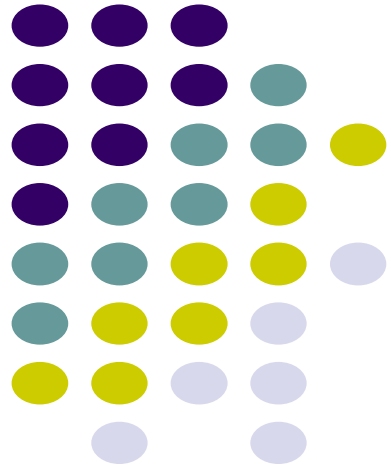
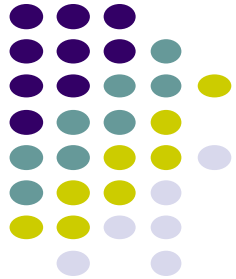
CS 528 Mobile and Ubiquitous Computing

Lecture 11a: Energy Efficiency

Emmanuel Agu





Sandra Helps You Learn: The More you Walk, the More Battery Your phone drains, *Ubicomp 2015*

Problem: Continuous Sensing Applications Drain Battery Power

C Min *et al,* Sandra Helps You Learn: the More you Walk, the More Battery Your Phone Drains, in Proc Ubicomp '15

- Battery energy is most constraining resource on mobile device
- Most resources (CPU, RAM, WiFi speed, etc) increasing exponentially *except* battery energy (ref. Starner, IEEE Pervasive Computing, Dec 2003)

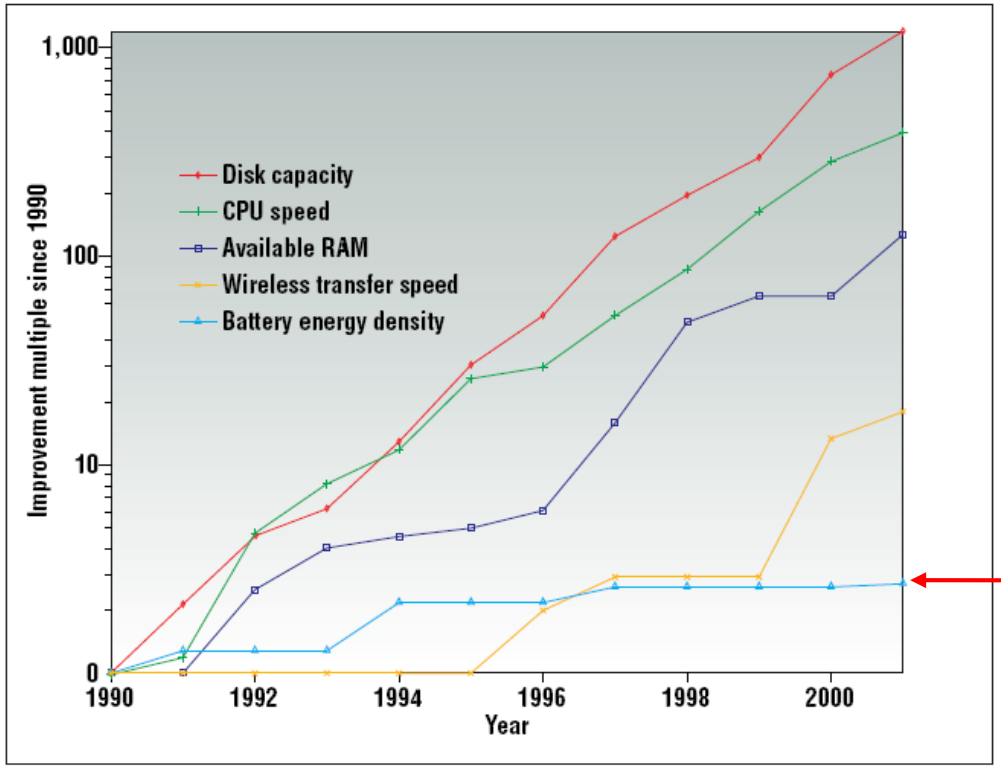


Figure 1. Improvements in laptop technology from 1990–2001.

