Modelling Smartphone Usage: A Markov State Transition Model

Vassilis Kostakos, Denzil Ferreira, Jorge Goncalves, Simo Hosio

Center for Ubiquitous Computing
University of Oulu, Finland

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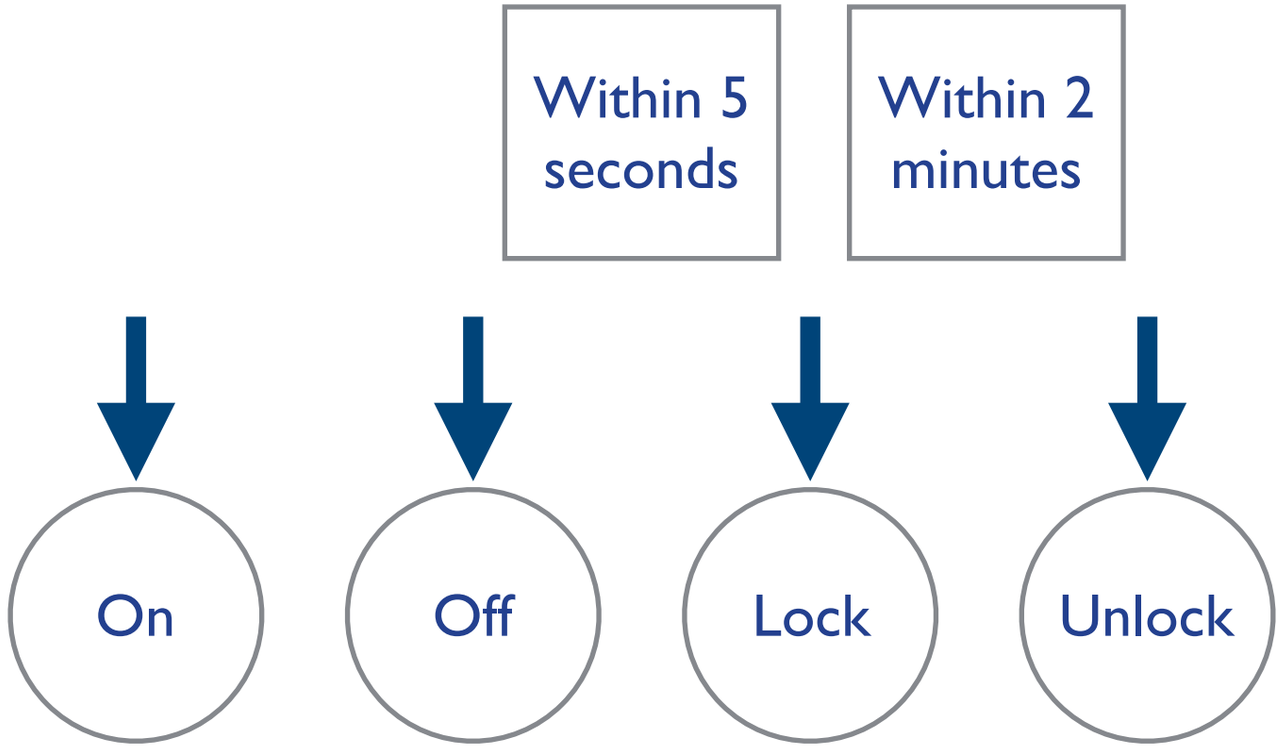
Motivation

- Model smartphone use
- Make predictions about next "screen event"
- In realtime and ongoing



Some prior work in HCI (Usability)

Markov modeling (variant)

- Probability of transitioning to a "state"
  - Given current state
  - Given elapsed time

Android Event	Description
0: **Off**	Power to the screen has stopped
1: **On**	Power to the screen has been activated
2: **Lock**	Screen locked (to avoid accidental input)
3: **Unlock**	Screen unlocked (input is enabled)

Why?

- Systemic model of "use"
- Realistic automated testing
- Optimise resources at runtime
- Provide a theoretical basis for more elaborate models

Why not machine learning?

