MANCHESTER 1824
The University of Manchester

IAMlab

Unobtrusive and Personalised Monitoring of Parkinson's Disease Using Smartphones

Julio Vega

Interaction Analysis and Modelling Lab

It’s all about **people**

You might know them

and another 5.2 million...

Technology-based monitoring

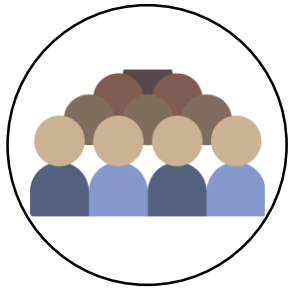
In the lab

Uncomfortable

Motor Focused

Short & Sporadic

Intrusive



Population based

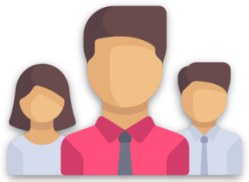
The potential of the digital world

Personal

Internet

Ambient

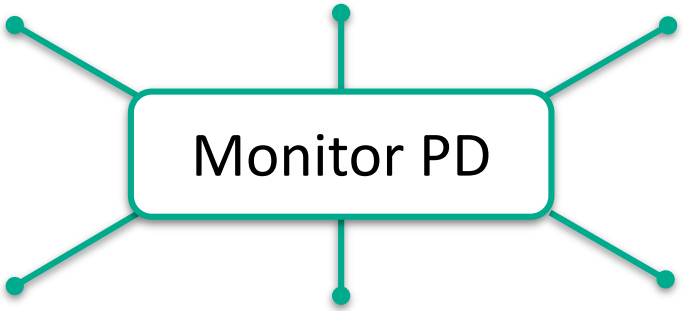
Our goal



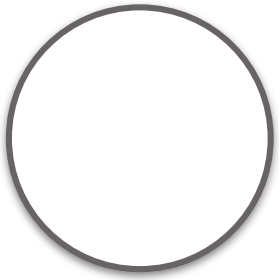
Personalised

Smartphone

24/7



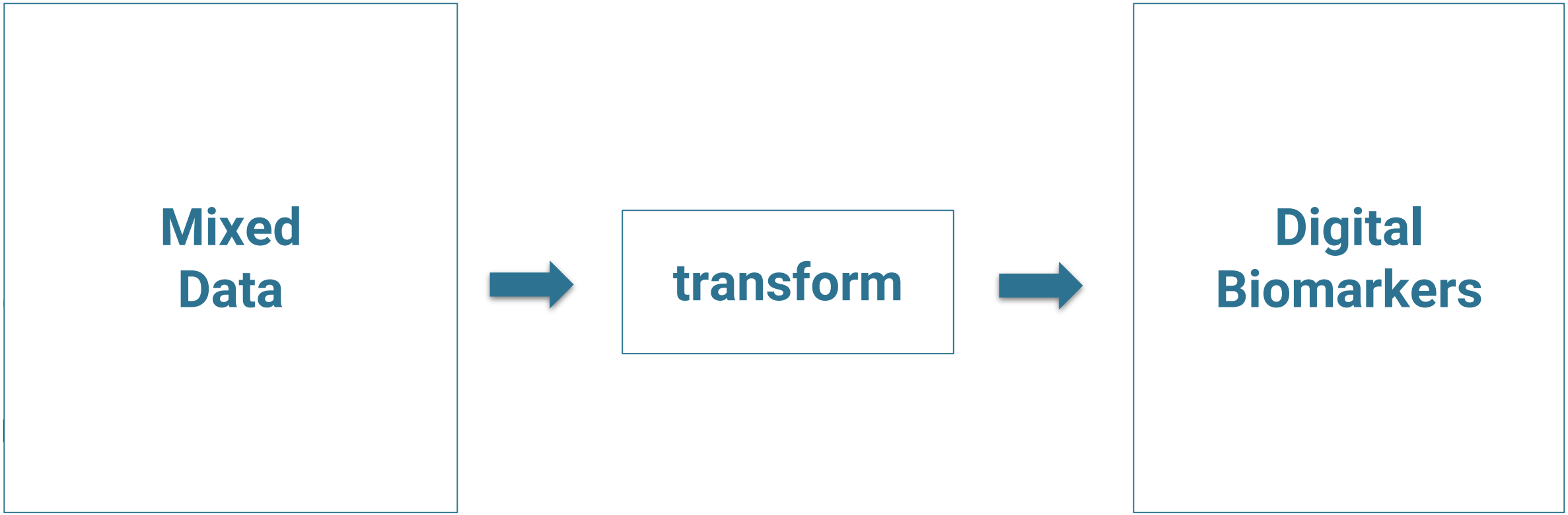
Outside the lab



Invisible

1 year

In more detail



In more detail

transform