Battery energy density barely increased

Problem: Continuous Sensing Applications Drain Battery Power

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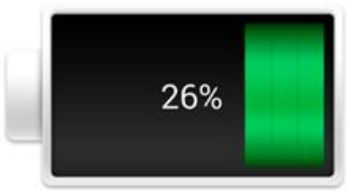
- CSAs (Continuous Sensing Apps) introduce new major factors governing phones' battery consumption
  - E.g. Activity Recognition, Pedometer, etc
- How? Persistent, mobility-dependent battery drain
  - Different user activities drain battery differently
  - E.g. battery drains more if user walks more



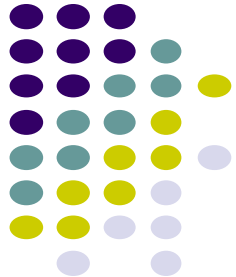
Google Fit:
activity tracking

Moves:
activity/place tracking

Accupedo:
pedometer

Dieter:
pedometer

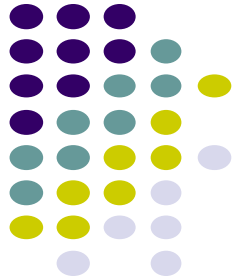
Sandra: Goal & Research Questions



- E.g. Battery at 26%. User's typical questions:
  - How long will phone last from now?
  - What should I do to keep my phone alive until I get home?

- Users currently informed on well-known factors draining battery faster
  - E.g. long calls, GPS, bright screen, weak cell signal, frequent app usage

Sandra: Goal & Research Questions

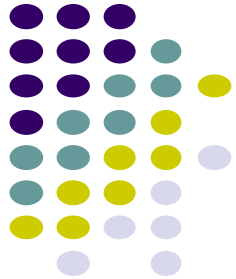


- Users currently don't accurately understand CSAs battery drain or include it in their mental model of battery drain
  - CSA energy drain sometimes counter-intuitive
  - E.g. CSA drain is **continuous** but users think drain only during activity (e.g. walking)
  - Battery drain depends on activities performed by user

- Paper makes 2 specific contributions about energy drain of CSAs

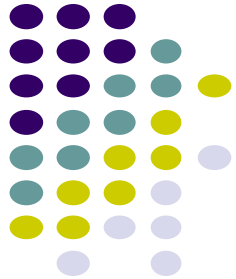
  1. **Quantifies CSA battery impact:** Nonlinear battery drains of CSAs
  2. Investigates/corrects **user's incorrect perceptions** of CSAs' battery behaviors

Sandra: Goal & Research Questions



- **Battery information advisor (Sandra):**
  - Helps users make connection between battery drain (including CSAs) and their activities
  - Forecasts battery drain under different **future** mobility conditions
    - E.g. (stationary, walking, transport) + (indoor, outdoor)
  - Maintains a history of **past** battery use under different mobility conditions