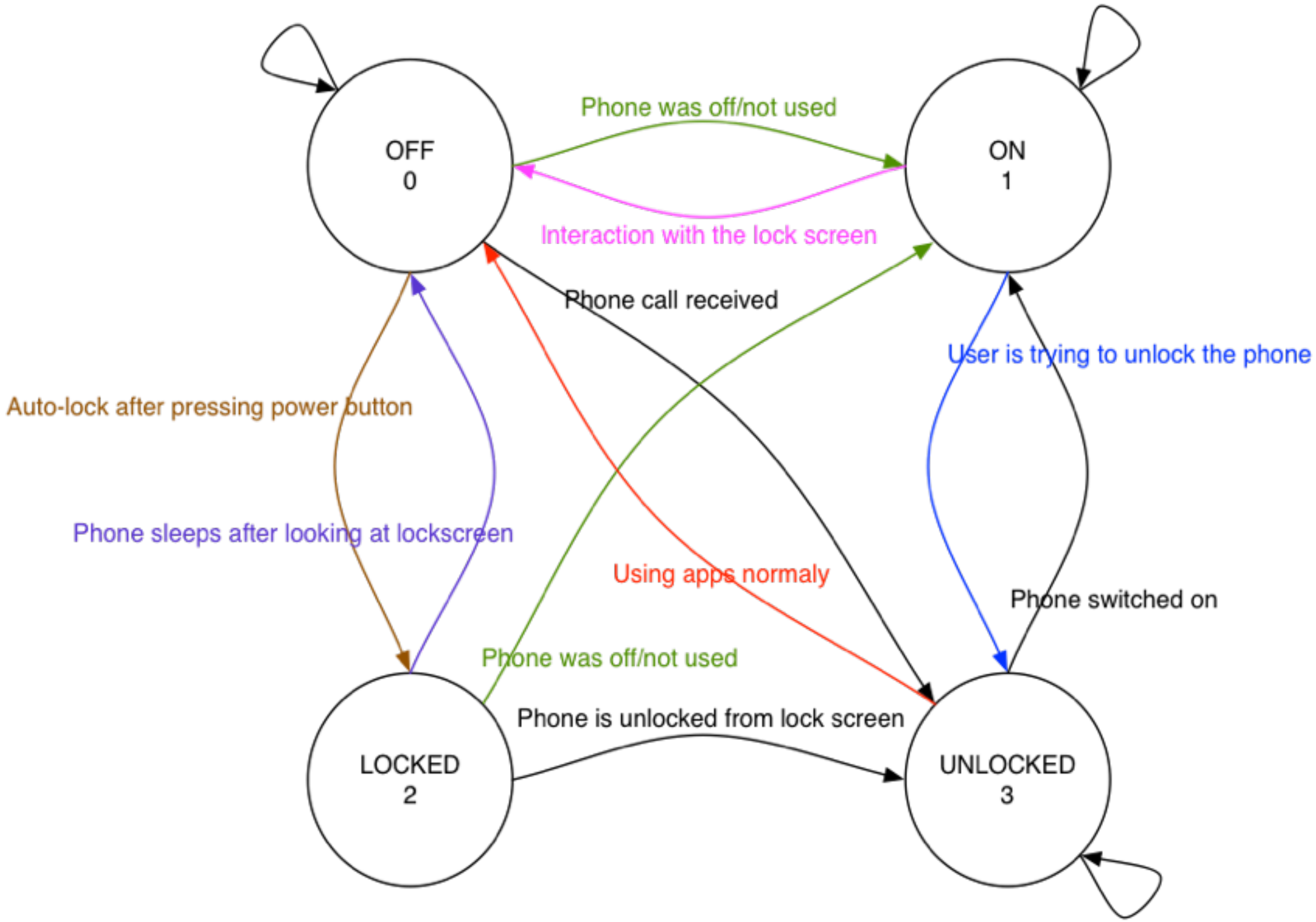
Method

- Re-analyse an existing dataset
  - 271,832 screen events
  - 90 days
  - n=218
  - Securacy: An Empirical Investigation of Android Applications' Network Usage, Privacy and Security (WiSec 2015)

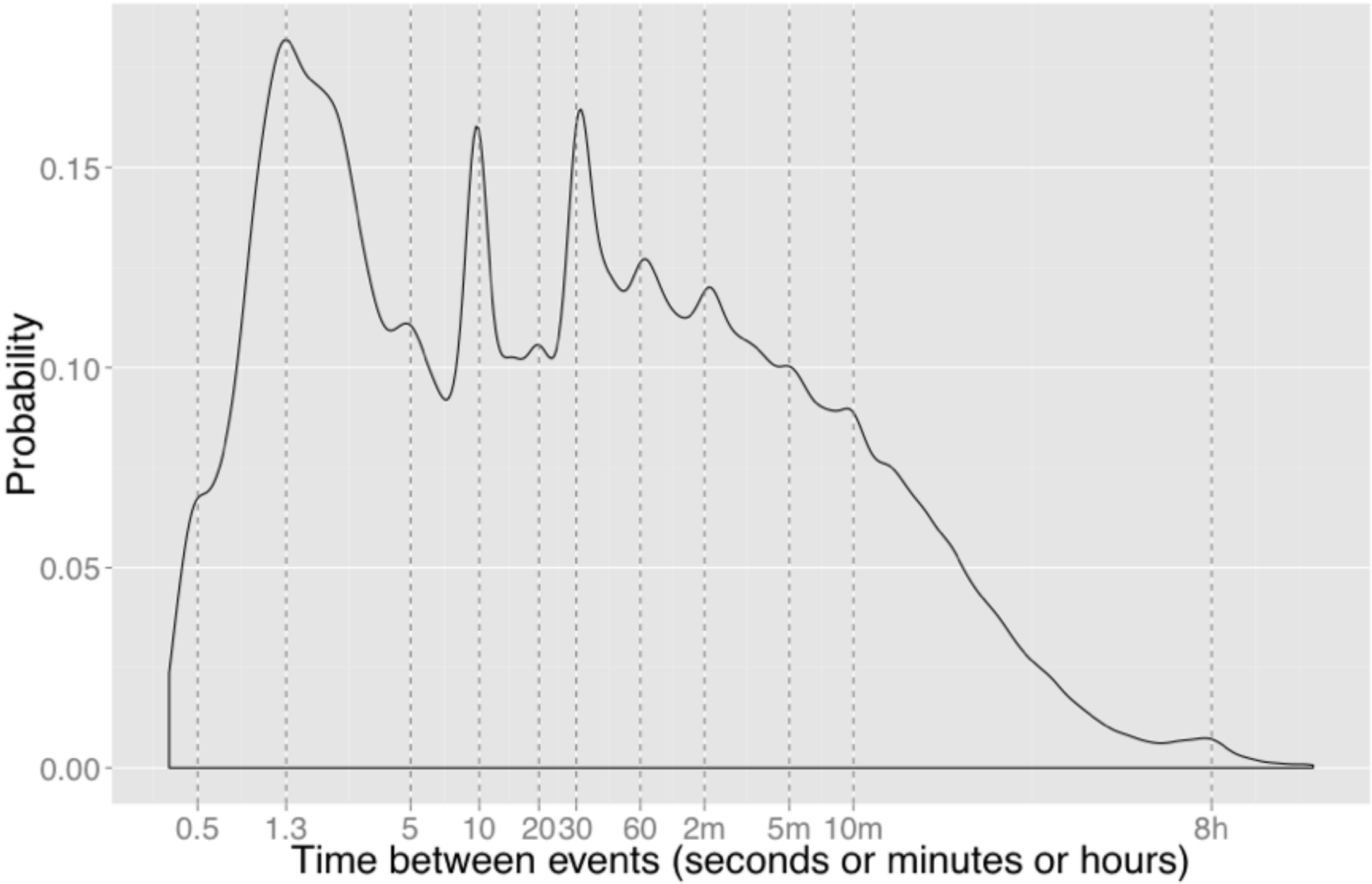
- Validate with another dataset
  - 34,169 screen events
  - 30 days
  - n=17
  - A Systematic Assessment of Smartphone Usage Gaps. (CHI 2016)

