Practical Trigger-Action Programming in the Smart Home

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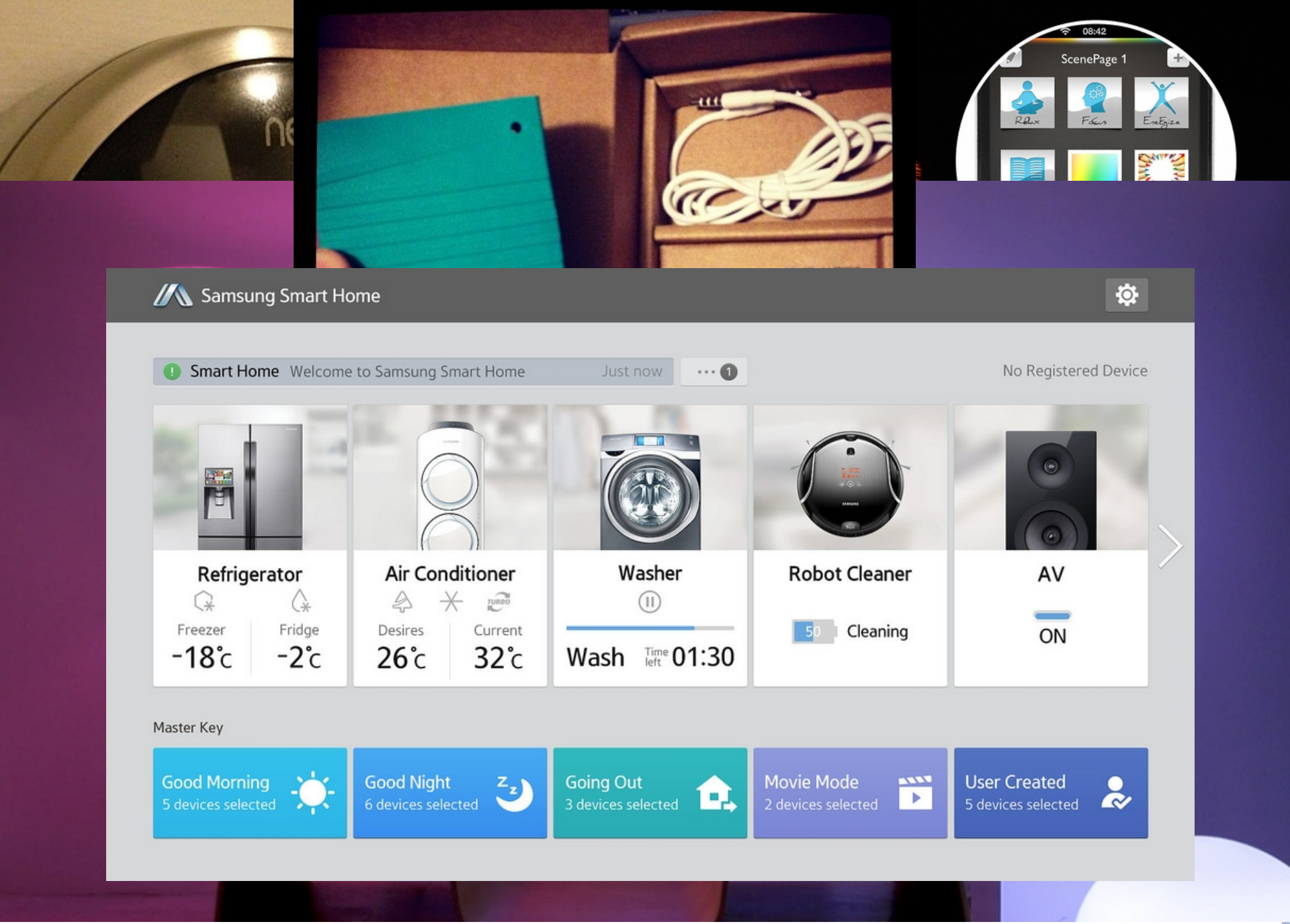
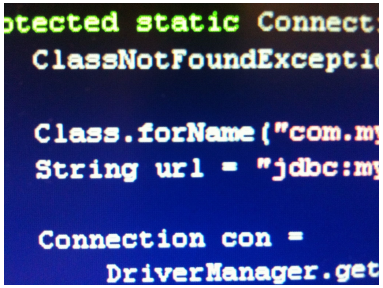


Programming a Smart Home

- Traditional programming languages



- App store

- End-user programming (e.g., “trigger-action”)

How do we make trigger-action programming in the smart home practical? (…and should we?)

Approach

- **Study 1:** Desired smart-home behaviors
- **Study 2:** Real-world IFTTT.com programs
- **Study 3:** Trigger-action usability

Study 1: Desired Behaviors

"Imagine that you have a home with devices that are Internet-connected and can therefore be given instructions on how to behave. What are five things you would want your home to do?"

- 318 U.S. MTurkers compensated $0.45
  - Ages 18–70 (median 25), 69% male
- Two coders classified each behavior