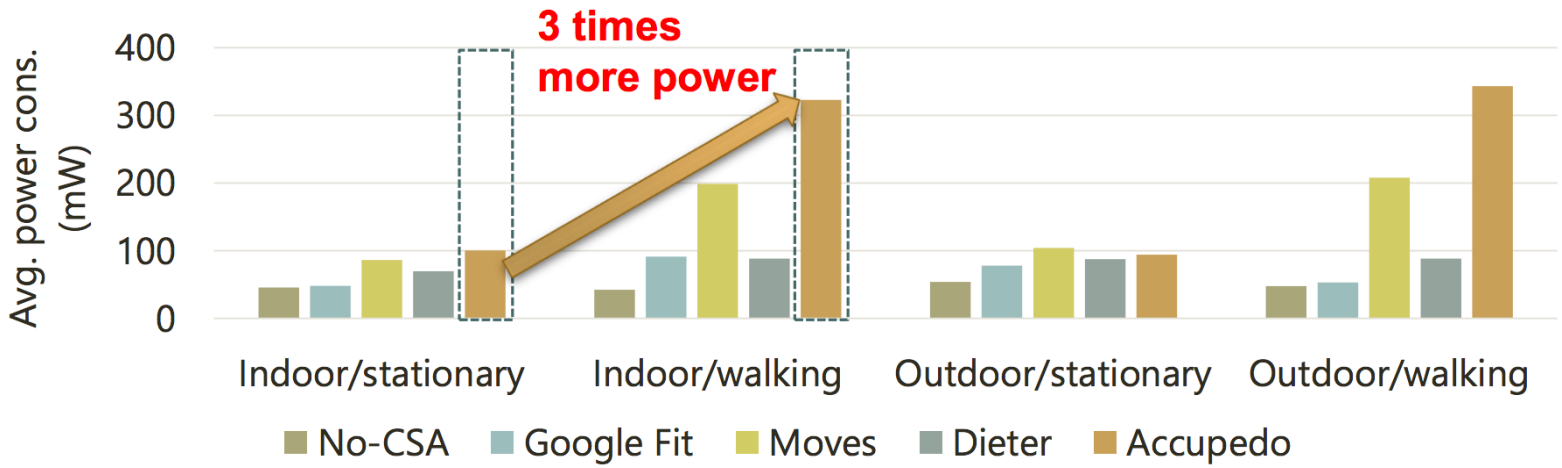
First Step: Measure Battery Consumption of 4 CSAs



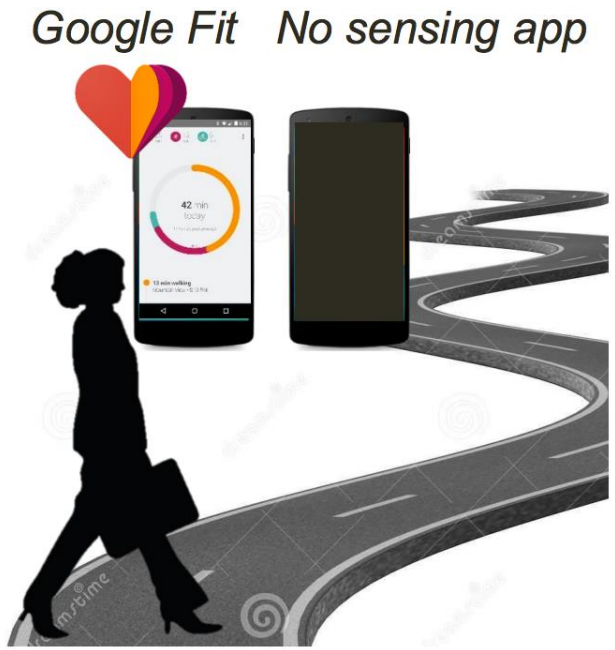
- **Google Fit:**
  - Tracks user activity continuously (walking, cycling, riding, etc)
- **Moves:**
  - Tracks user activity (walking, cycling, running), places visited and generates a storyline
- **Dieter:**
  - Fitness tracking app in Korea
- **Accupedo:**
  - Pedometer app