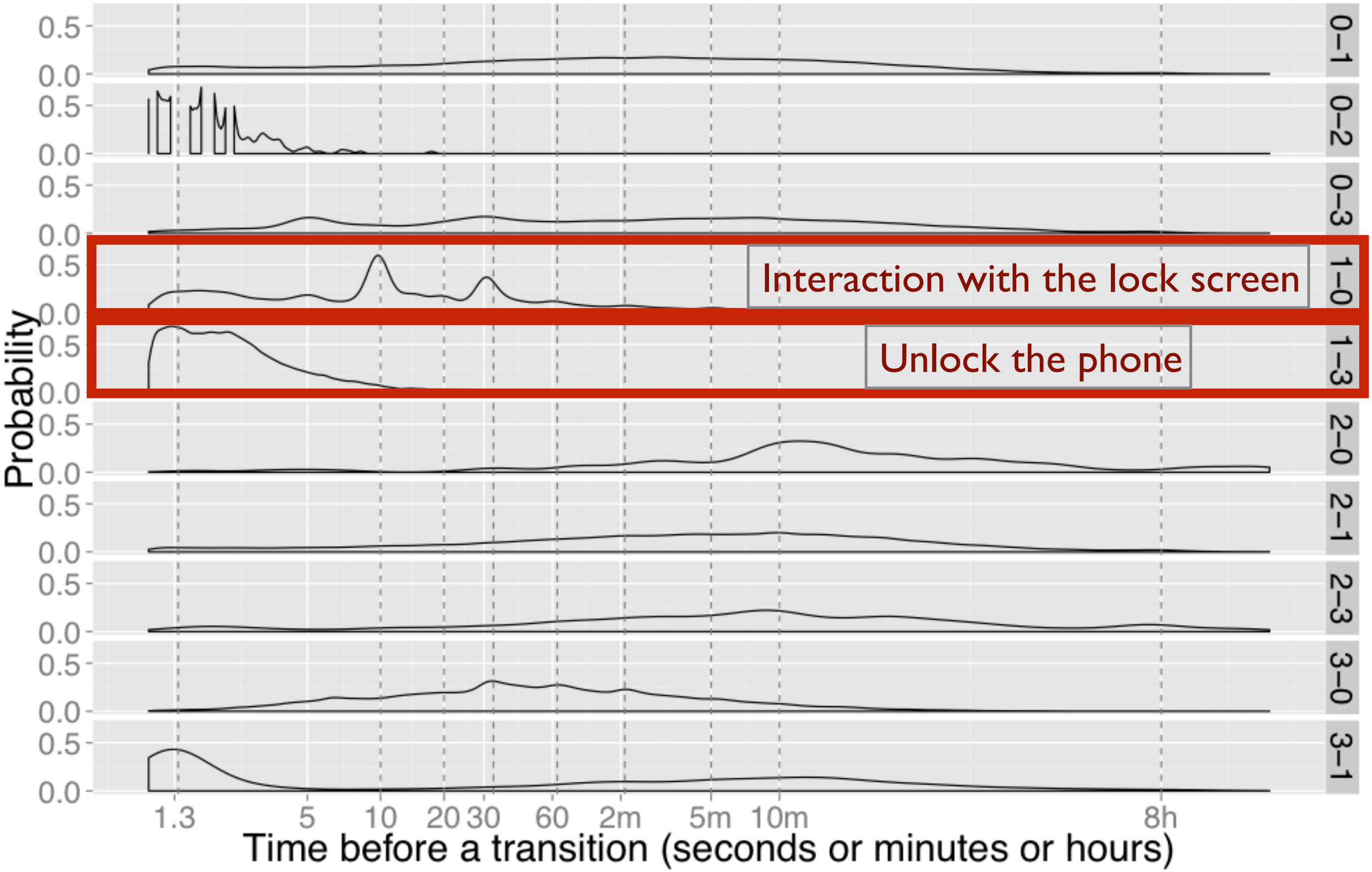
Results

		To			
		0: Off	**1: On**	**2: Lock**	**3: Unlock**
From	**0: Off**	0.50%	33.03%	59.4%	7.05%
	1: On	45.32%	2.03%	0	52.64%
	2: Lock	2.83%	95.64%	0	1.53%
	3: Unlock	80.5%	13.58%	0	5.92%


OFF
0
ON
1
Phone was off/not used
Interaction with the lock screen
Phone call received
Auto-lock after pressing power button
User is trying to unlock the phone
Phone sleeps after looking at lockscreen
Using apps normaly
Phone switched on
Phone was off/not used
Phone is unlocked from lock screen
LOCKED
2
UNLOCKED
3

