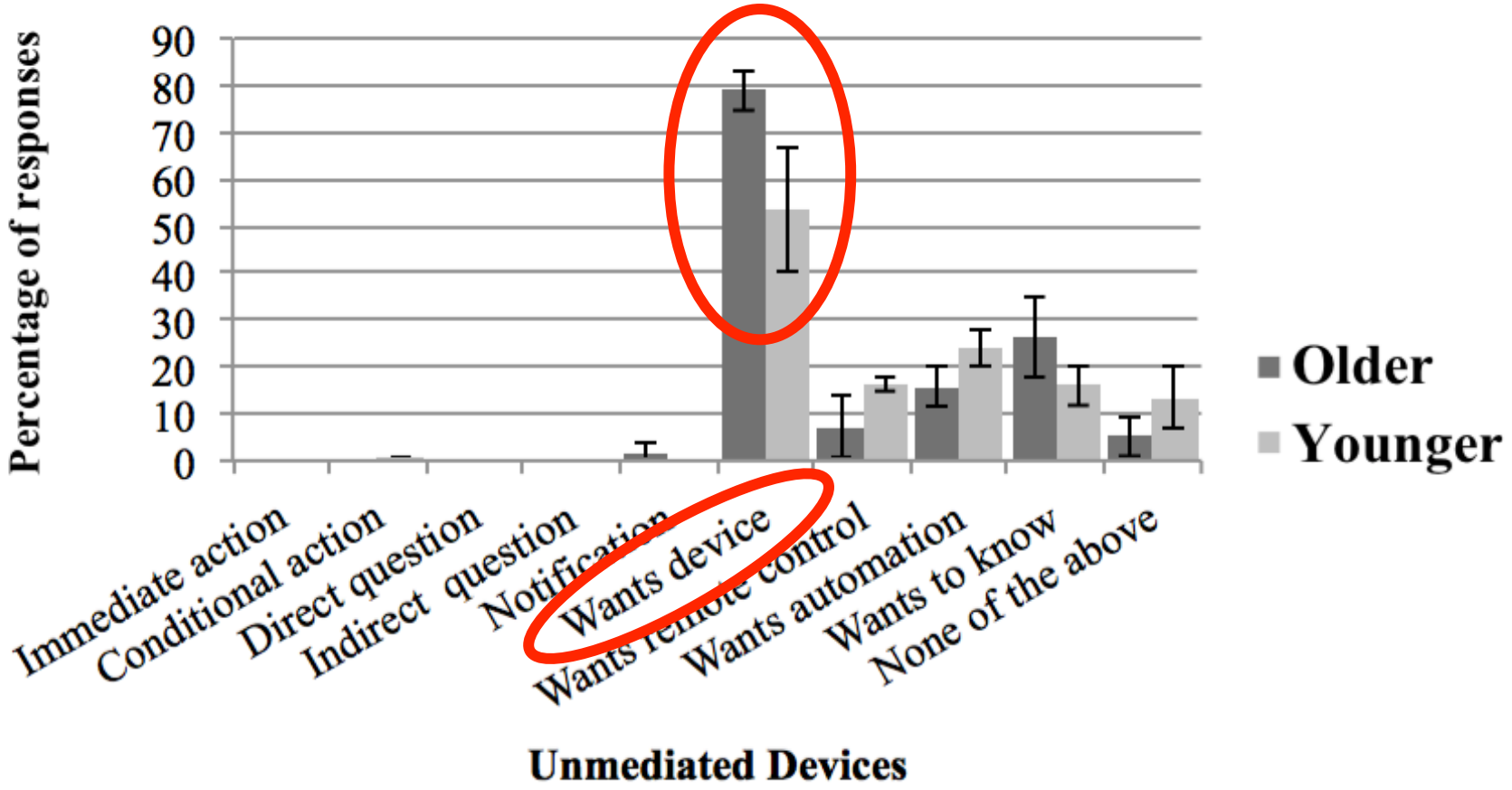
- Older subjects responded more strongly to priming than younger subjects
- Subjects with no CS exposure responded no differently than subjects with high CS exposure on Unmediated Devices prompt
- Subjects with no CS exposure responded more strongly to priming on remaining three prompts