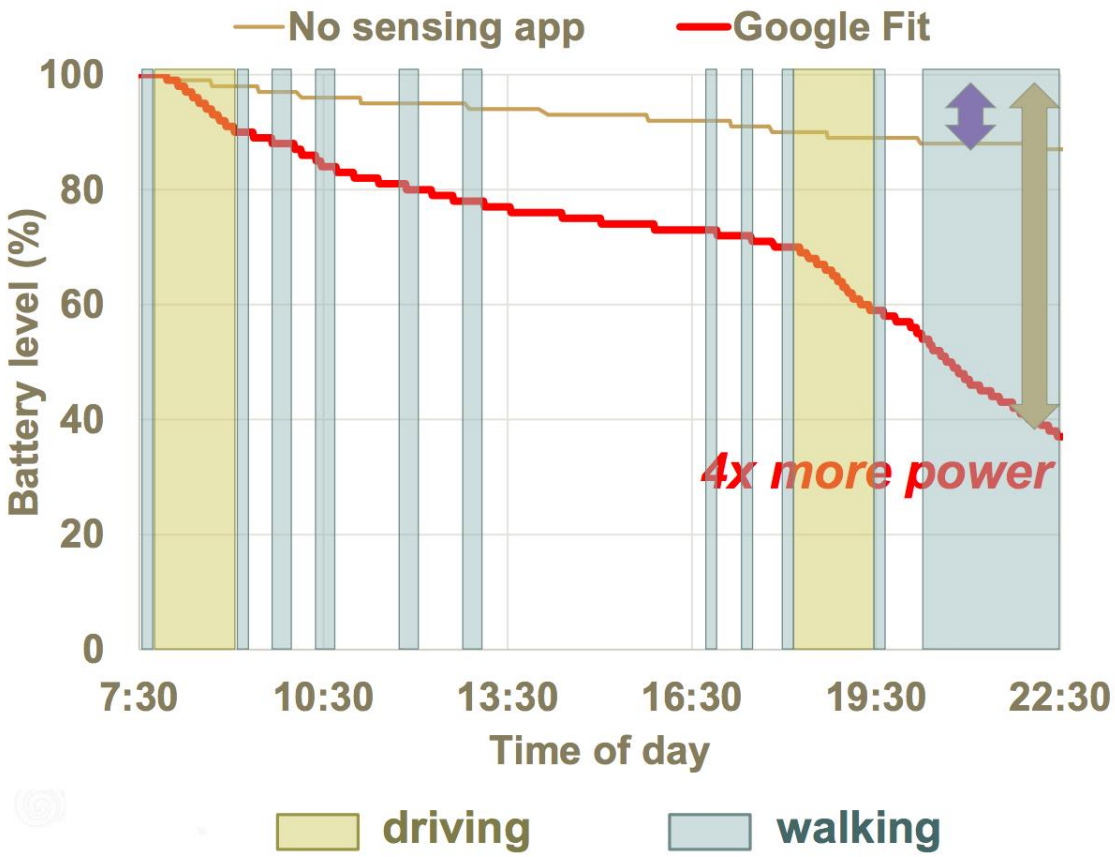
Energy Consumed by CSAs under different mobility conditions

- CSAs drain extra stand-by power
- Average increase in battery drain: 171% vs No-CSA
- Drains 3x more energy when user is walking vs stationary