Time between events

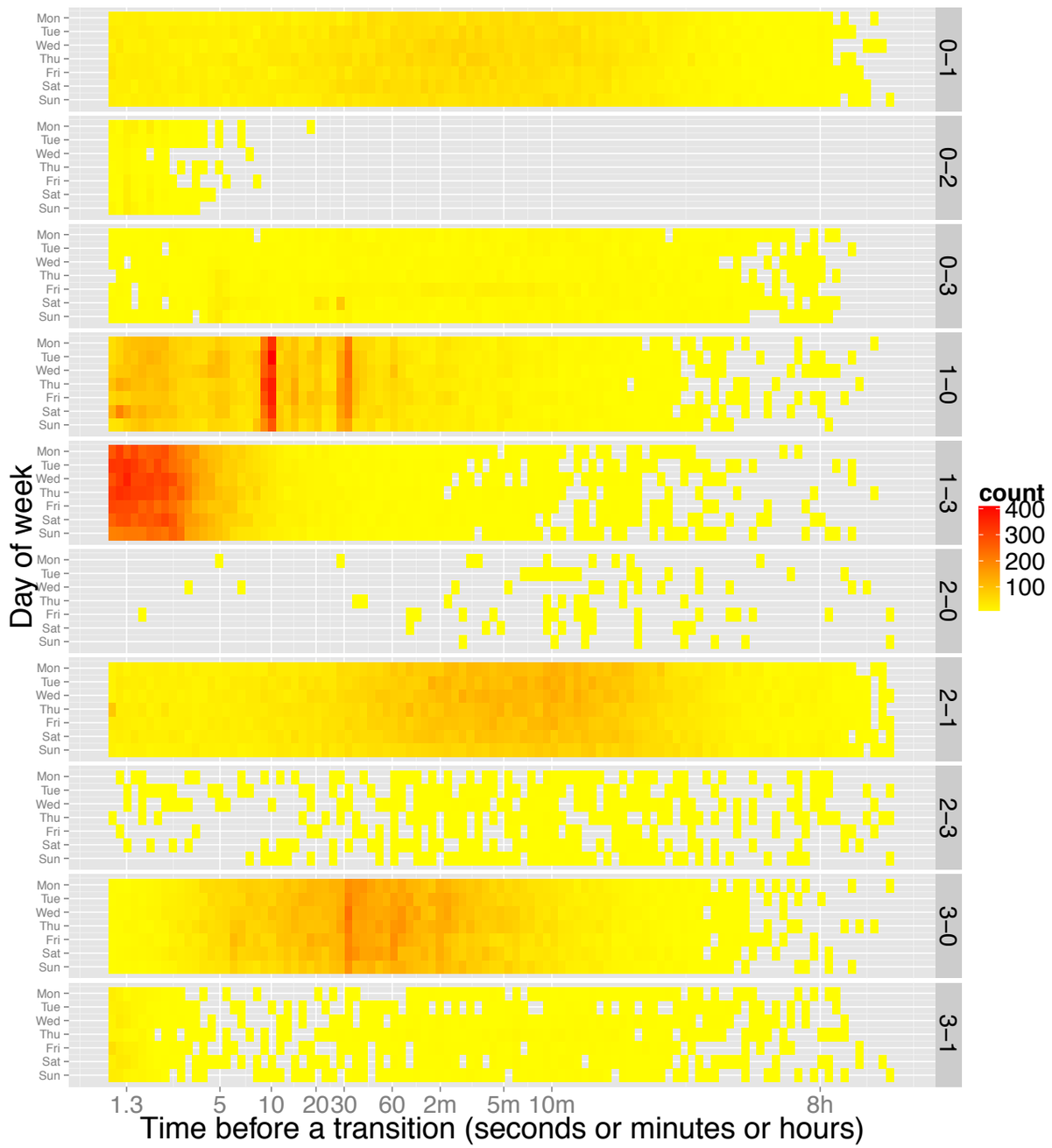


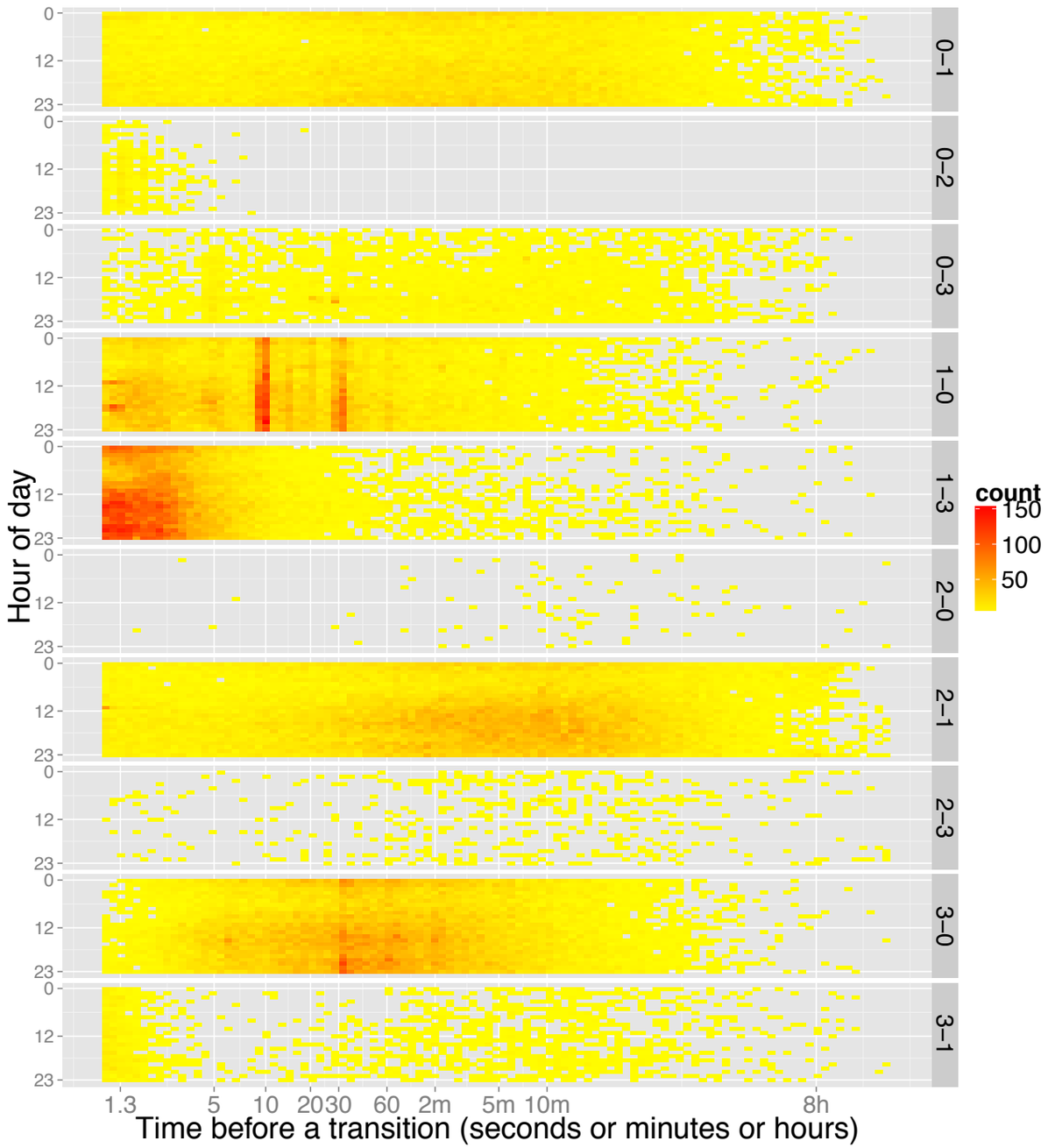

Interaction with the lock screen
Unlock the phone
Probability
0.5
0.0
0–1
0–2
0–3
1–0
1–3
2–0
2–1
2–3
3–0
3–1
1.3
5
10
20
30
60
2m
5m
10m
8h
Time before a transition (seconds or minutes or hours)