Implications:

- Smart home work motivated by elder care needs to evaluate with older subjects
- Evaluations for general population must involve non-technical users, especially since the primary users of home technology are often non-technical “passive users.”*

* Sarah Mennicken and Elaine M Huang. 2012. Hacking the Natural Habitat: An In-the-Wild Study of Smart Homes, Their Development, and the People Who Live in Them. LNCS 7319 (2012), 143–160

Older subjects responded more strongly to priming than younger subjects



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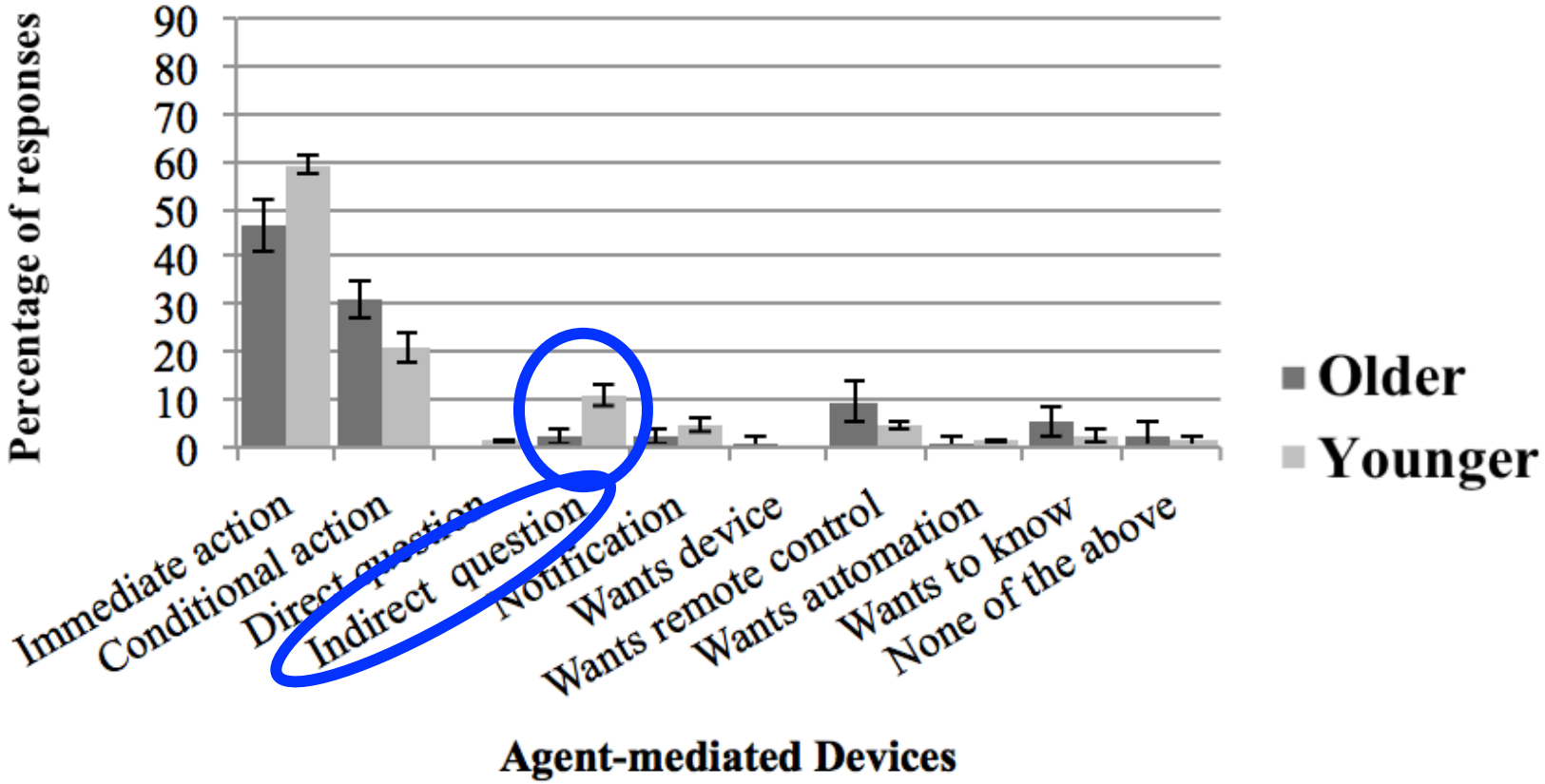