Digital Biomarkers

In more detail

Personal Predictions

Digital Biomarkers

In more detail

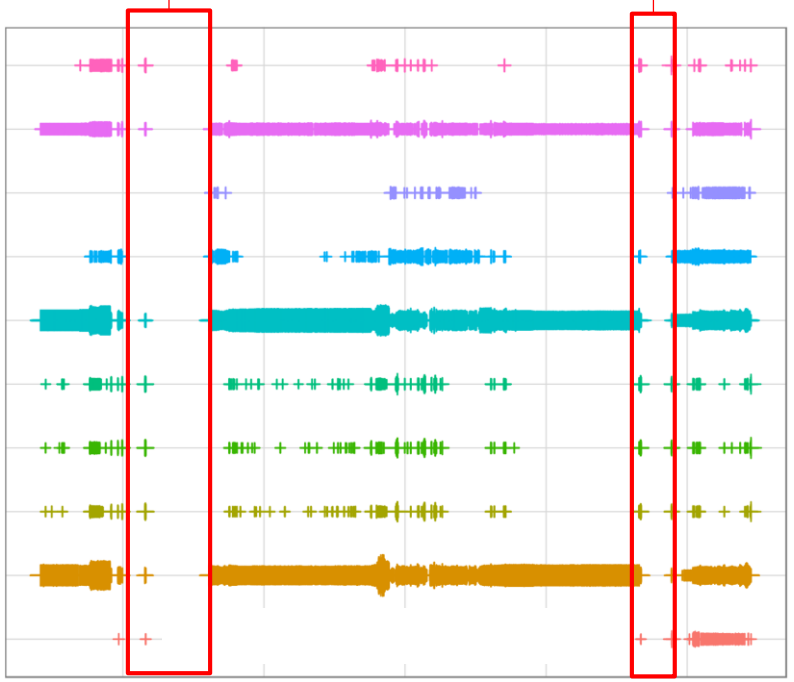
Personal Predictions

Social Interaction

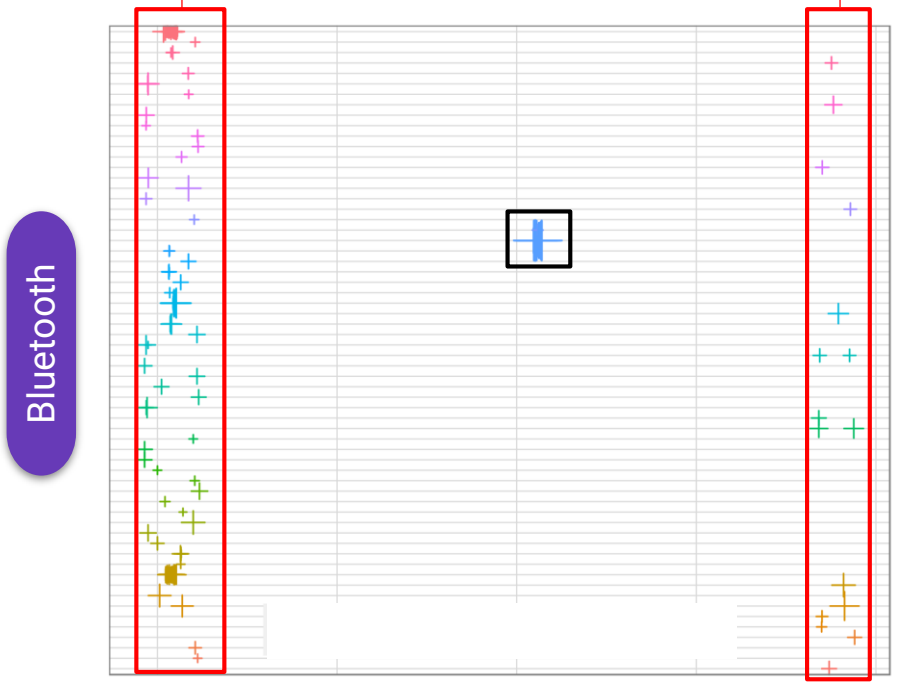
Phone Use

Social Interaction

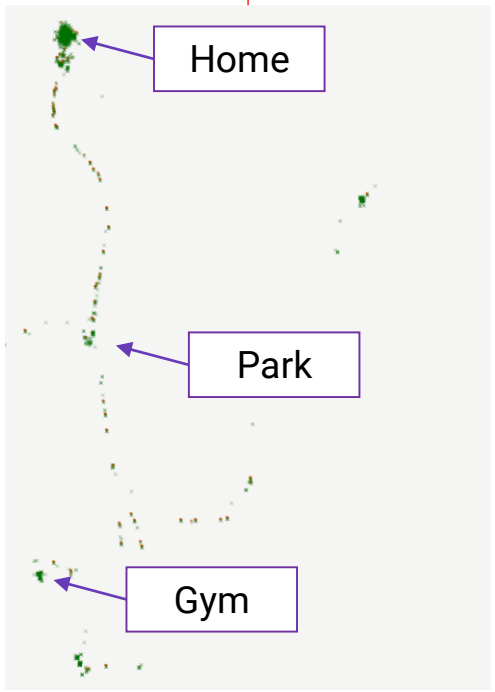
Time outside home



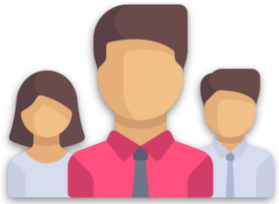
Social Interactions



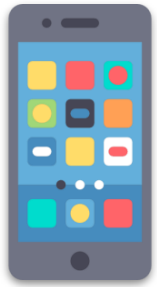
Frequented places



Our protocol



11 participants



22 sensors per participant

6-week visits

and nine months to get ethical approval…

Validation

Compare smartphone inferences vs symptom changes

Every 6 weeks
Clinical Scores

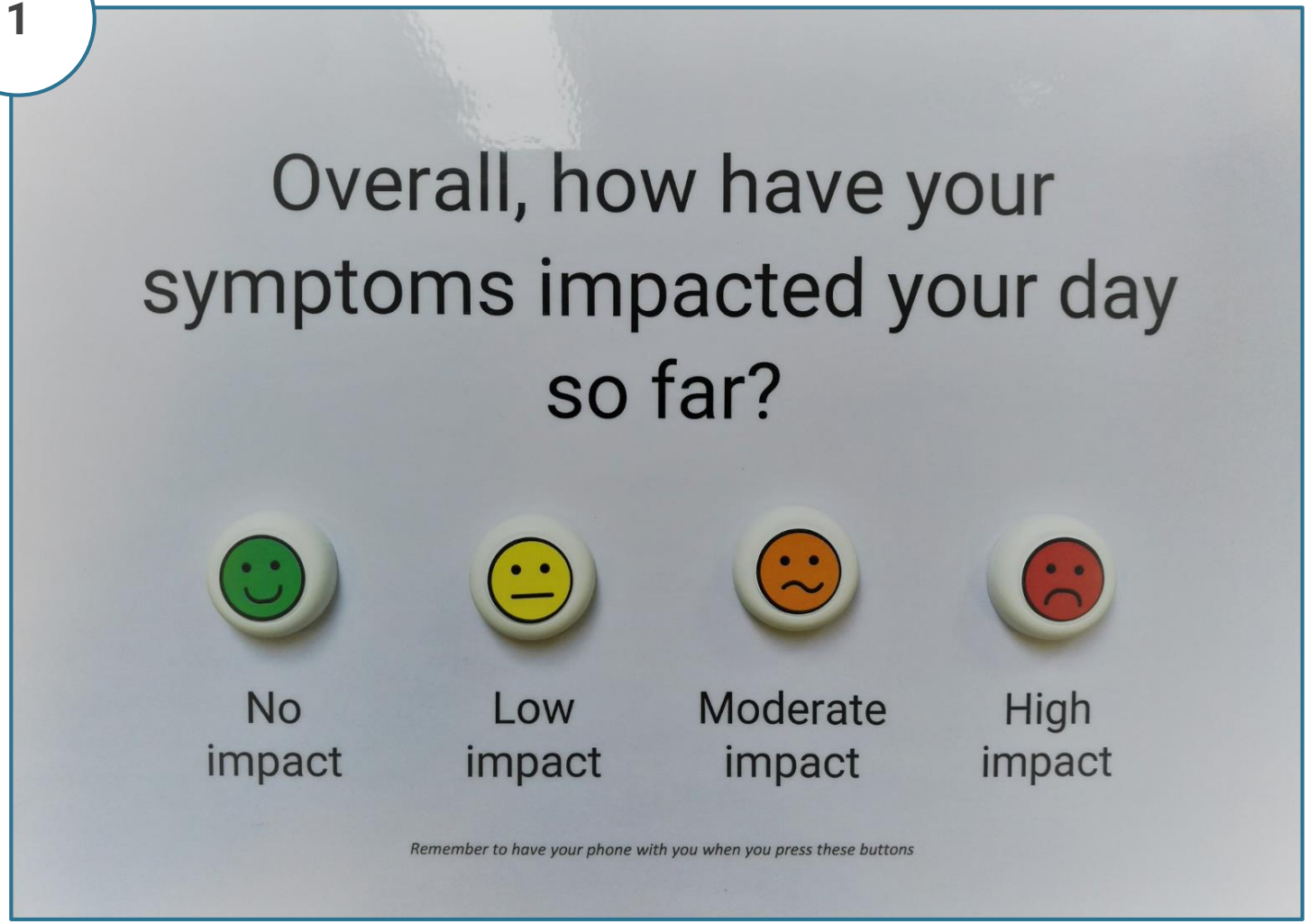
Every day
Self-Reporting

Start designing, implementing, executing, early

Go tech!