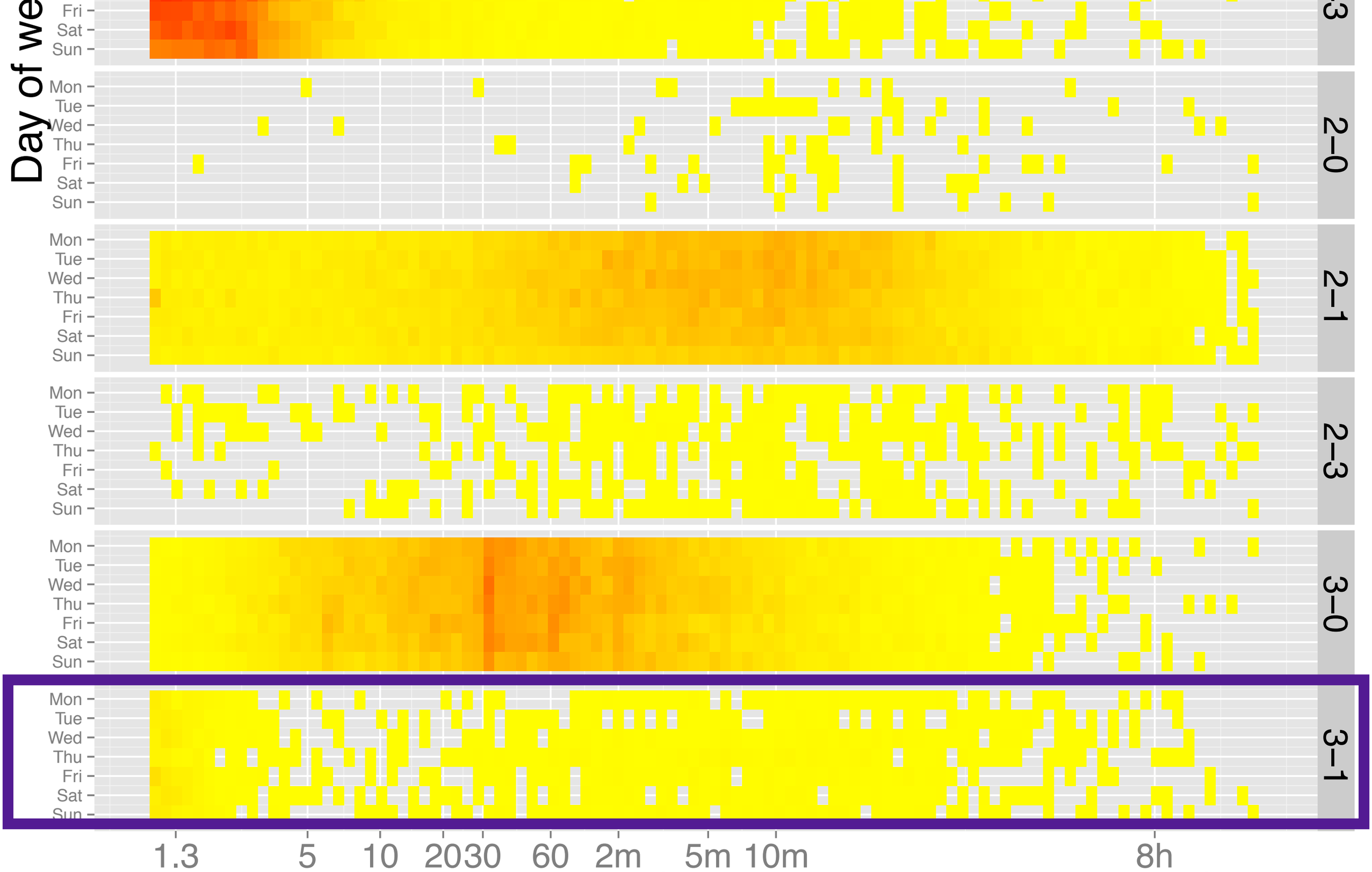
Account for context

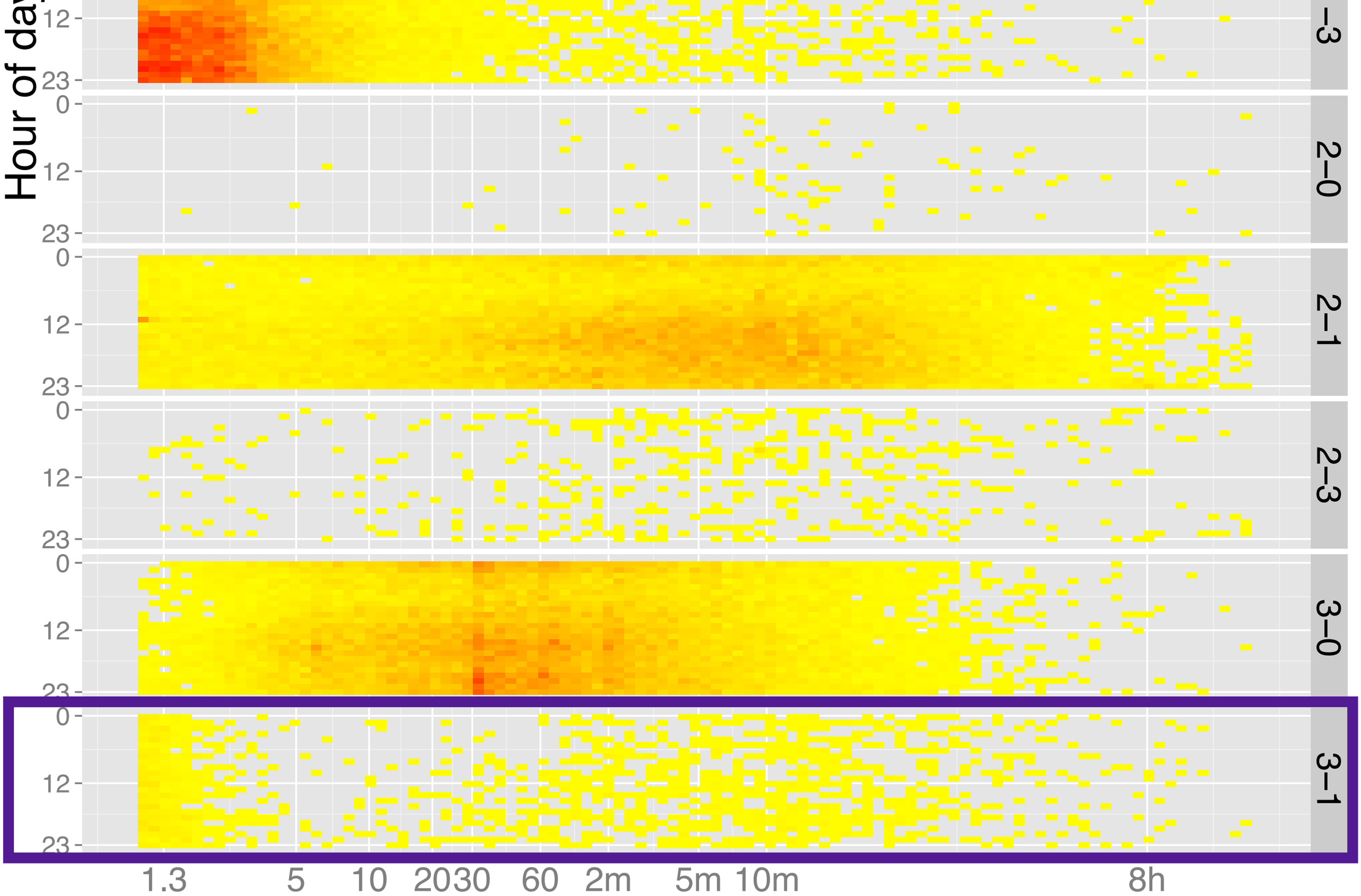
- Day & time
- Battery level
- User “type”