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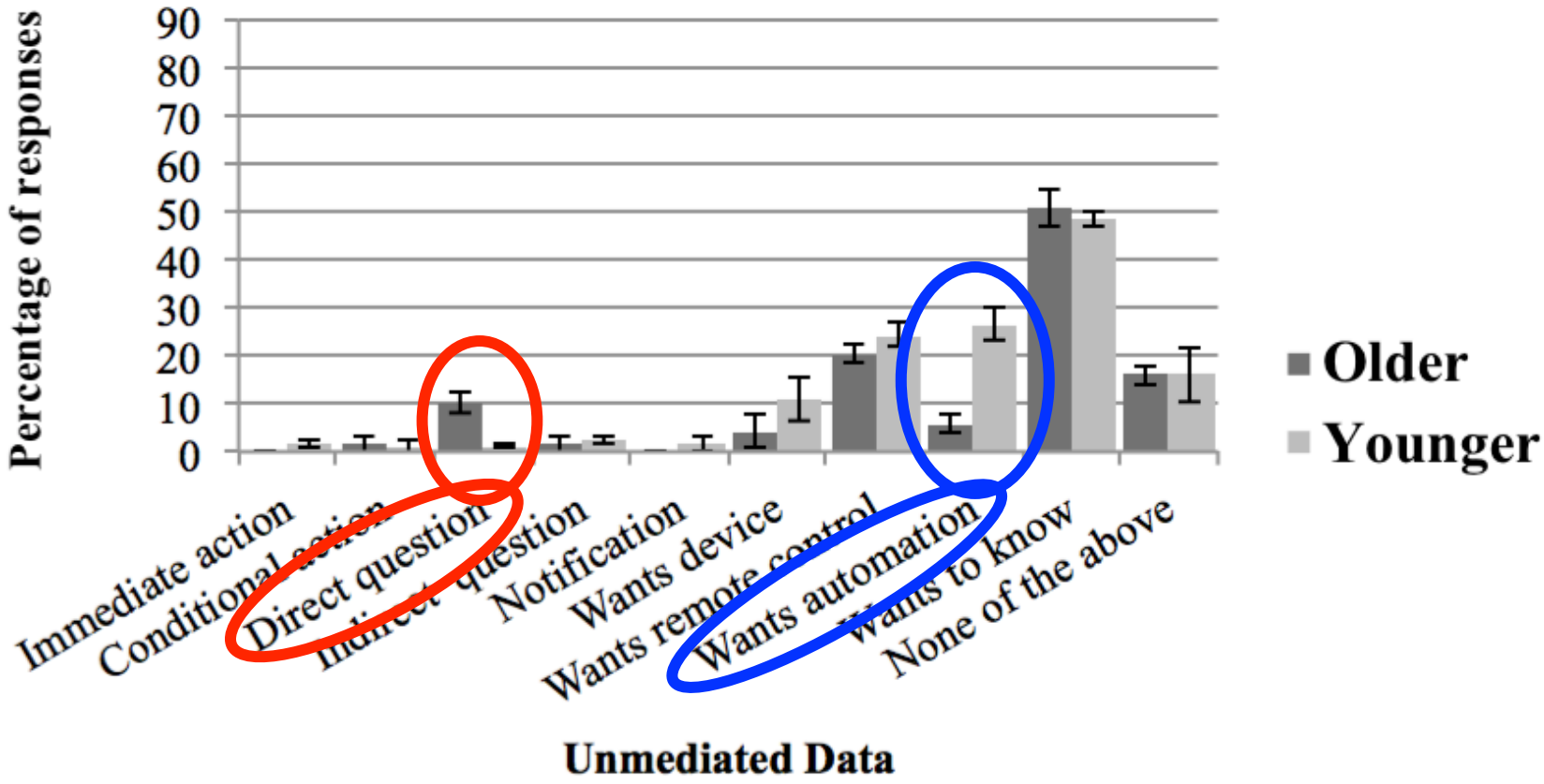