Buttons

1

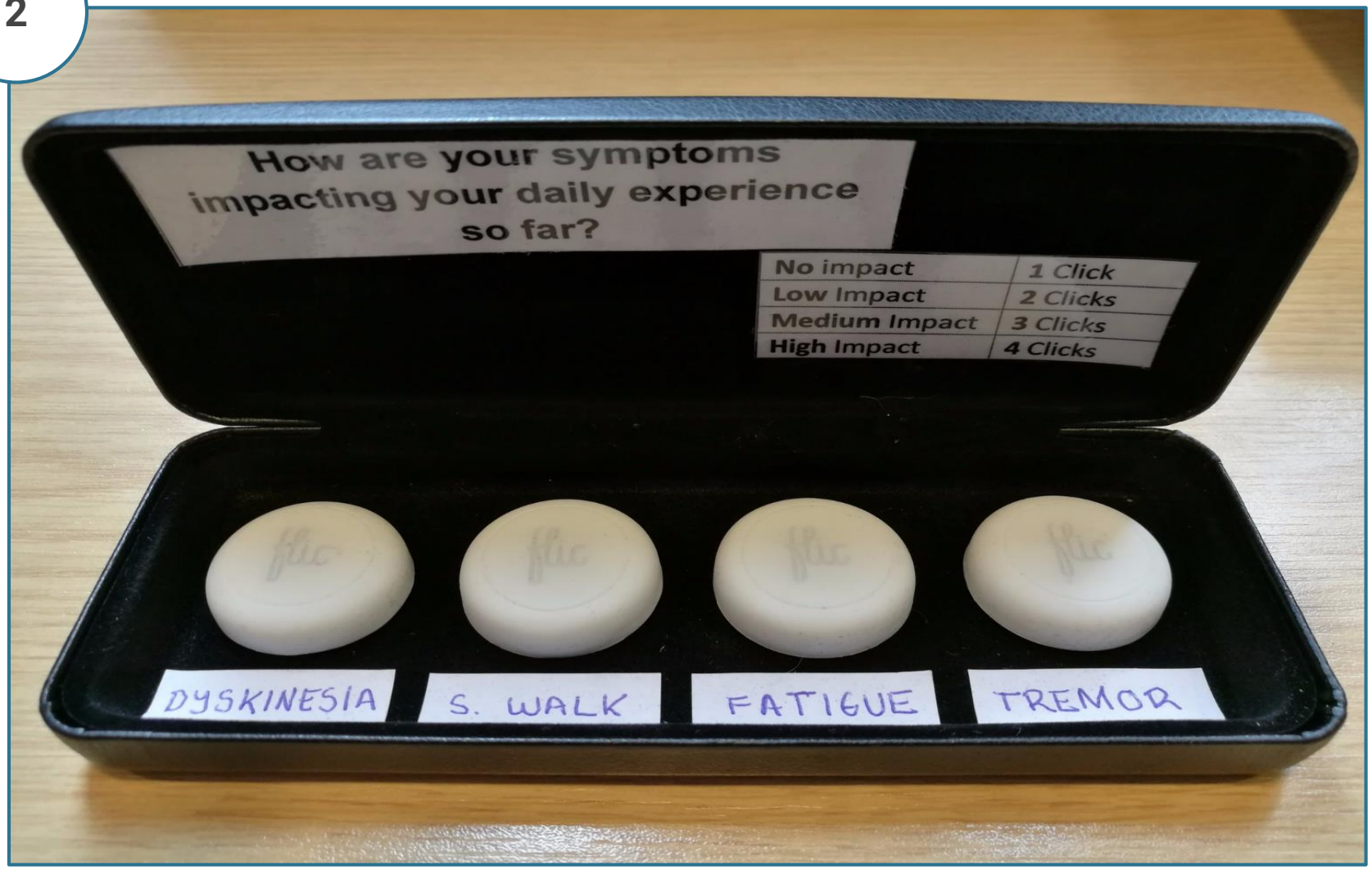

Overall, how have your symptoms impacted your day so far?
No impact
Low impact
Moderate impact
High impact
Remember to have your phone with you when you press these buttons

Buttons

1a

Buttons 2.0

2


How are your symptoms impacting your daily experience so far?
No impact 1 Click
Low Impact 2 Clicks
Medium Impact 3 Clicks
High Impact 4 Clicks
DYSKINESIA
S. WALK
FATIGUE
TREMOR

But tech can fail...