Day-long Battery Drain under real Life Mobility

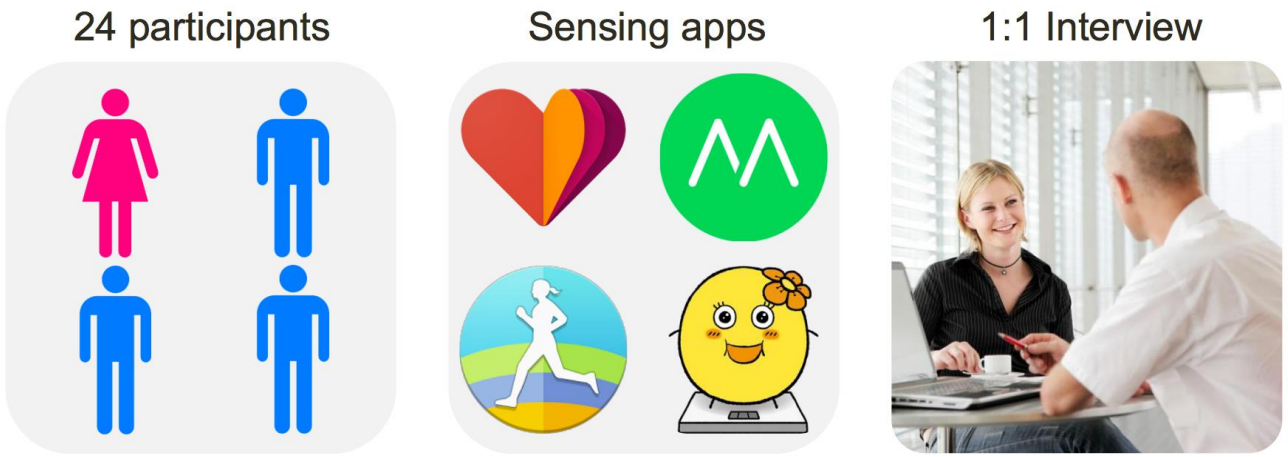




Also steeper battery drain when user is walking

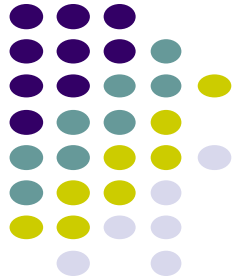
Users may focus on only battery drain caused by their foreground interactions

Next: Investigate User perceptions of CSAs' Battery Consumption



- Interviewed 24 subjects to understand factors influencing phone's battery life
- Questions included:
  - Do you feel concerned about phone's battery life?
  - Have you suspected that CSAs reduce battery life?

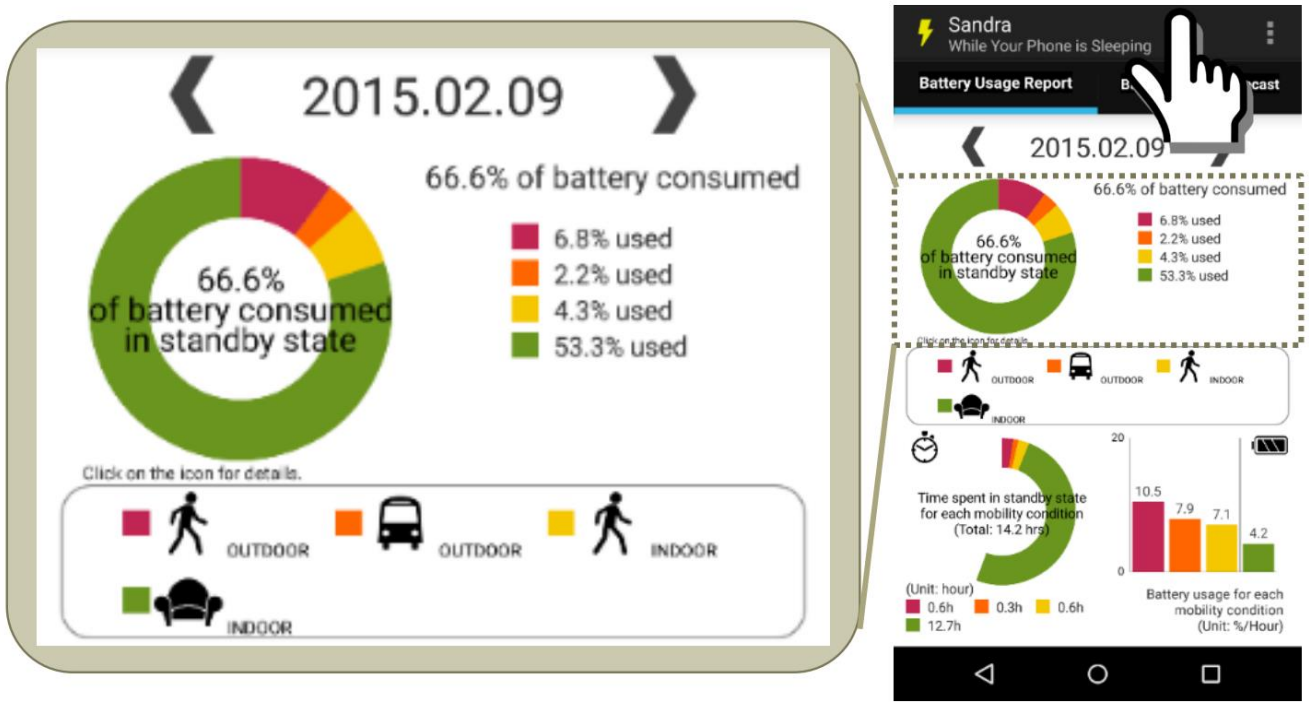
Findings: Investigate User perceptions of CSAs' Battery Consumption