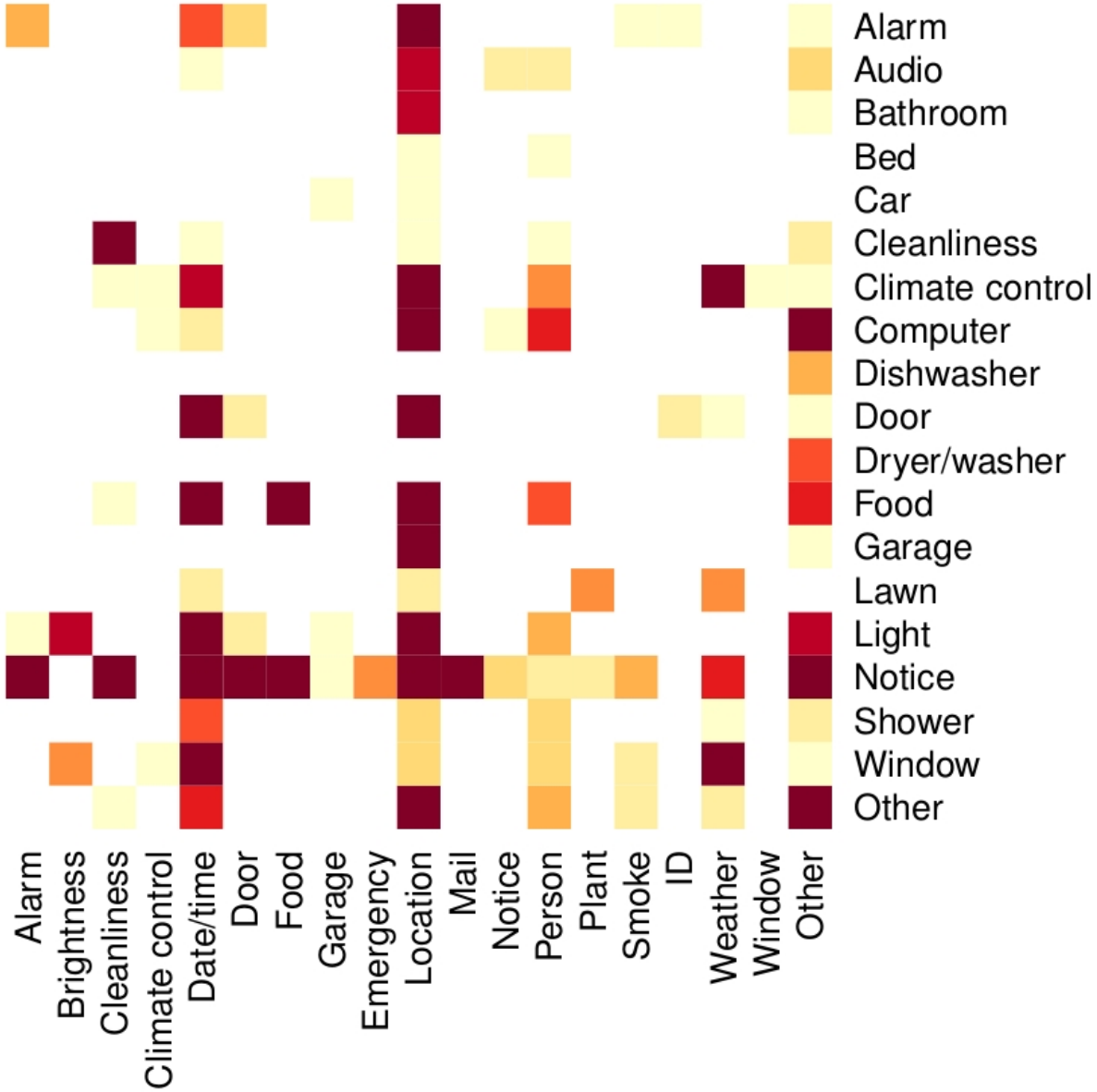
Programming?

- Over half of behaviors were programming
  - e.g., “I would like my home to automatically clean the floors on a daily basis while no one is in the room”
- Remaining behaviors:
  - Remote operation
  - Automatic adjustments
  - Specialized functionality

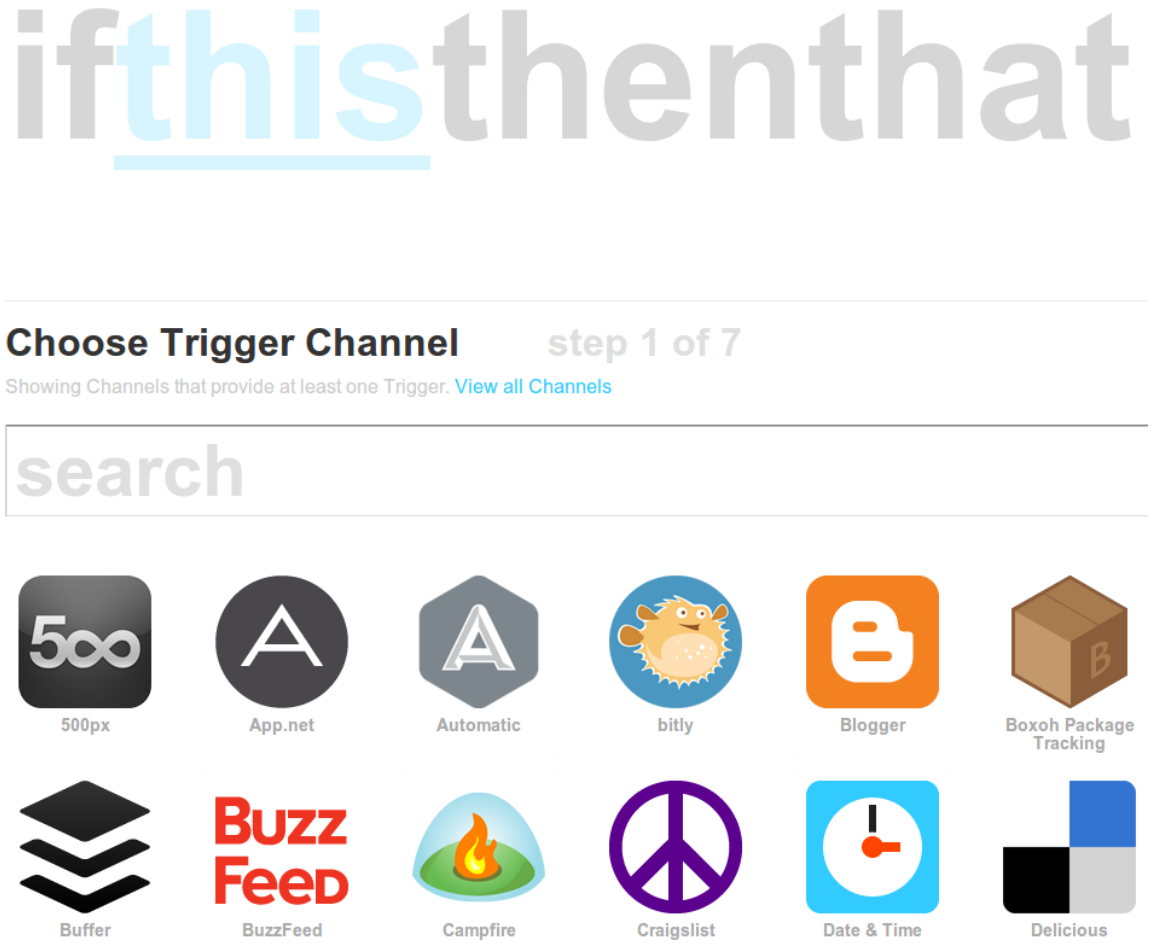
Triggers' Level of Abstraction

- 31 triggers were sensors in the engineering sense (e.g., doorbell, light, moisture)
- 26 triggers were activities / states (e.g., “when I pick up my toothbrush”)
- 14 triggers required complex decision making
  - “I would like to be notified when my pool chemicals drop lower than normal”
  - “Turn off the air conditioning when it senses I'm cold and shivering at night”
  - Hunger, cooked, dirtiness, discomfort