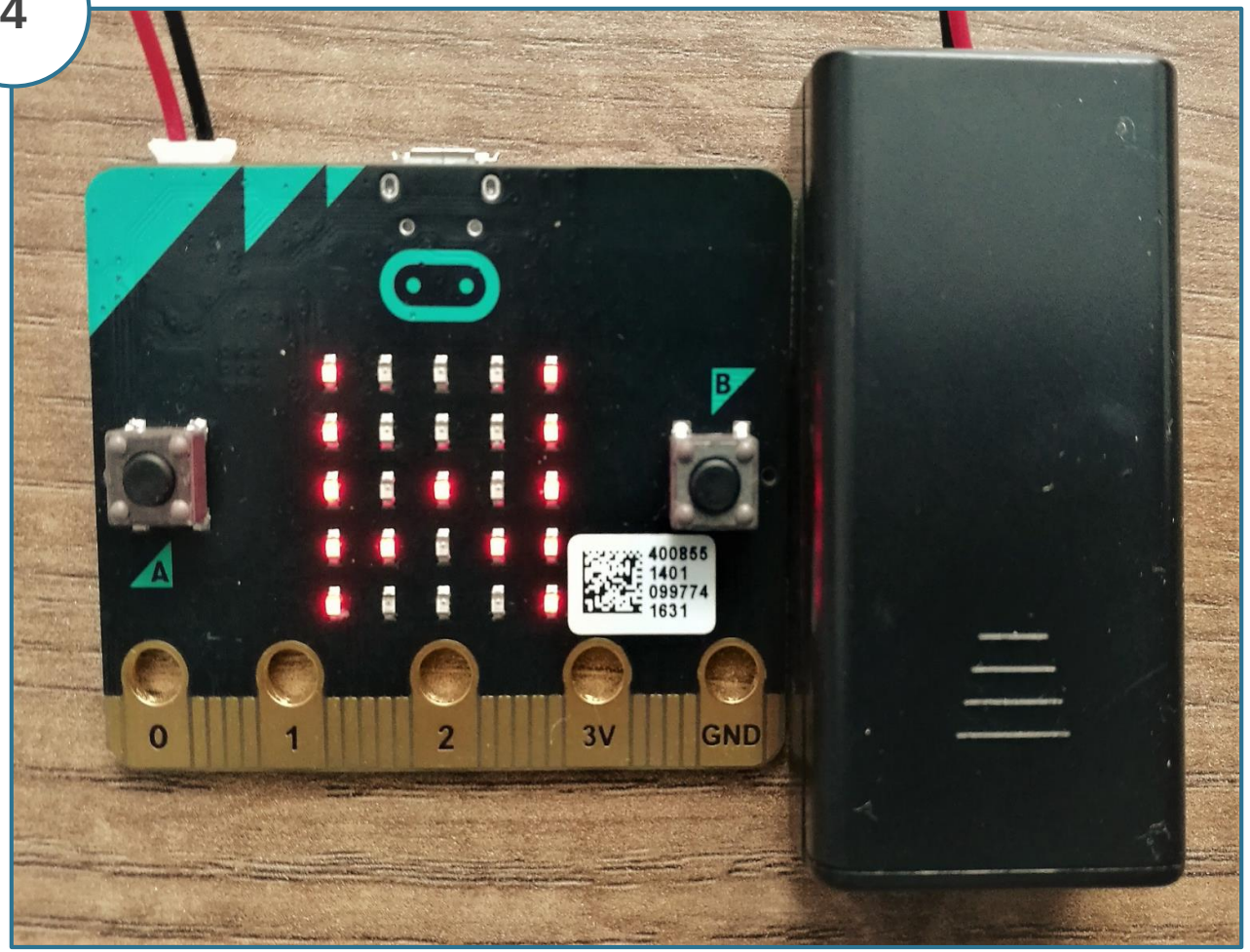
Trying even more tech

3

Cube with NFC tags

Trying even more tech

4

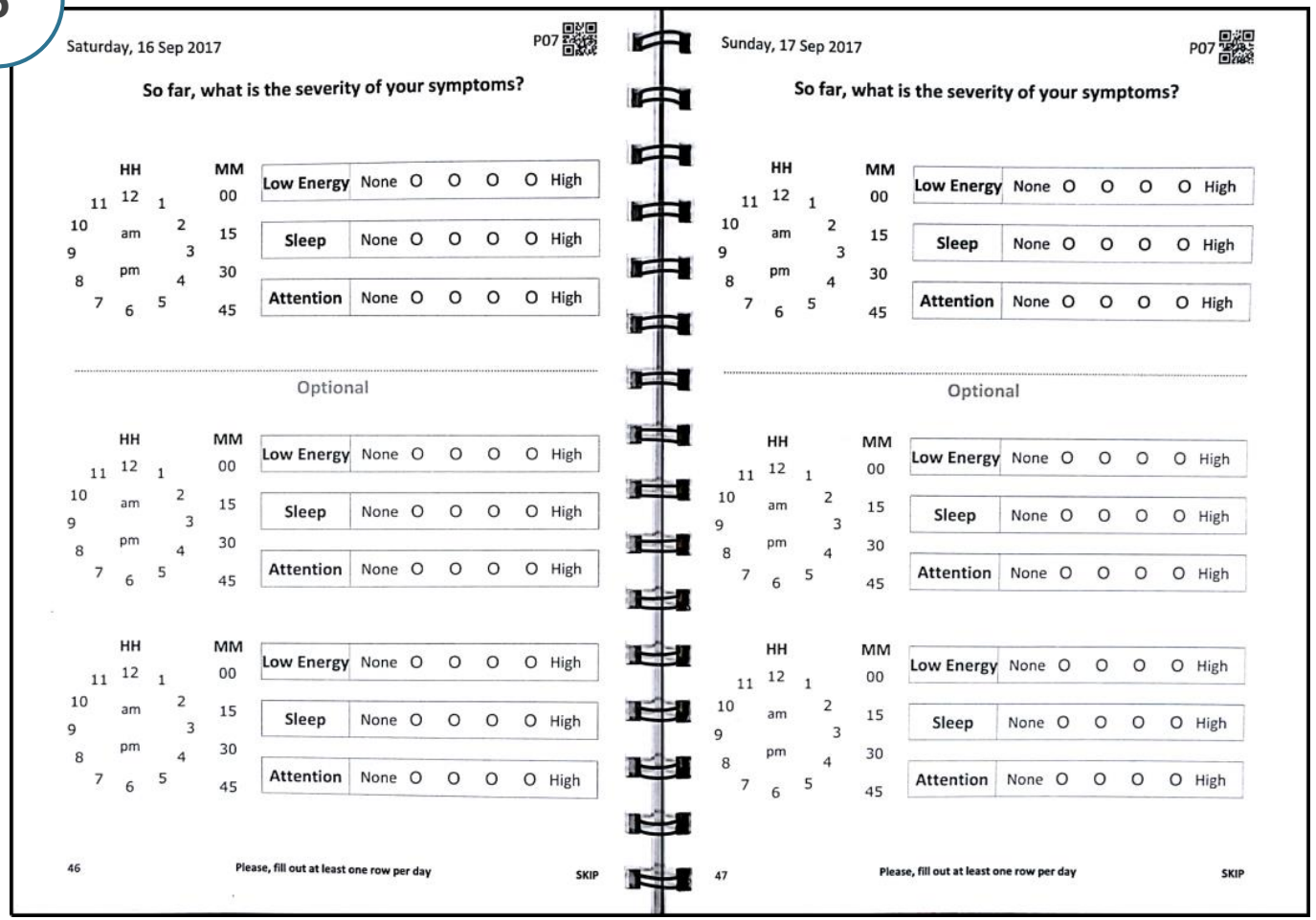


Micro:Bit

BACK TO ANALOGUE

Paper Diary

5



Saturday, 16 Sep 2017 P07

So far, what is the severity of your symptoms?

HH MM

Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

Optional

Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

46 Please, fill out at least one row per day SKIP

Sunday, 17 Sep 2017 P07

So far, what is the severity of your symptoms?