- Subjects
  - Already knew well-known sources of battery drain (display, GPS, network, voice calls, etc)
  - Felt battery drain should be minimal when phone is not in use
  - Were very concerned about battery life. E.g. kept multiple chargers in office, home, car, bedside, etc
  - Had limited, sometimes inaccurate understanding of details of CSA battery drain
  - Disliked temporarily interrupting CSAs to save battery life.
    - E.g. Users kill battery hungry apps, but killing step counter misses steps, 10,000 step goals

Sandra Battery Advisor Design

- **Goal:**
  - Educate users on mobility-dependent CSA battery drain
  - Help users take necessary actions in advance
- Sandra Interfaces show breakdown of past battery use
- Battery usage information retrieved using Android system calls

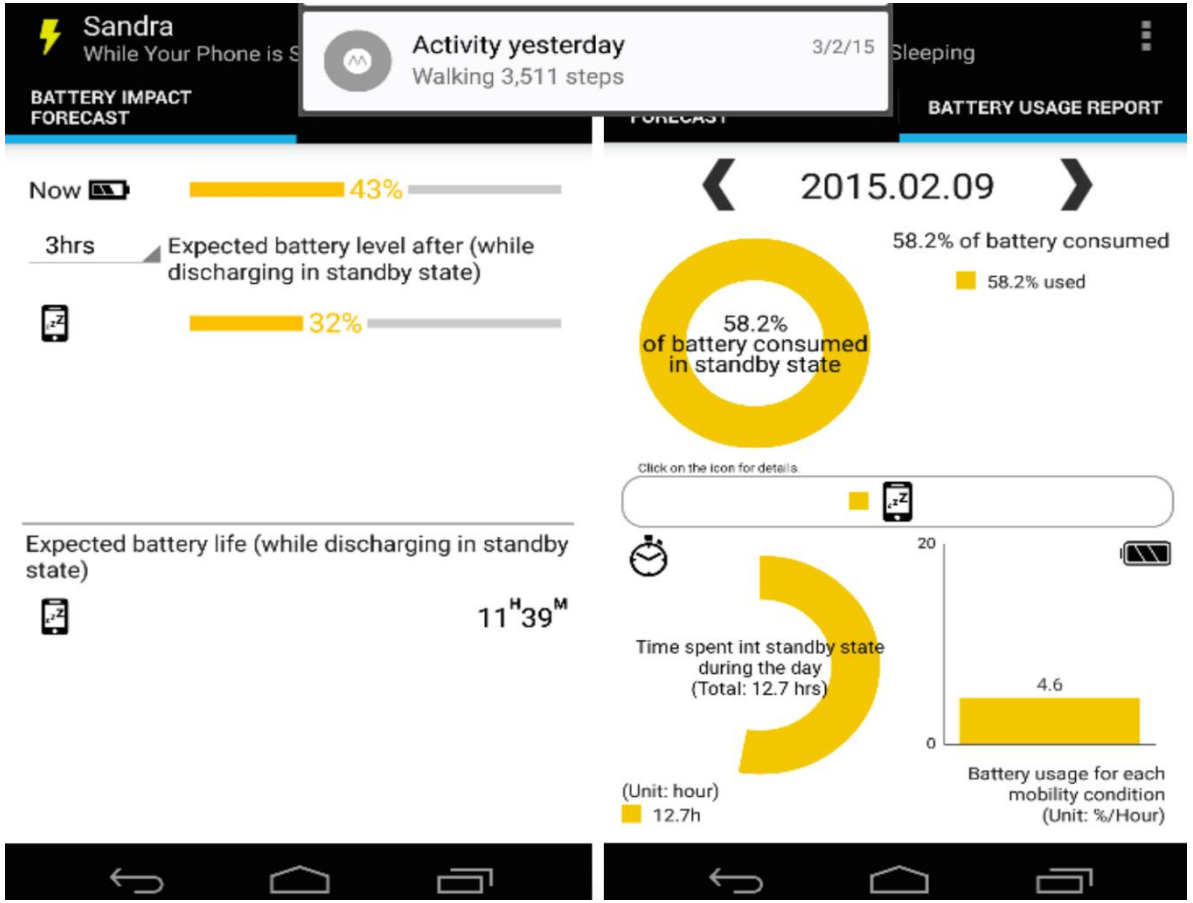


Sandra Battery Advisor Design

- Sandra interfaces that **forecasts expected** standby times for a commonly occurring mobility conditions
  - E.g. Walking indoors/outdoors, commuting outdoors, etc

Sandra Battery Advisor Design

- Sandra-lite version: less detailed
  - No mobility-specific breakdown of battery drain
  - Single standby life expectation