Combinatorics

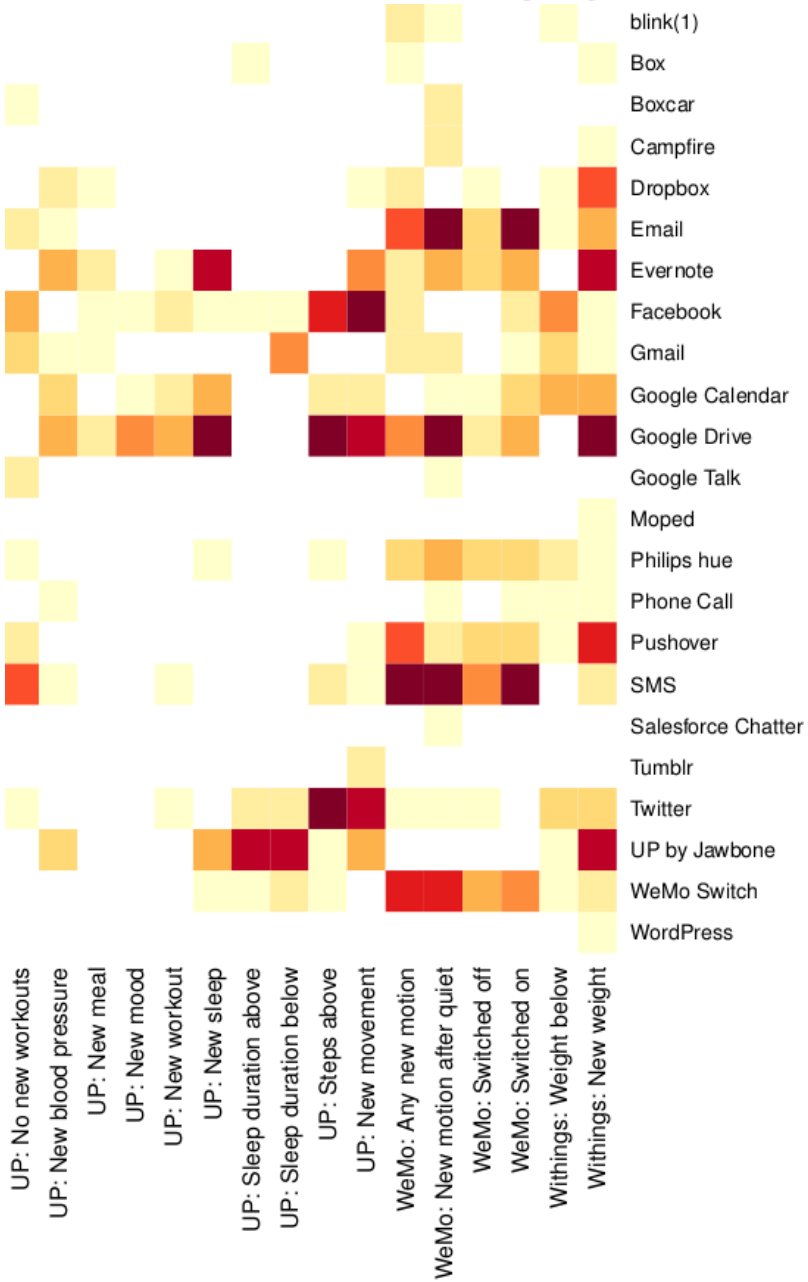


Study 2: IFTTT Analysis

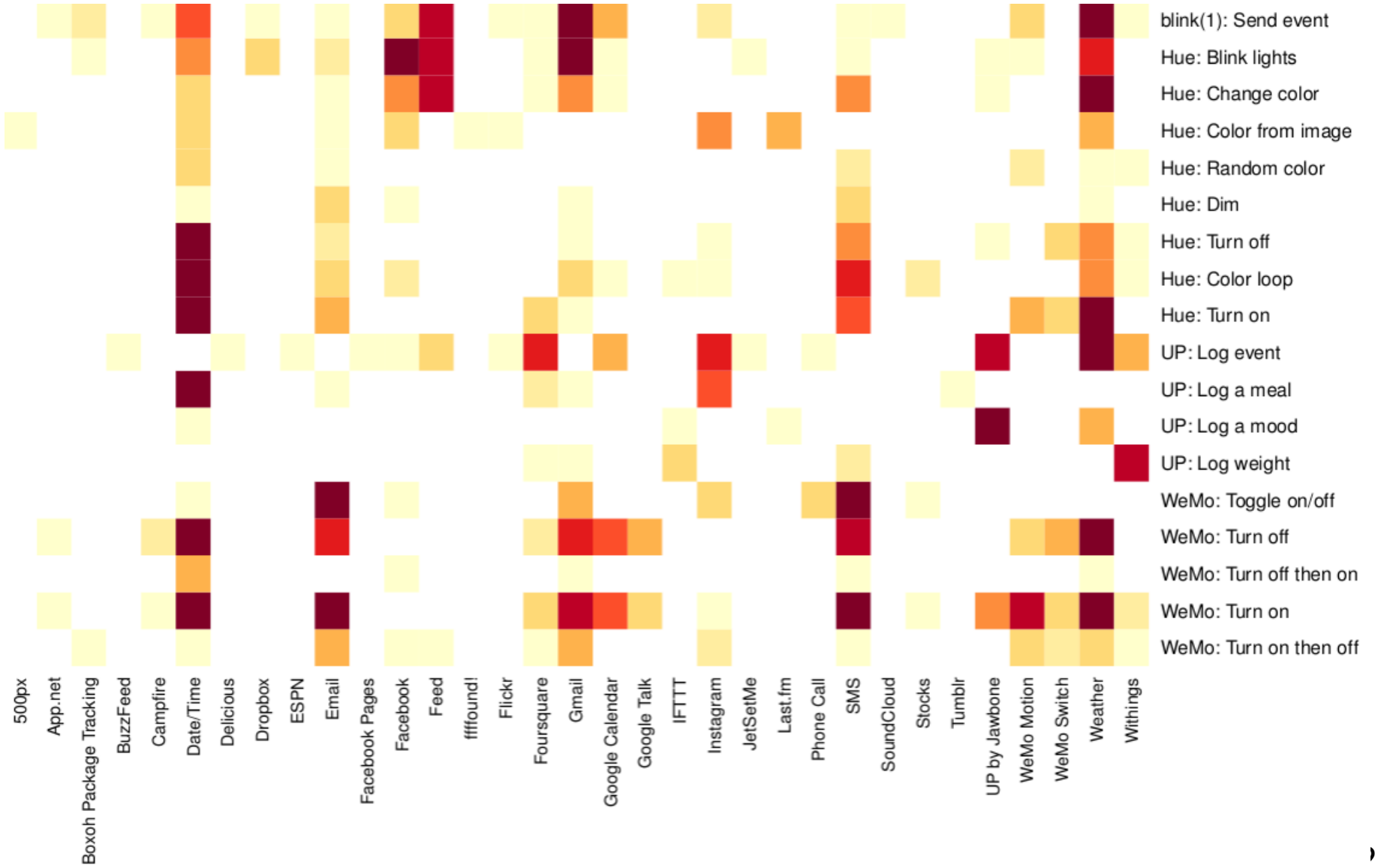


- Scraped all 67,169 programs shared publicly on IFTTT.com by 35,295 different authors

Combinatorics (Triggers)