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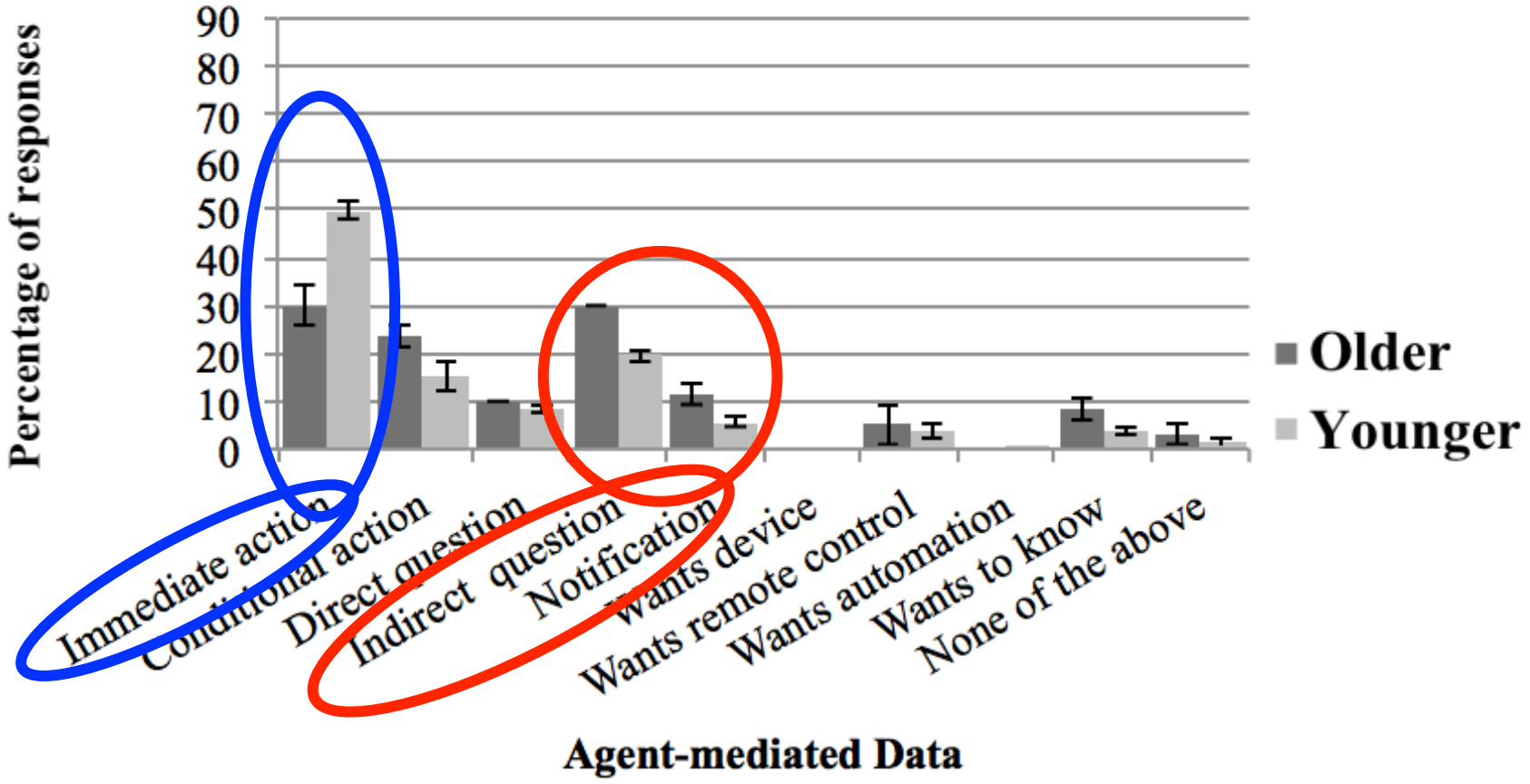
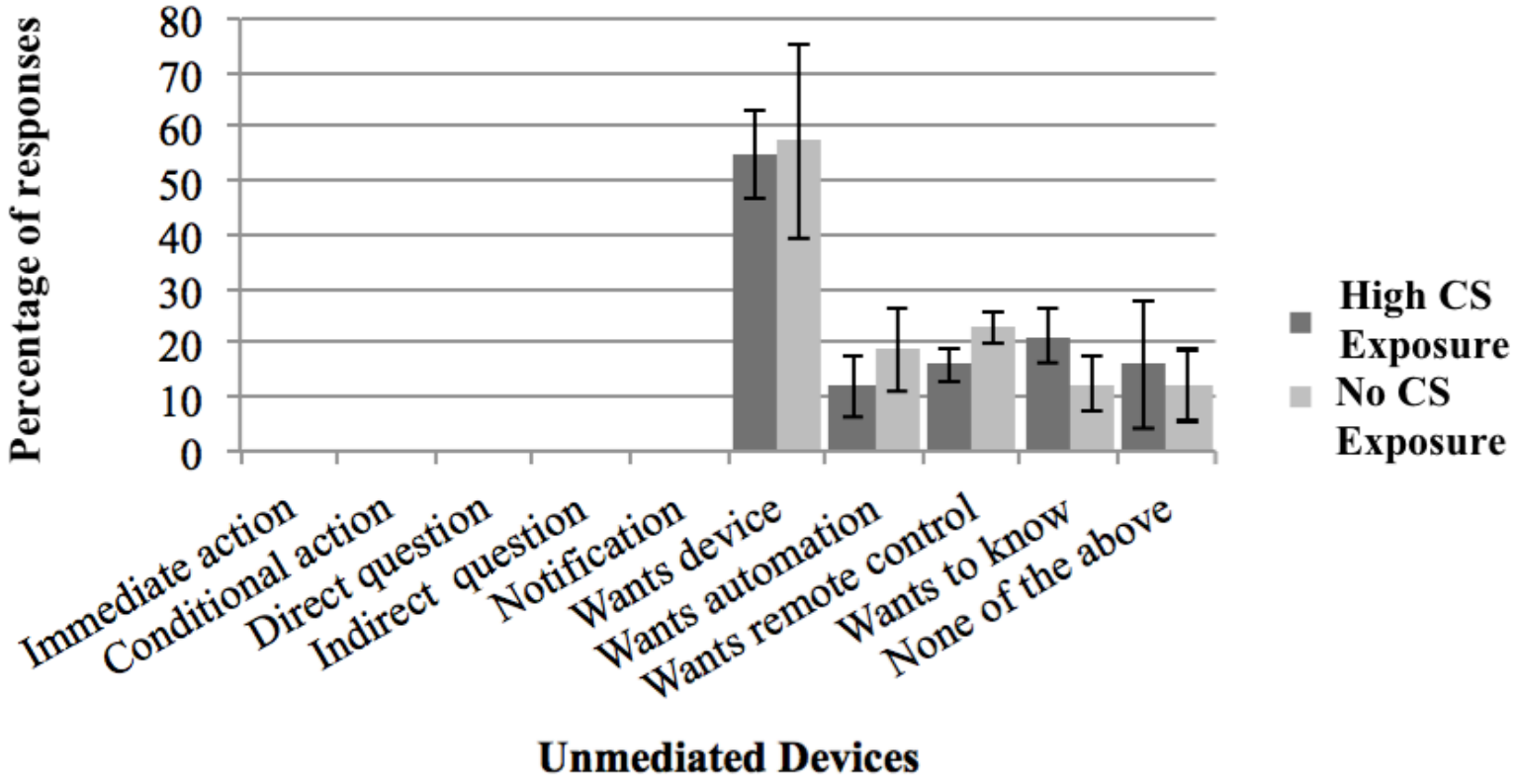