HH MM

Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

Optional

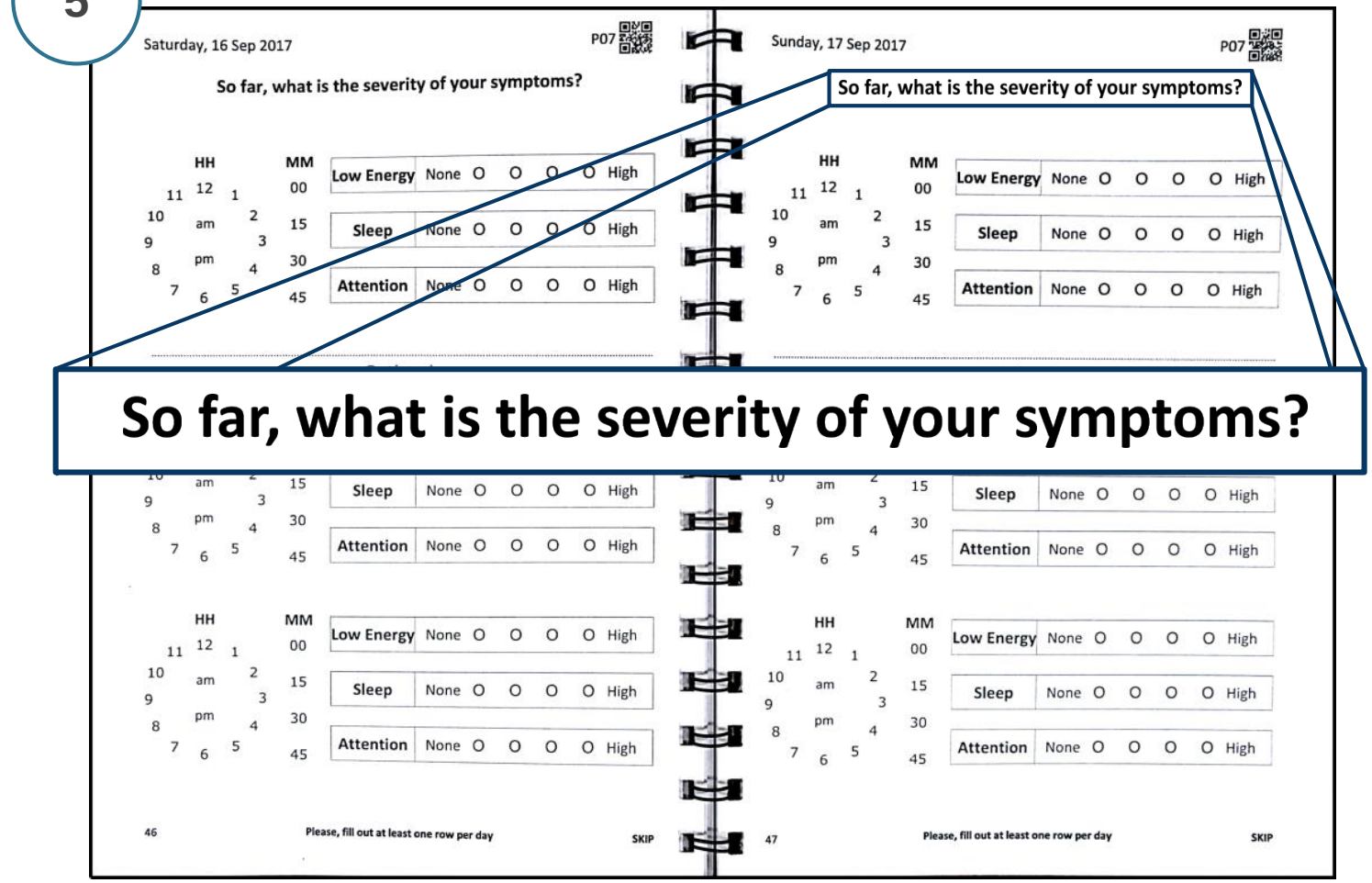
Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

Low Energy	None	O	O	O	O	High
Sleep	None	O	O	O	O	High
Attention	None	O	O	O	O	High

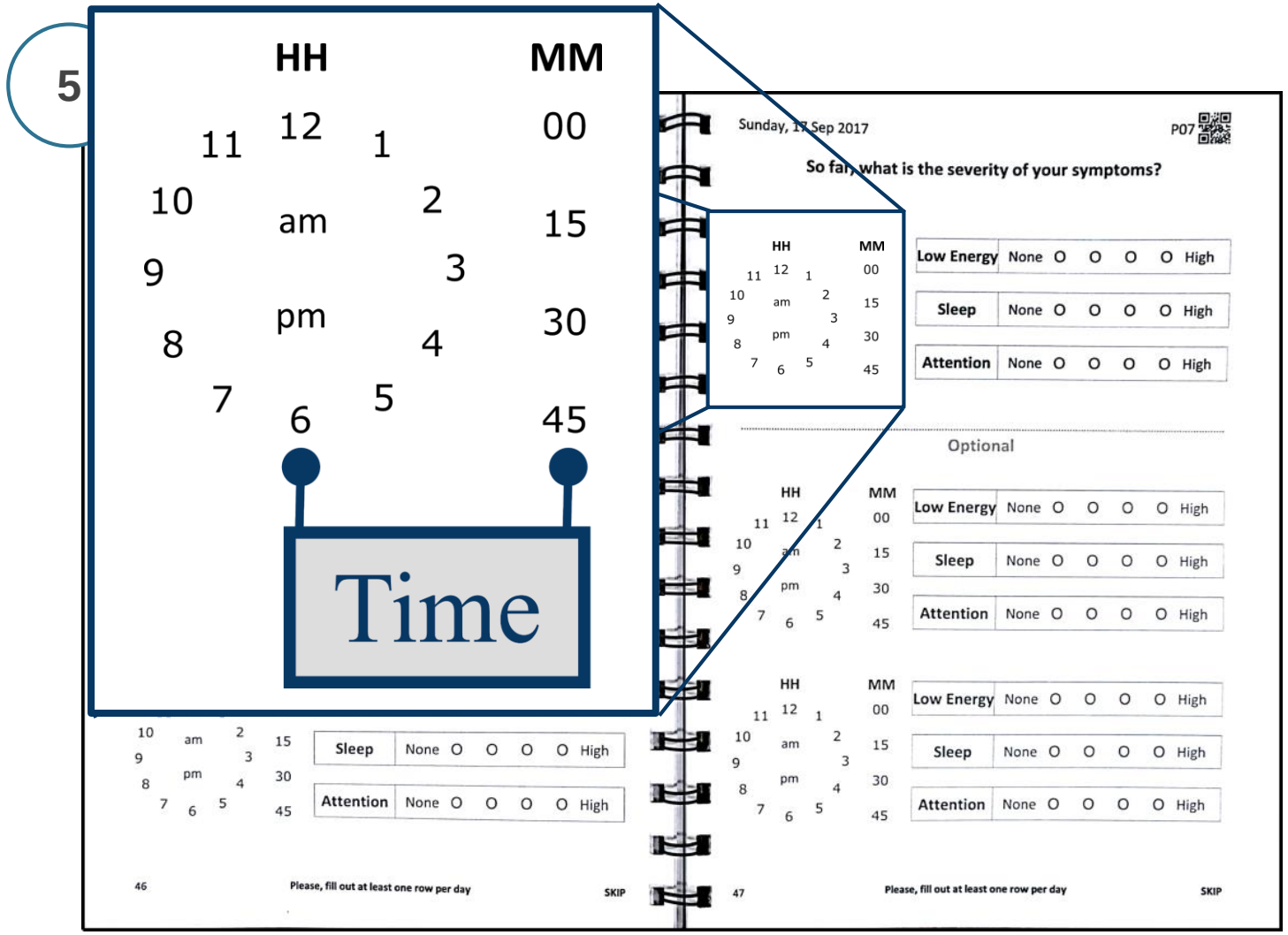
47 Please, fill out at least one row per day SKIP