Forecast of Future

Breakdown of Past battery usage

Sandra Evaluation

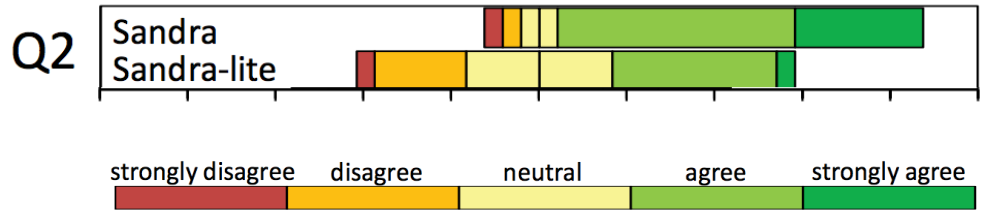
- Experimental Setup

- First 10 days Sandra just gathered information (no feedback)
- Last 20 days gave feedback (forecasts, past usage breakdown)
- Surveyed users using 2 questionnaires for using Sandra and Sandra-lite
  - 5-point Likert-scales (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree)

Sandra Evaluation

- Q1: “Did it bring changes to your existing understanding about your phone’s stand-by battery drain? ”

- Q2: “Do you think the provided information is useful”



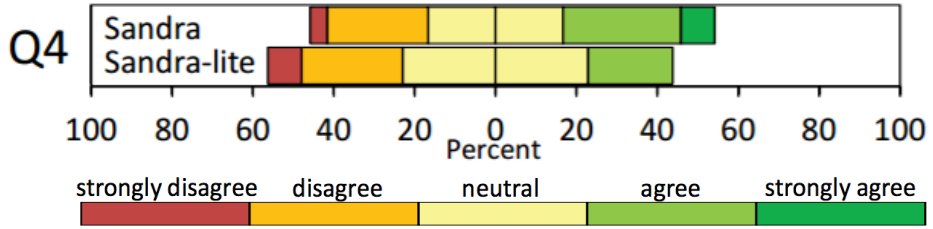
Sandra vs Sandra-lite: Mobility-aware battery information of Sandra increased users’ existing understanding(p-value 0.023)

Realizing that the phone consumes different power

Sandra Evaluation

- Q3: “Did you find it helpful in managing your phone’s battery?”

- Q4: “Did you find it helpful in alleviating your battery concern?”



Mobility-aware battery information was perceived as useful (p-value= 0.005)

Acquiring
new everyday practices:
Turning off GoogleFit on driving

Feeling less nervous
under limited battery:
Before sleeping