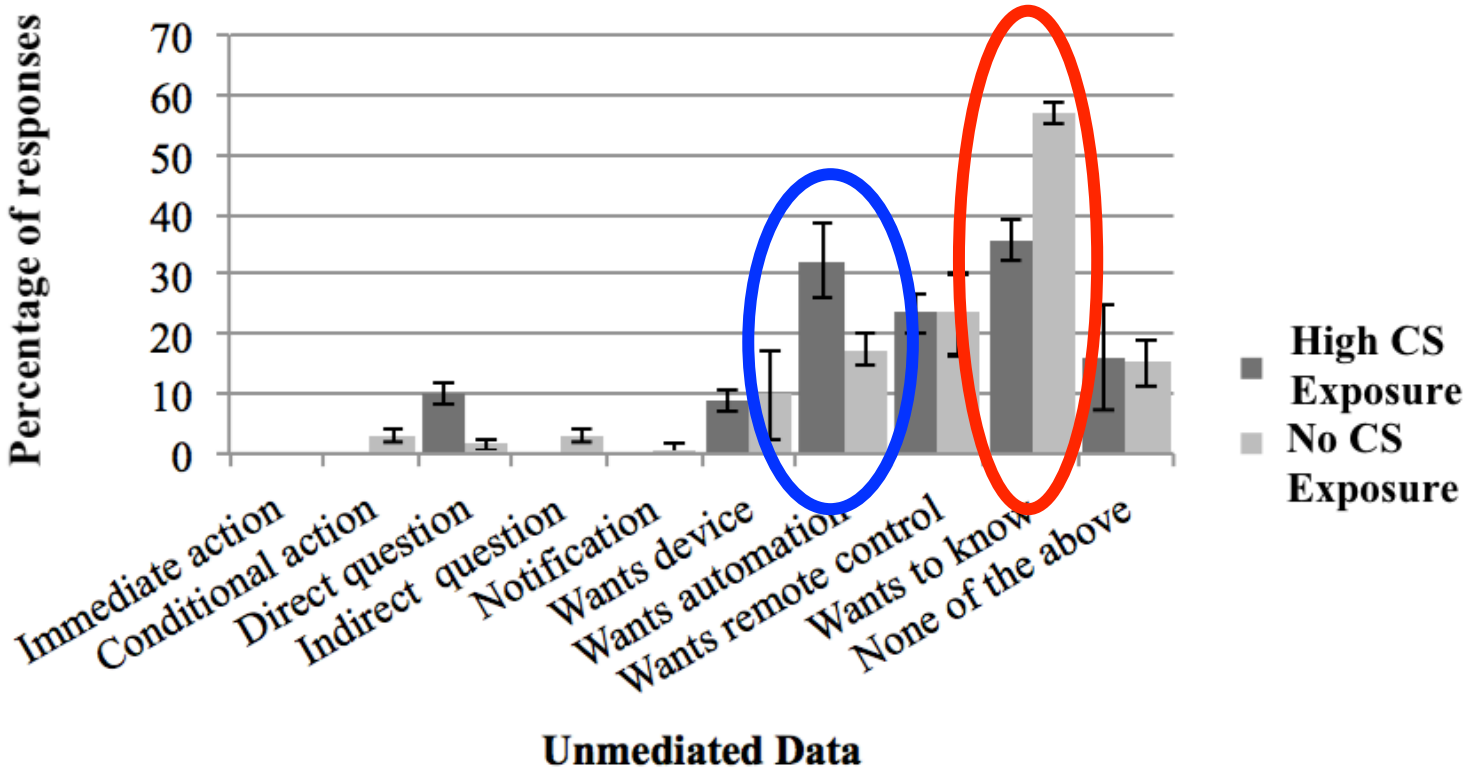