Paper Diary

5

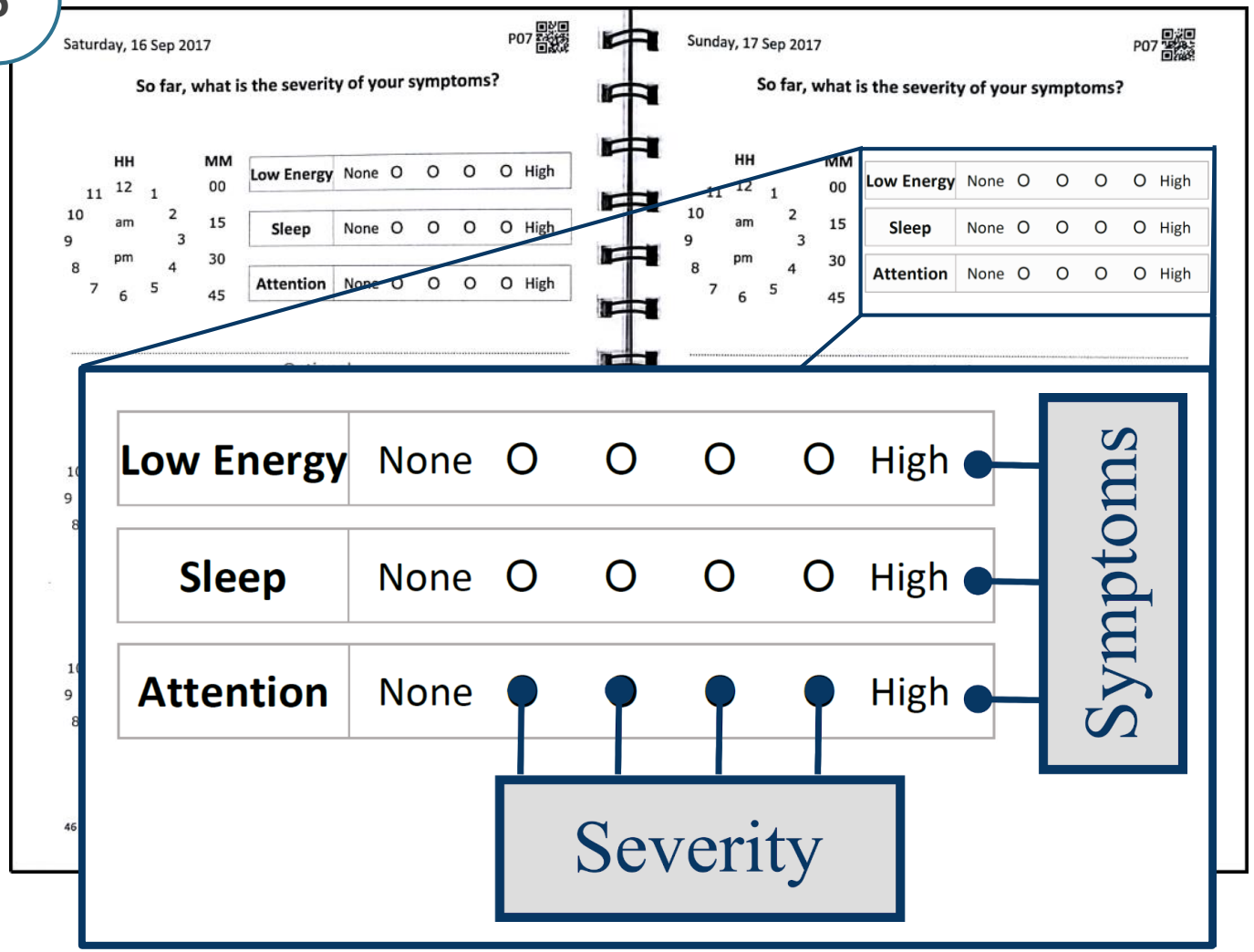


Paper Diary

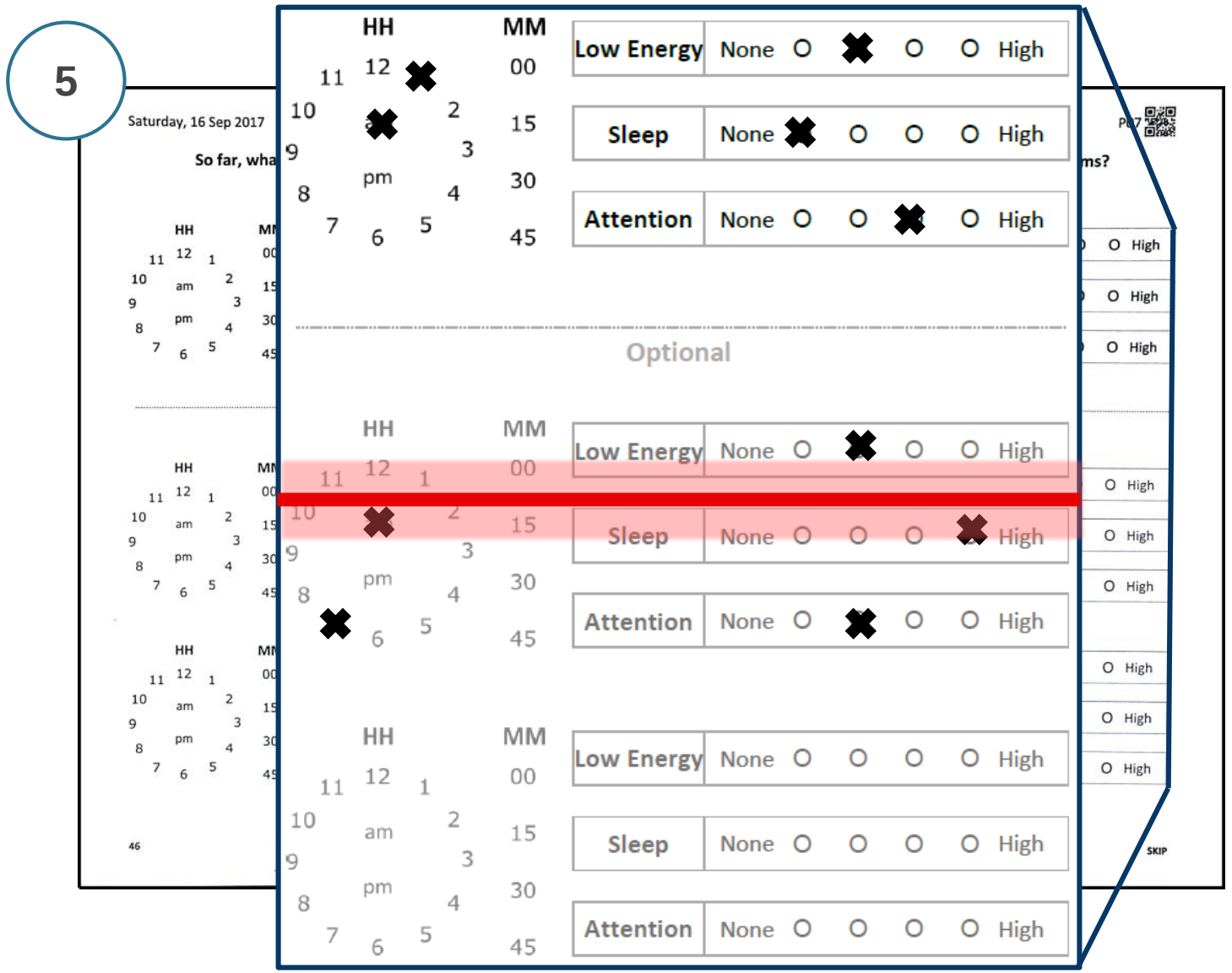

5
HH
MM
12
1
00
11
10
2
15
am
9
3
pm
30
8
4
7
6
5
45
Time
Sunday, 17 Sep 2017
P07
So far, what is the severity of your symptoms?
Low Energy None O O O O High
Sleep None O O O O High
Attention None O O O O High
Optional
Low Energy None O O O O High
Sleep None O O O O High
Attention None O O O O High
Low Energy None O O O O High
Sleep None O O O O High
Attention None O O O O High
46
Please, fill out at least one row per day
SKIP
47
Please, fill out at least one row per day
SKIP