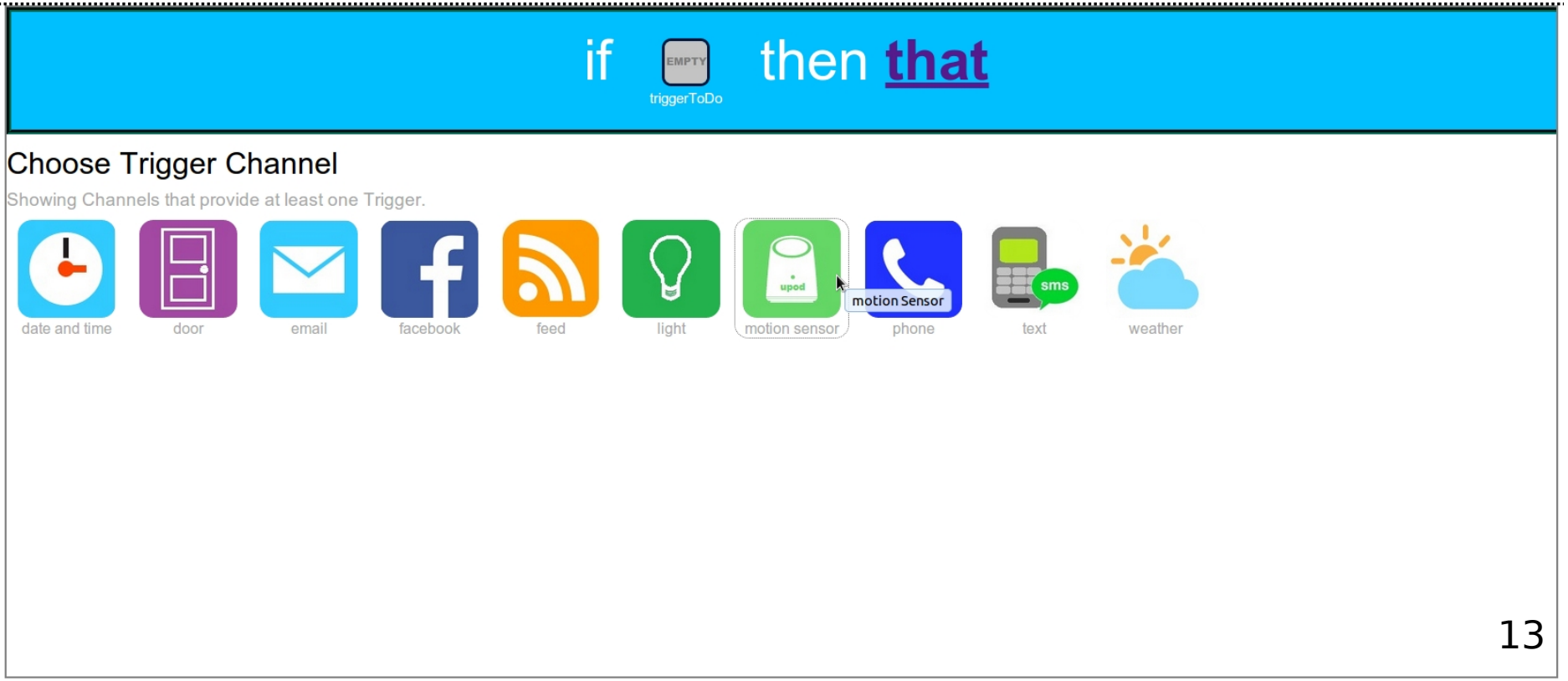


Combinatorics (Actions)



Study 3: Usability Test

- We built an interface styled after IFTTT.com
  - *Simple* version: 1 trigger, 1 action
  - *Complex* version: 2+ triggers, 2+ actions