Context: day & time

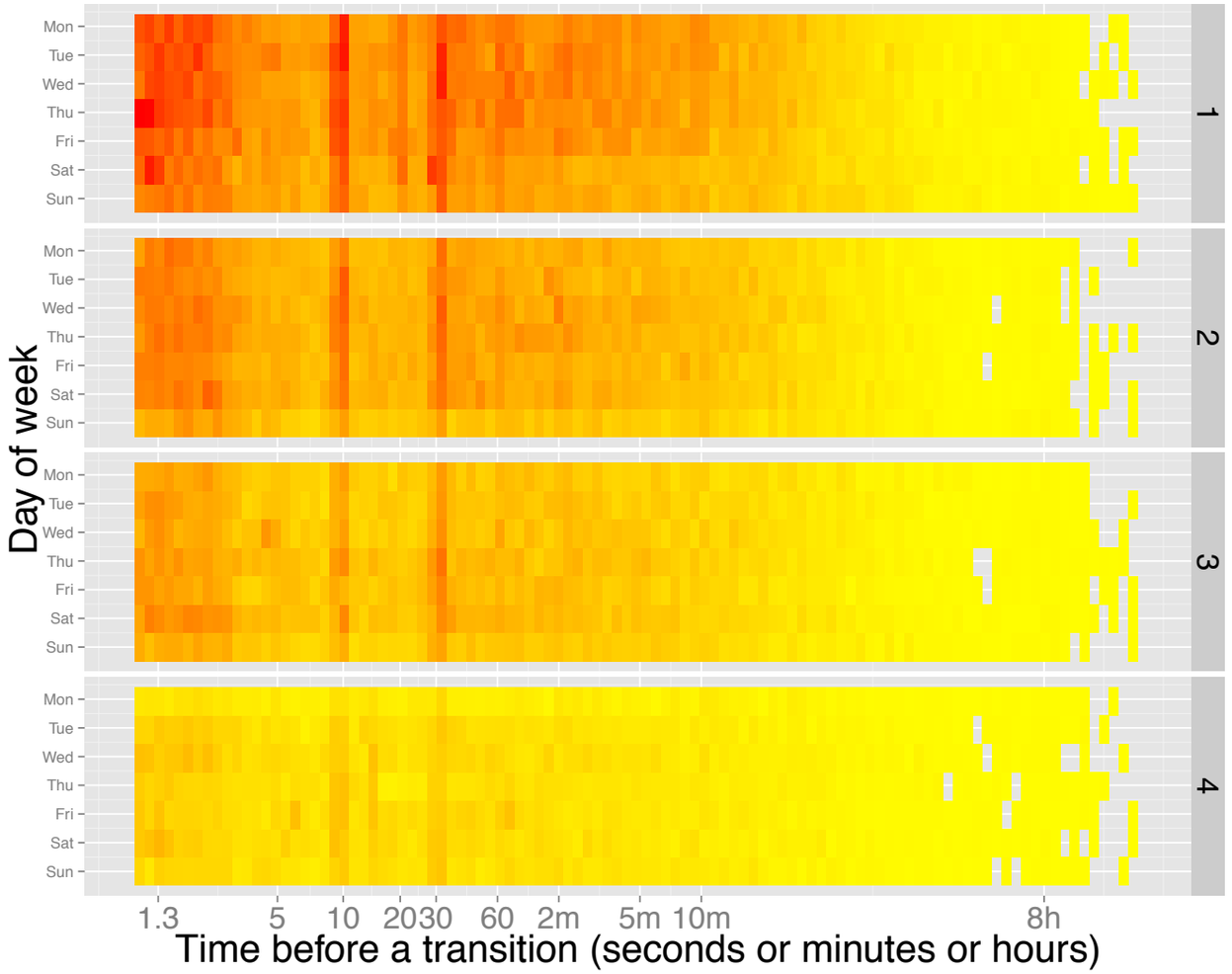


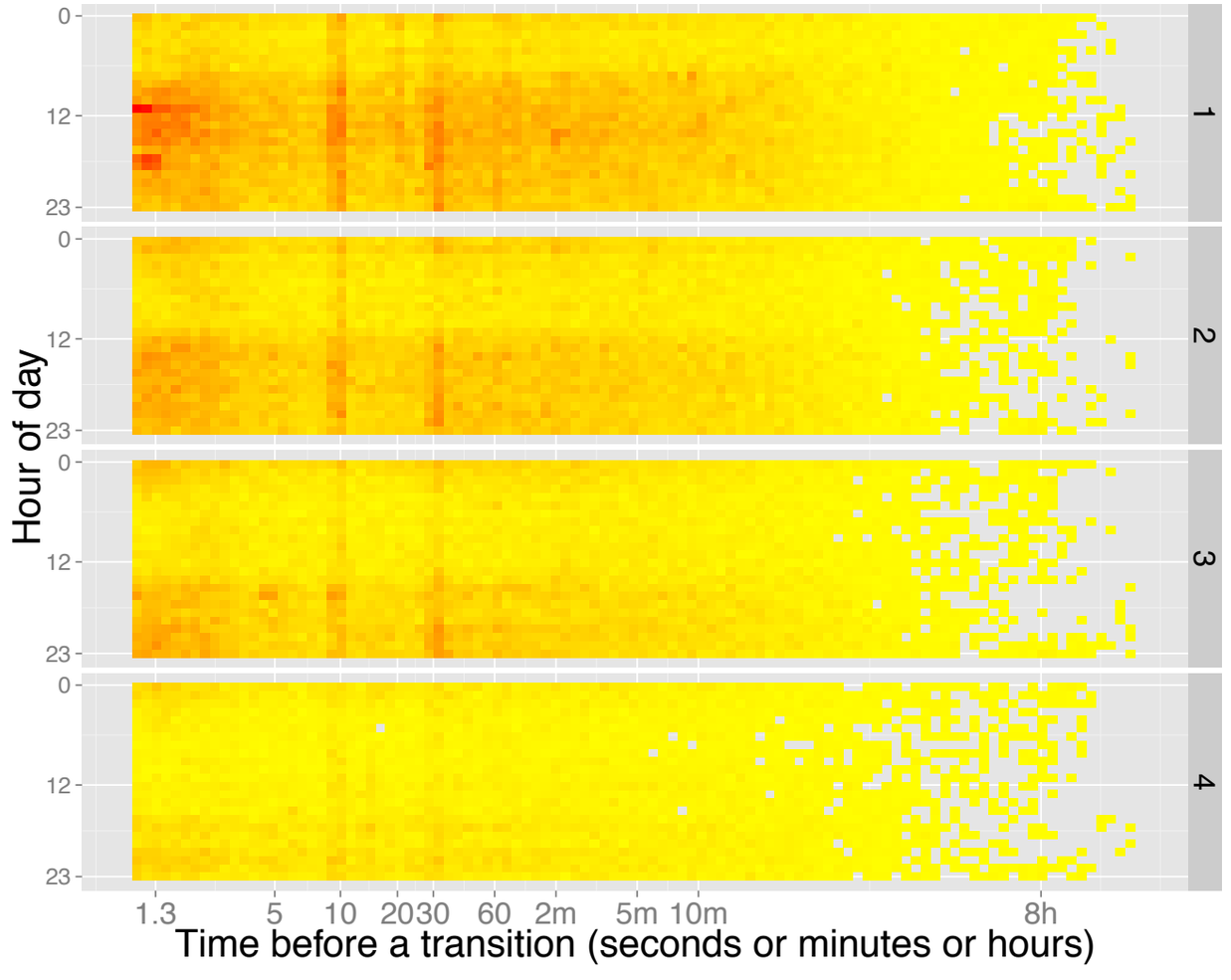



Day of week
Mon
Tue
Wed
Thu
Fri
Sat
Sun
3–3
2–0
2–1
2–3
3–0
3–1
1.3
5
10
20
30
60
2m
5m
10m
8h
Time before a transition (seconds or minutes or hours)