How about technical vs. non-technical populations?

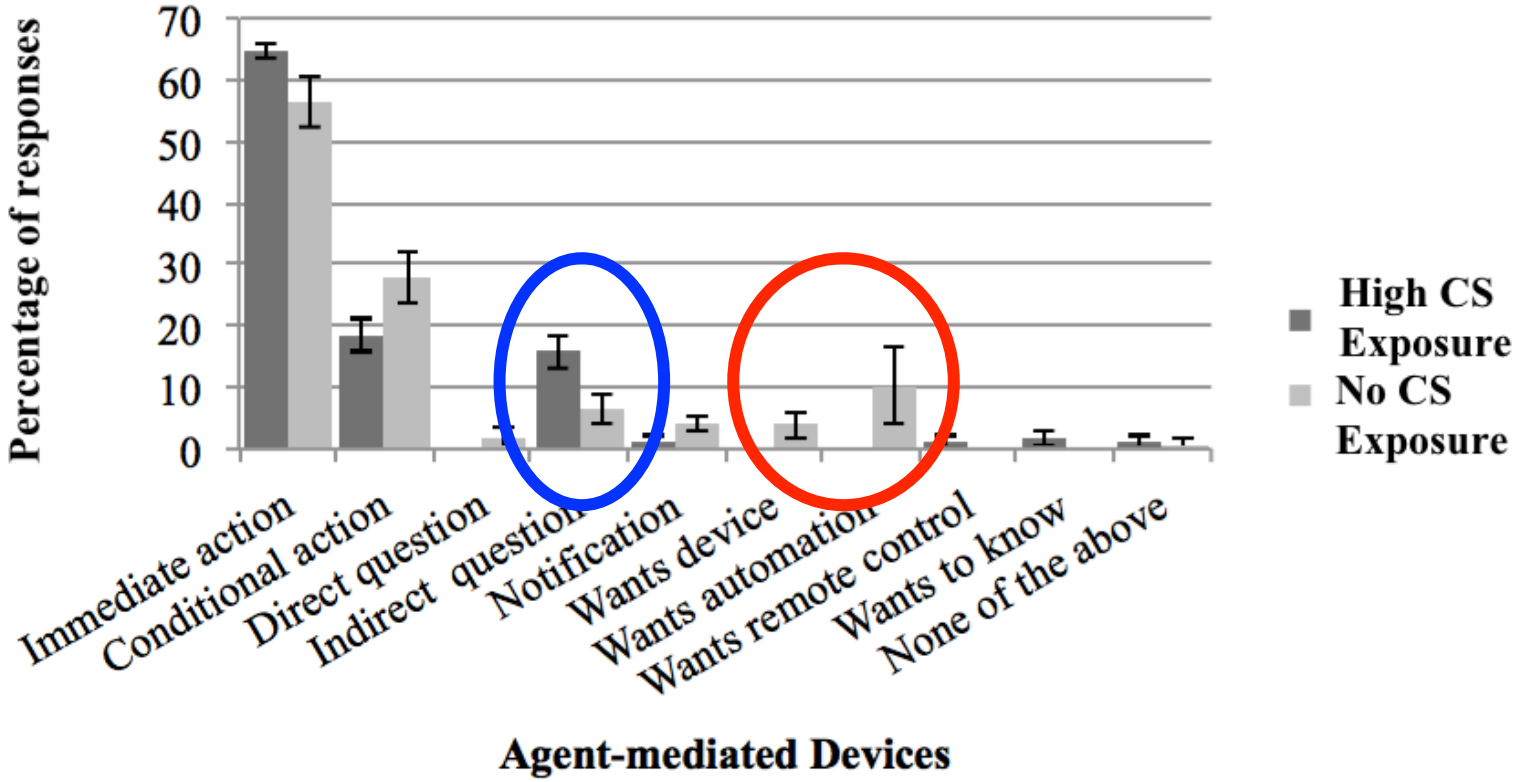
There was no significant difference between experts and non-experts for the most common conceptual model.