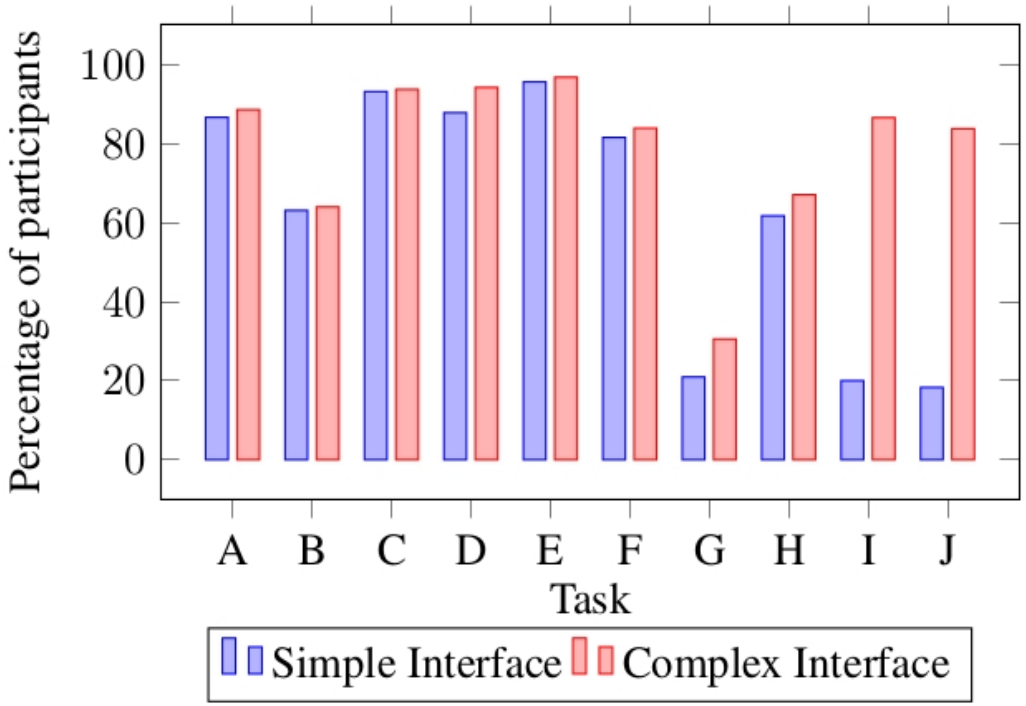


Study 3: Usability Test

- Participants tried to program 10 tasks:
  - 6 could be solved with either interface
  - 2 could not be solved
  - 2 could be solved with complex interface
- 226 U.S. MTurkers compensated $2.00
  - Ages 18–67 (median 30), 47% male
  - 72% had no prior programming experience

Results

- Most tasks solved by 80%+ of participants



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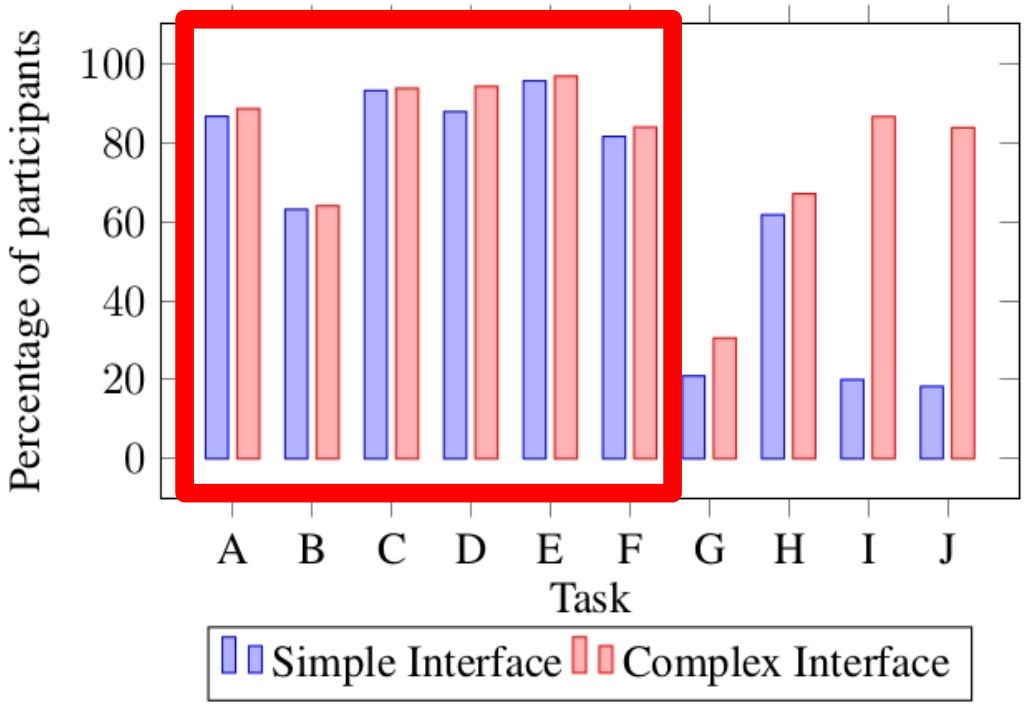

“Turn on the lights when the sun sets.” (D)