Paper Diary

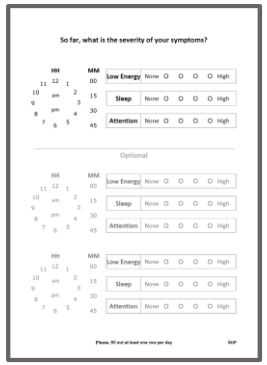
5



Paper Diary

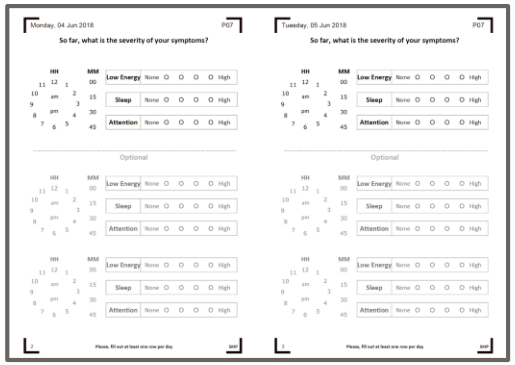

5
Saturday, 16 Sep 2017
HH
MM
Low Energy
None
High
Sleep
Attention
Optional

Create and encode paper diaries or surveys



Template

Create



Diary

https://PaperStream.netlify.com

Scan Diaries

Encode

Answers

Did the diary work?

7 participants

~380 days
(at least once a day)

Answer rate
96%

Why 96%? It was simple, flexible, and physical

Put your users first

Data Analysis

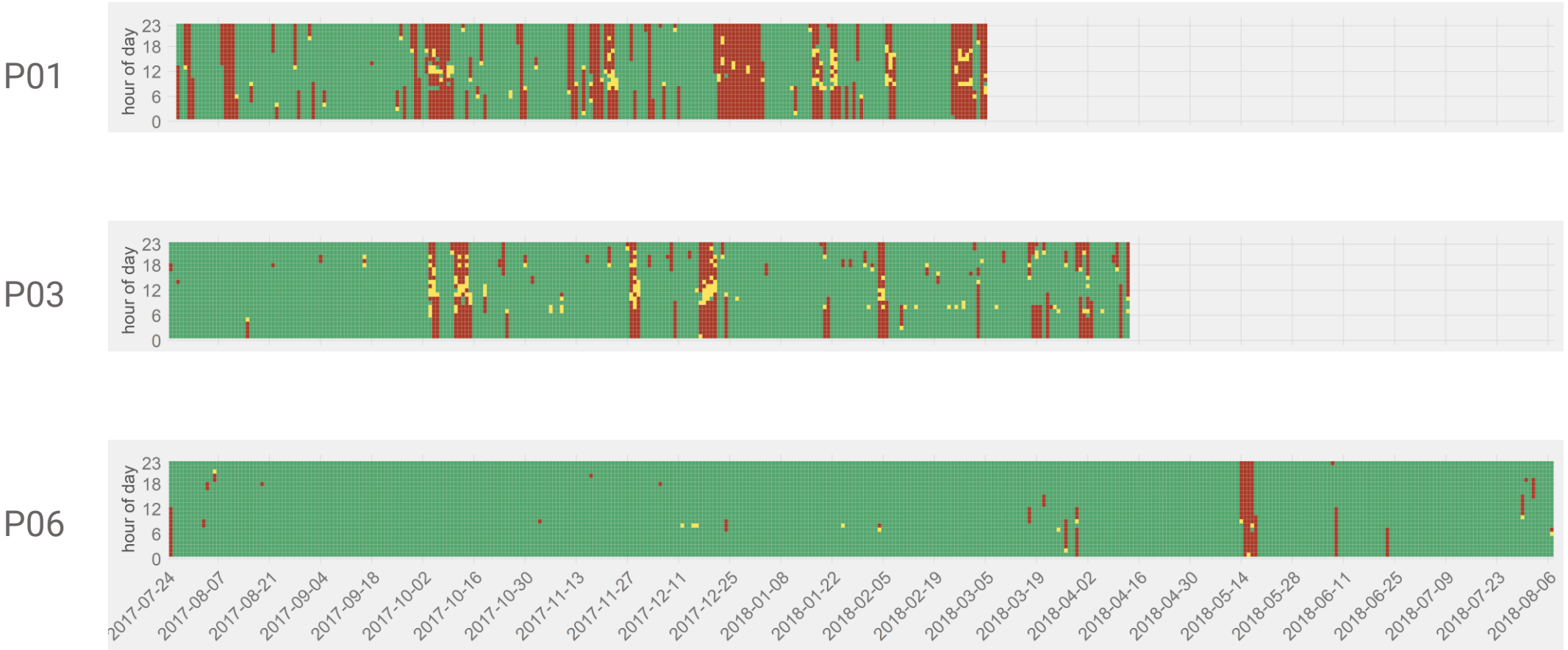
(a.k.a. data cleaning)

Key factor

Personalisation → Precision Medicine

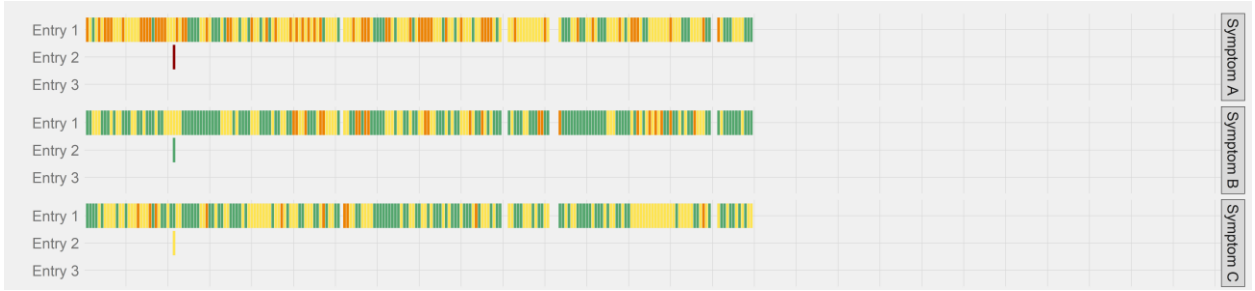
~~Generalisation~~ → ~~Population Methods~~