However, there were differences for the remaining three conceptual models.



Subjects without CS exposure responded more strongly to priming than those with high CS exposure



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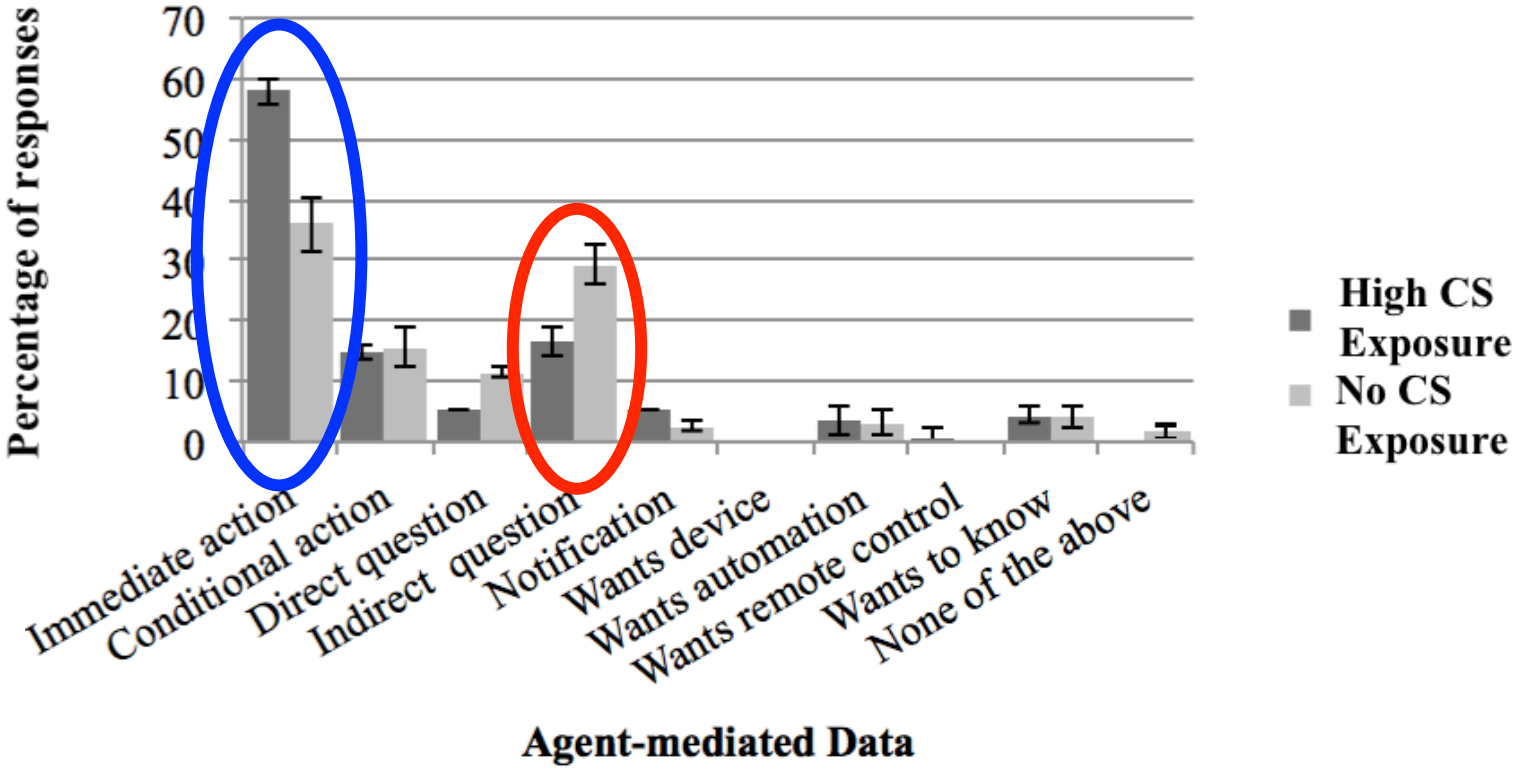

Bonus Finding: User-friendly IoT systems require native AI support

Bonus: Systems require native AI support

- Prediction (“Have coffee ready **before** I wake up”)

Bonus: Systems require native AI support

- Prediction
- Goals ("Turn on the lights at 8 AM **so that** I wake up")

Bonus: Systems require native AI support

- Prediction
- Goals
- Explanation
  - Not a single agent-based response included “why”!

So what are the takeaways?

THE IMPLICATIONS

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- Mental models researchers should do comparative studies

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- Mental models researchers should do comparative studies
- System designers should be aware that the interface choices will influence system workload
- Choose your test subjects well
- Both questions and commands are important
- AI should be built into low levels of the IoT stack
- And finally...

Unmediated Devices considered harmful?

IoT Interfaces for Everyday People

Meghan Clark

Intel/NSF CPS-Security Final PI Meeting

7/12/2018

mclarkk@berkeley.edu