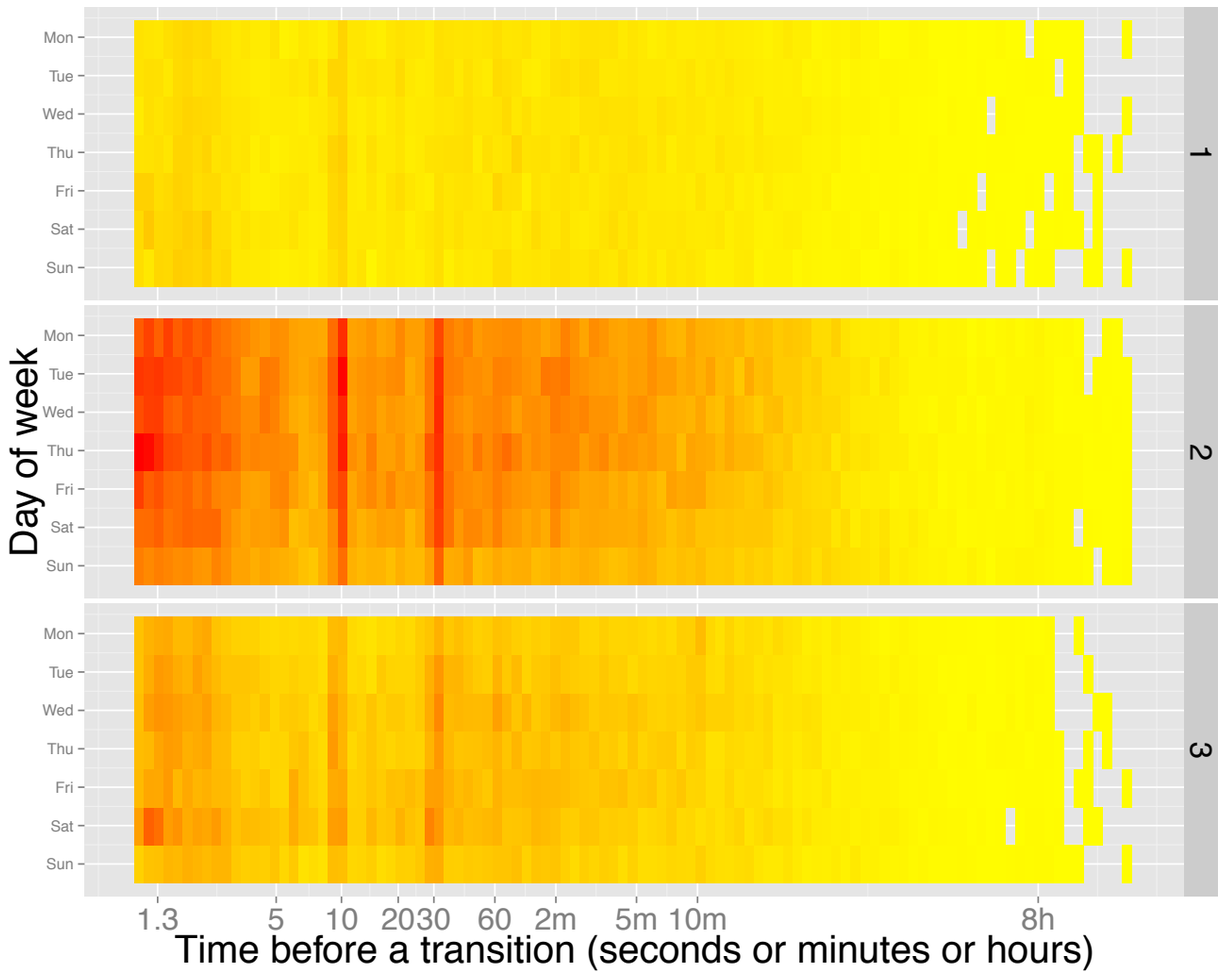

Hour of day
0
12
23
3–3
2–0
2–1
2–3
3–0
3–1
1.3
5
10
20
30
60
2m
5m
10m
8h
Time before a transition (seconds or minutes or hours)

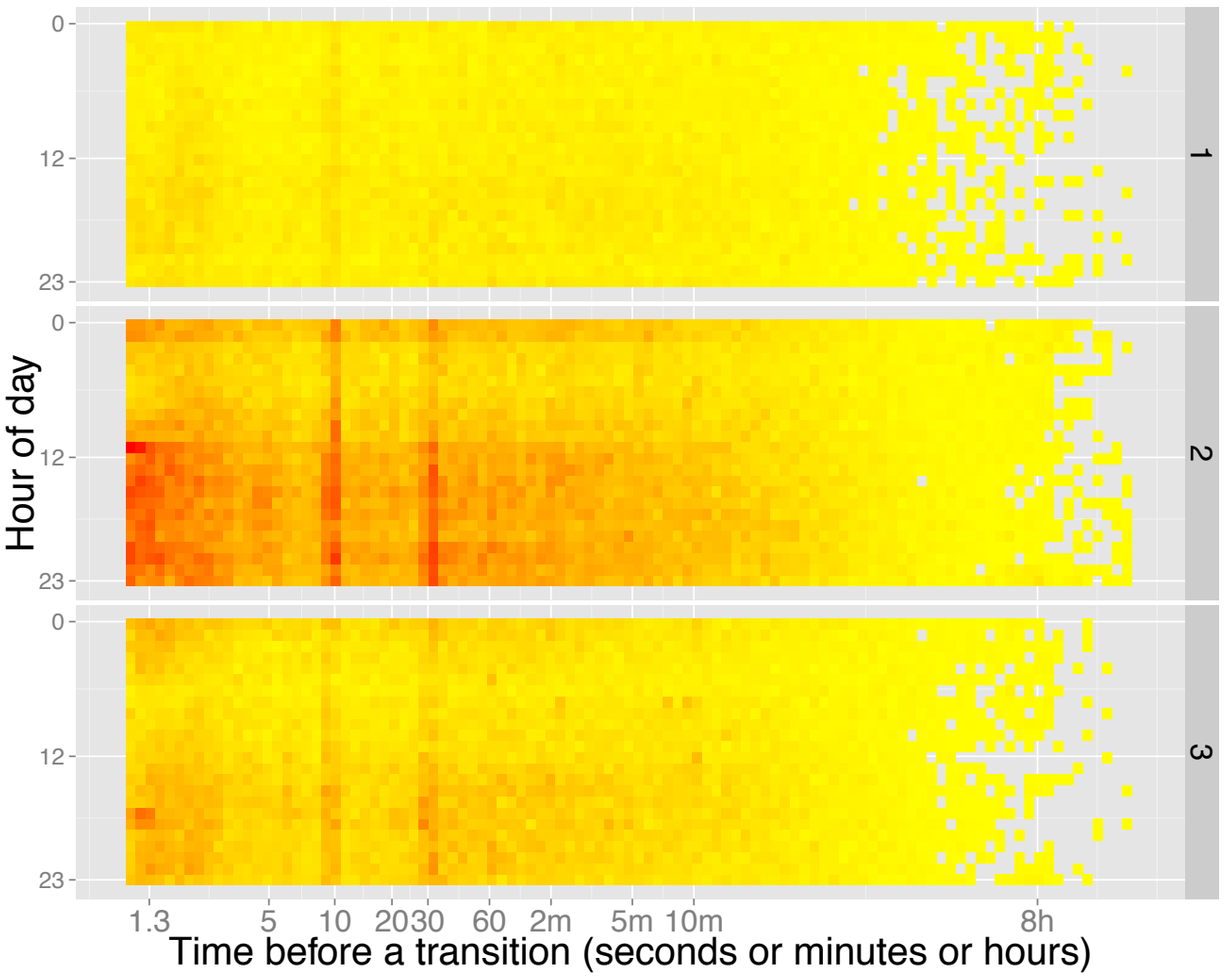
Context: battery level





Context: user “type”





OS can "Interrogate" the model

- How much time do we spend at each state?
- Starting in state 3, how much time (on average) does it take to reach either state 2 or 1?
- If the user turns on the phone (state 1), what is the probability that the phone remains in that state for 20 seconds?
  - For 120 seconds?
  - How does this change with context?