Results

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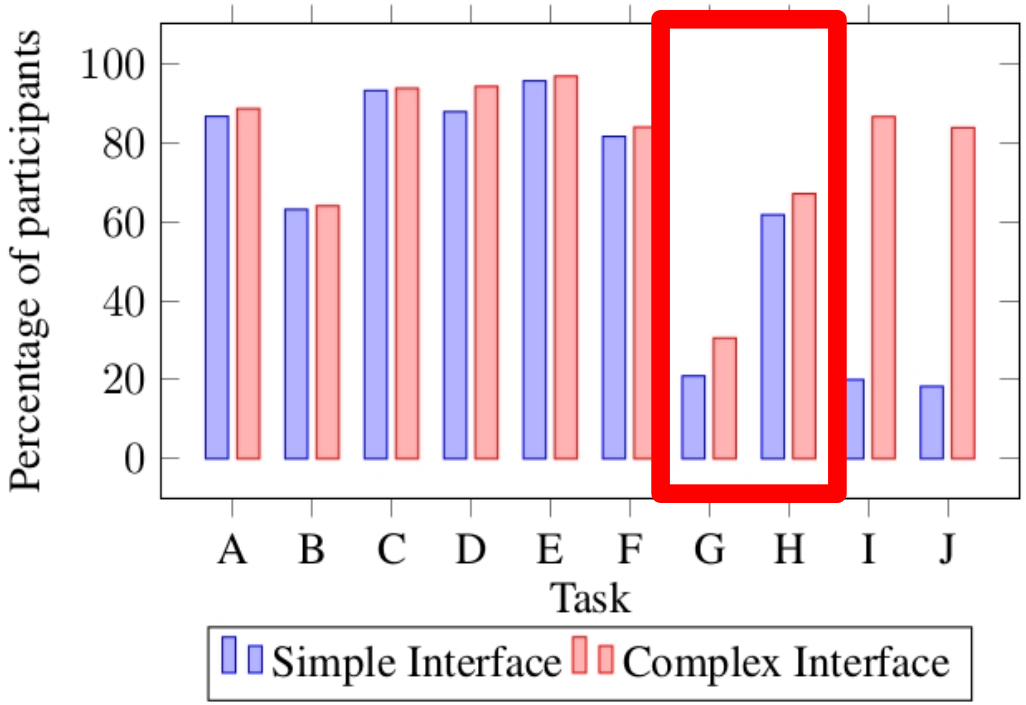

“The lighting in my bedroom should be on when I am there and off when I am not there.” (G)

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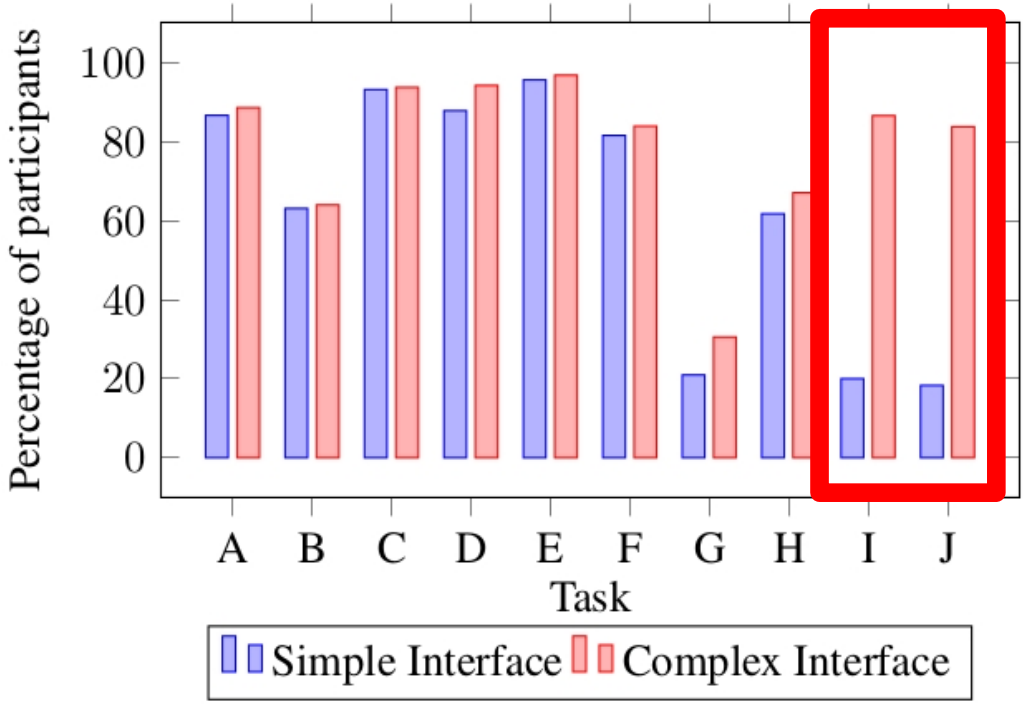


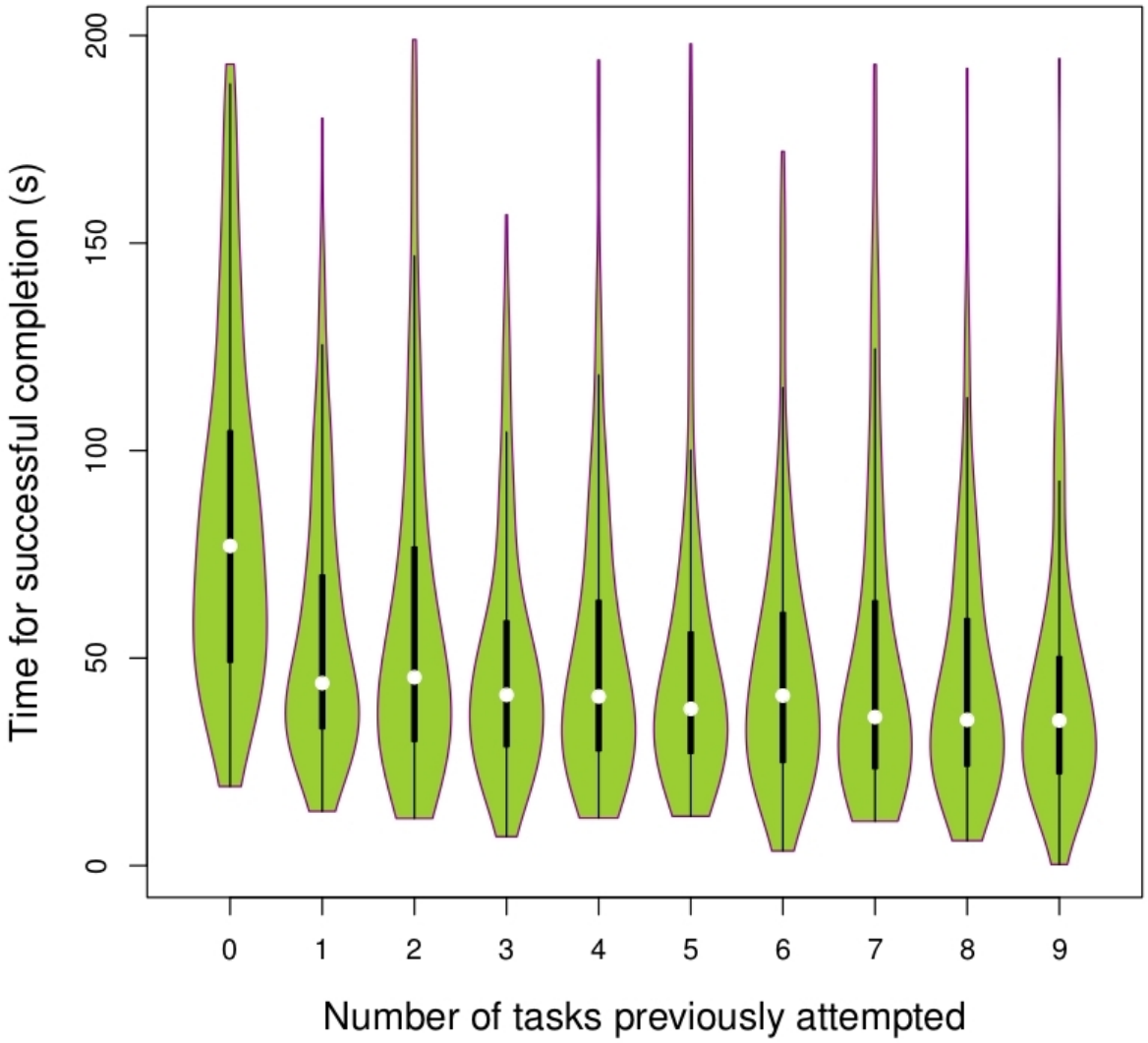
“If it is 10:00pm and my bedroom door is closed and the lights are off, turn the television off.” (I)