A worked example

- If we arrive to state 1 (screen ON), what is the probability that we are still in state 1 after 20 seconds?

= 1 - (
  probability we move to state 0 in less than 20 seconds +
  probability we move to state 2 in less than 20 seconds +
  probability we move to state 3 in less than 20 seconds
)

		To			
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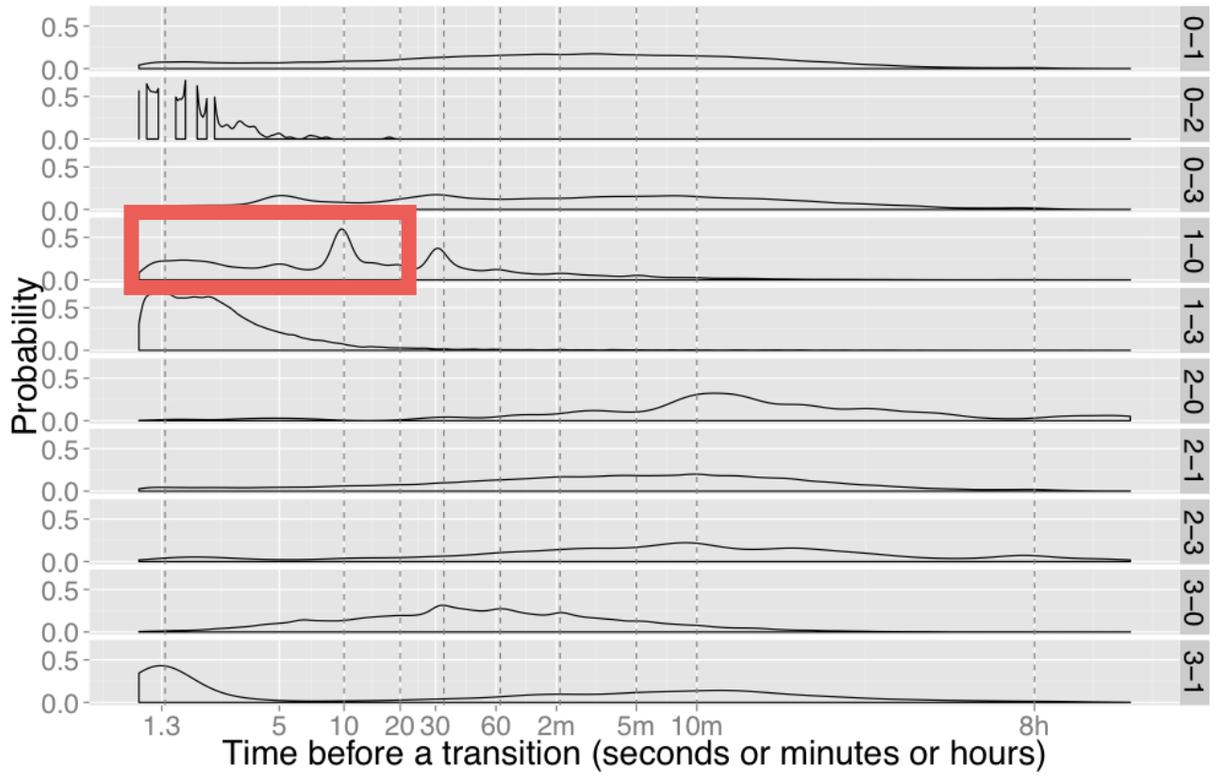

= 1 - (

prob. we move to state 0 * (integral 0<t<20 for 1➡0) +

prob. we move to state 2 * (integral 0<t<20 for 1➡2) +

prob. we move to state 3 * (integral 0<t<20 for 1➡3)

)

$$= 1 - \Big(0.4532 * (\text{integral } 0<t<20 \text{ for } 1\rightarrow 0) + 0 * (\text{integral } 0<t<20 \text{ for } 1\rightarrow 2) + 0.5264 * (\text{integral } 0<t<20 \text{ for } 1\rightarrow 3) \Big)$$

$$= 1 - (0.4532 * 0.6659034 + 0 + 0.5264 * 0.9705692)$$

$$= 0.187 \quad \text{i.e. } 18.7\%$$

Hence:	Model	Dataset 2
• Staying in state 1 for at least 20 sec:	18.7%	10.5%
• For 120 sec:	6.9%	4.5%
• For 20 sec & battery > 75%:	19.0%	10.9%
• For 20 sec & battery < 25%:	17.7%	10.8%
• For 20 sec & 2pm:	17.5%	10.8%
• For 20 sec & 4am:	18.4%	6.6%

Error (RMSE) = 7.8%

Discussion

- Statistical model of phone use (screen events)
- Can be extended
  - predict next app (Gouin-Vallerand & Neila Mezghani, 2014)
  - predict next app button (Andrei et al., 2016)
- Basis for modelling smartphone use
- Model: abstraction of reality
  - Captures statistical properties
  - Lets us interrogate

- Automated testing & resource optimisation

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vassilis.kostakos@oulu.fi
http://ubicomp.oulu.fi

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From\To	0: Off	1: On	2: Locked	3: Unlocked
0: Off	n/a	The phone was off and the user took action to activate the screen.	If a phone is configured to auto-lock, then when it is turned off it will quickly and automatically lock itself.	This can happen when a phone-call is received.
1: On	The user was interacting with the lock-screen (e.g. checking time) and then turned off the phone. This transition helps us measure how long people glance at their lock-screen	n/a	n/a - to become locked, the screen needs to be turned off first.	The user was interacting with the lock-screen and then unlocked the phone. This transition helps us measure how quickly people unlock their phone
2: Locked	The user is interacting with the lock screen and then leaves the phone untouched until power-saving turns off the screen automatically.	The phone was not used (i.e. off and locked) and the user pressed the power button to turn the screen on.	n/a	Happens when the phone is locked (but the screen is on) and then unlocked again.
3: Unlocked	The user was using apps, and then pressed the power button to turn off the screen.	The screen turned off (but did not lock the phone) and then the user took action to turn on the screen.	n/a - to become locked, the screen needs to be turned off first.	n/a