Results

- Examined correlation between demographics and success / time
- Older participants less successful and took longer than younger participants
- Prior programming experience and gender not significant factors

Results

- Significant learning effect



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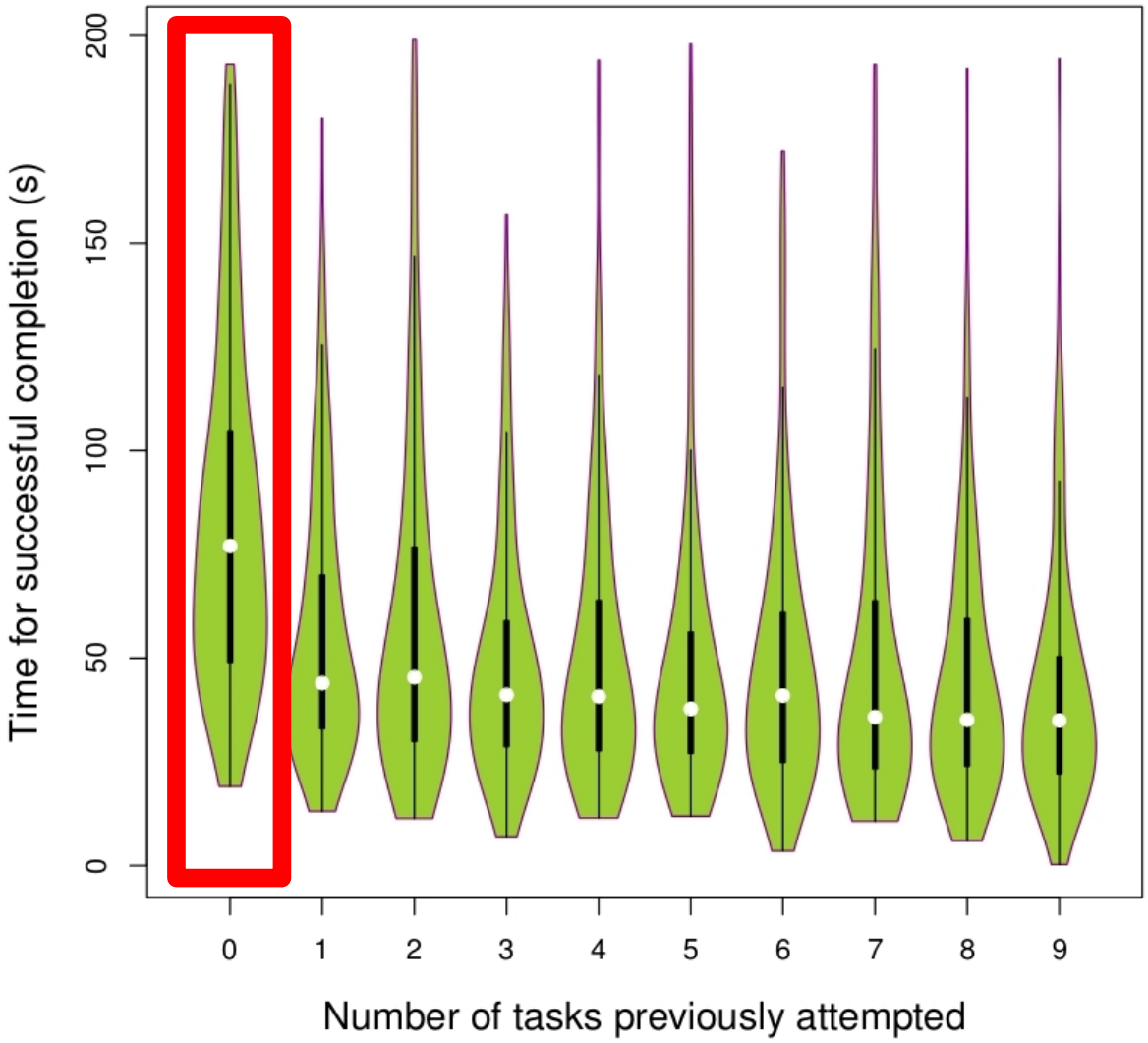

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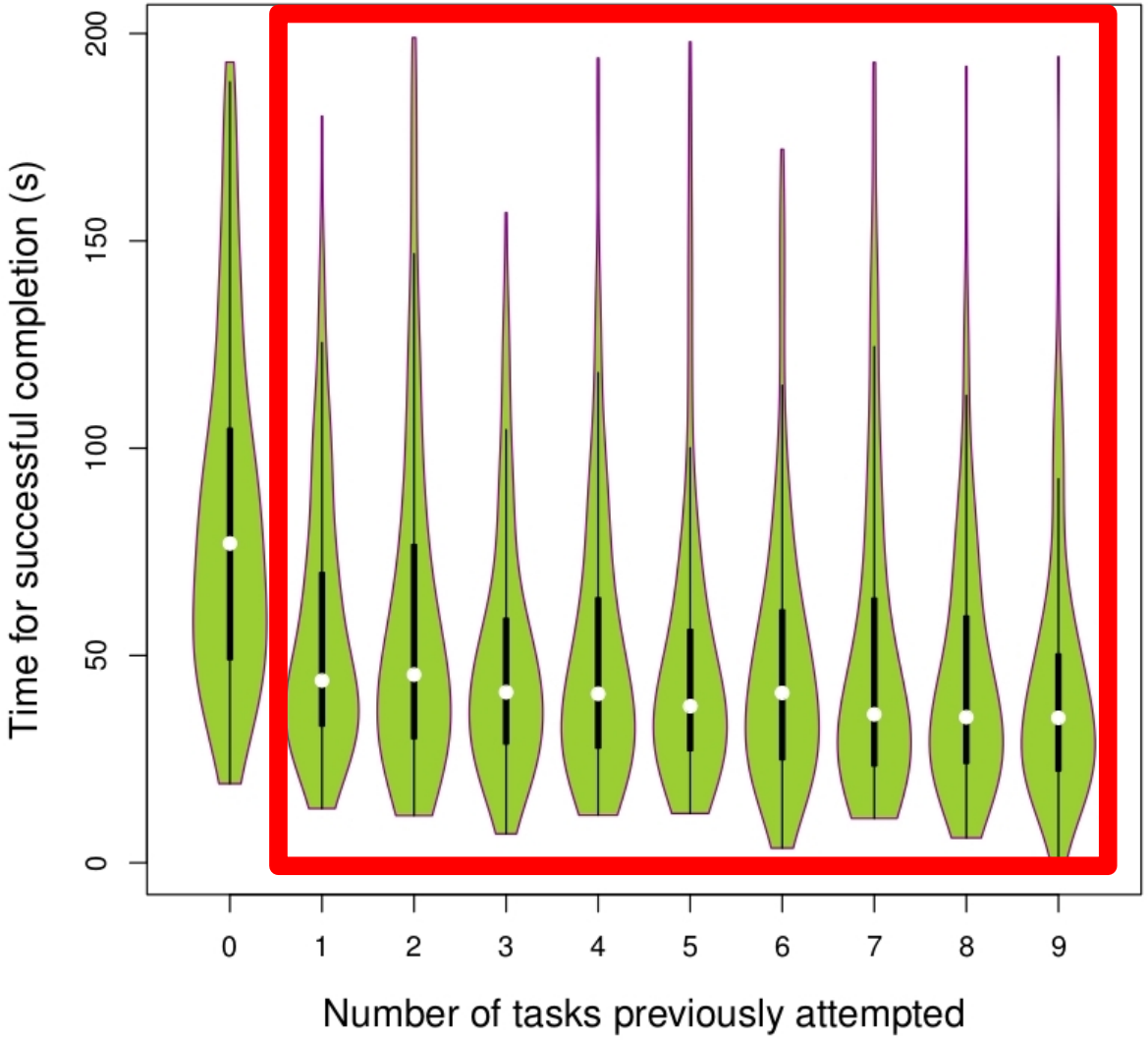

Limitations

- Did not investigate any competing approaches to smart-home programming
- Hypothetical smart home
- IFTTT and MTurk communities are self-selected early adopters (not necessarily generalizable)

Conclusions

- Most desired behaviors involved programming
- Triggers with complex decision making
- Diversity of behaviors → end-user programming
- Participants 80%+ successful on most tasks
  - Including non-programmers
  - Including multiple triggers / actions

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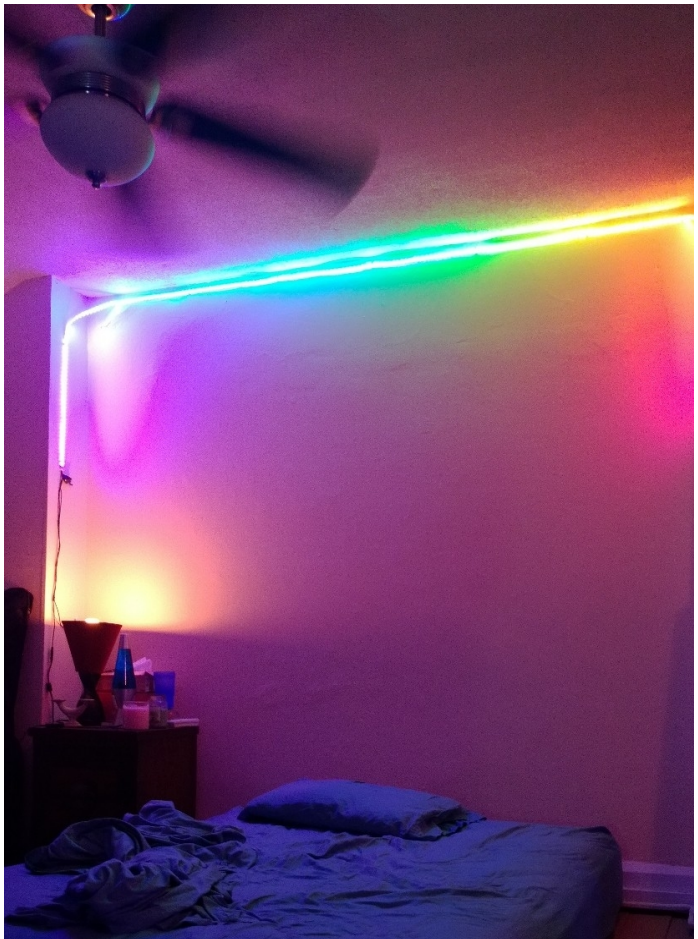

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