Smartphone data

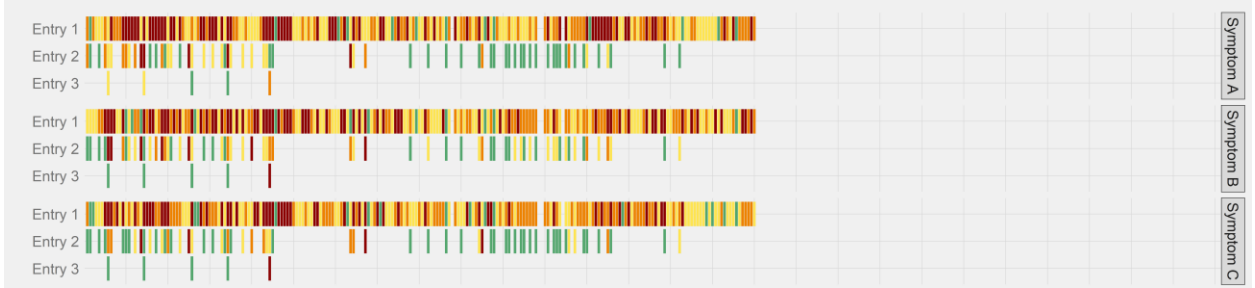


Diary data

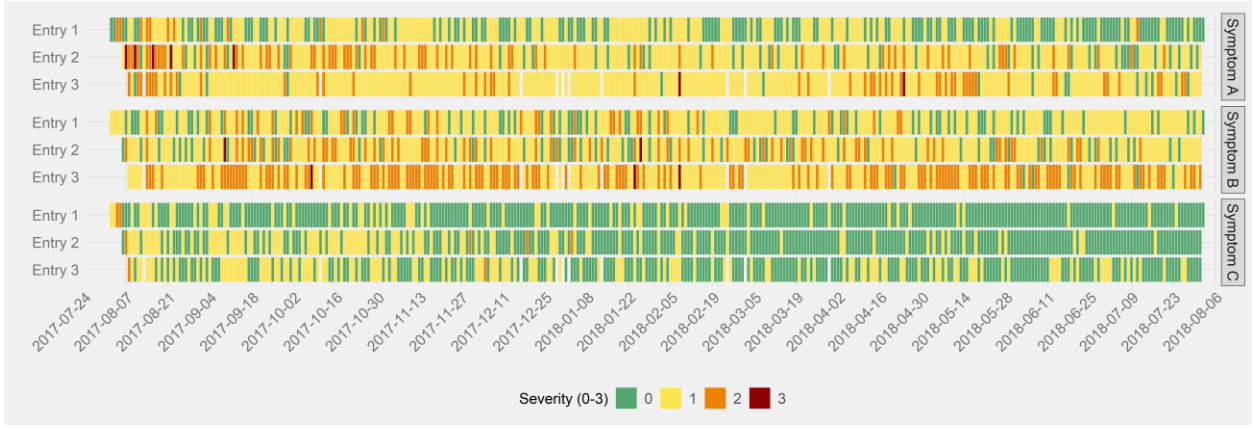
P01



P03



P06



Our data

Smartphone data

- **14 location (Canzian ‘15, Barnett ‘18)**
- **2 Activity Recognition (Google API)**
- 4 calls
- 2 screen
- 2 sleep
- 1 Wi-Fi
- 1 light, 2 SMS, 5 keyboard (only Android)

Groundtruth data

- **Daily self-reported top 3 personal symptoms**
- Clinical (every 6 weeks)
  - MDS-UPDRS: Gold standard
  - PDQ-39: Quality of life
  - NMS: Non-motor symptoms
  - ACE: cognition
  - Six laptop-based cognitive tests

Be aware of the benefits and limitations of technology

The bottleneck

… a main bottleneck in the current digital phenotyping work is not due to technical challenges but more due to the lack of sufficient statistical methodology…

Lisa A. Marsh
Opportunities and needs in digital phenotyping
Nature Neuropsychopharmacology April '18

Personal Predictions

1 Create Prediction

Define relation between smartphone features and human behaviour

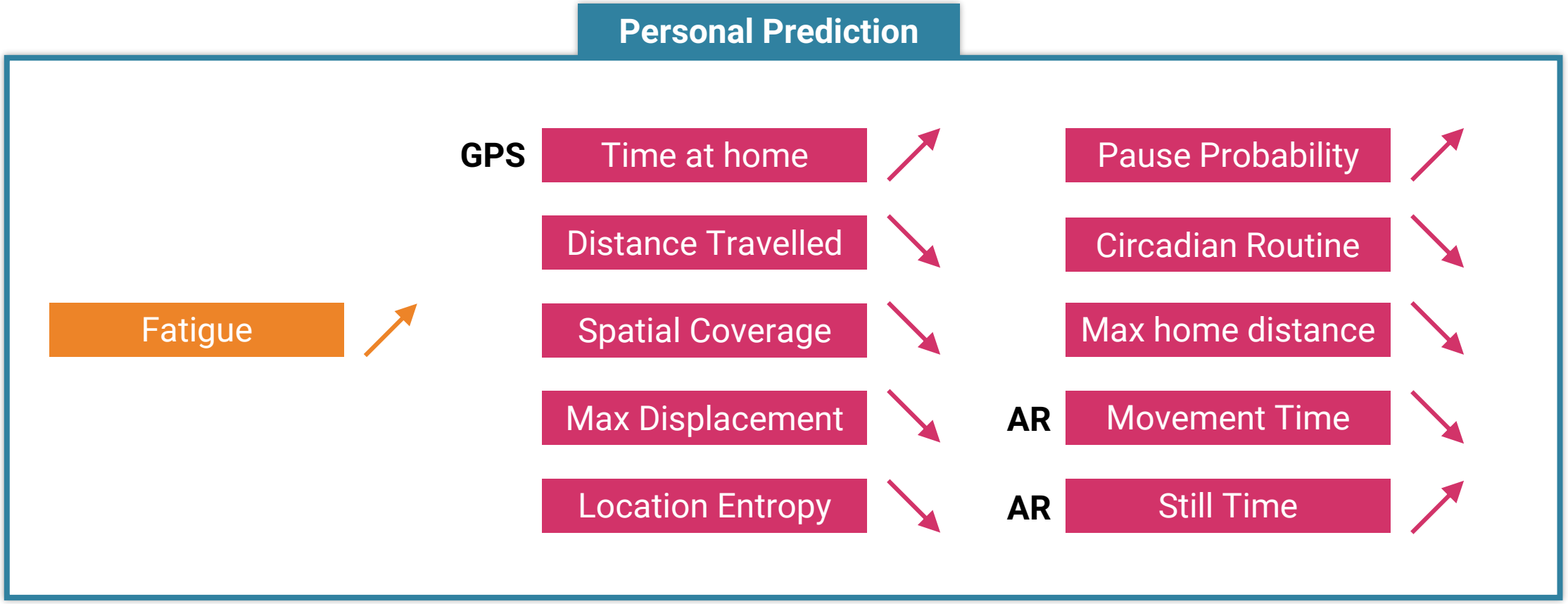
2 Personalise Prediction

Adapt smartphone features to each person's symptom fluctuations

3 Test Prediction

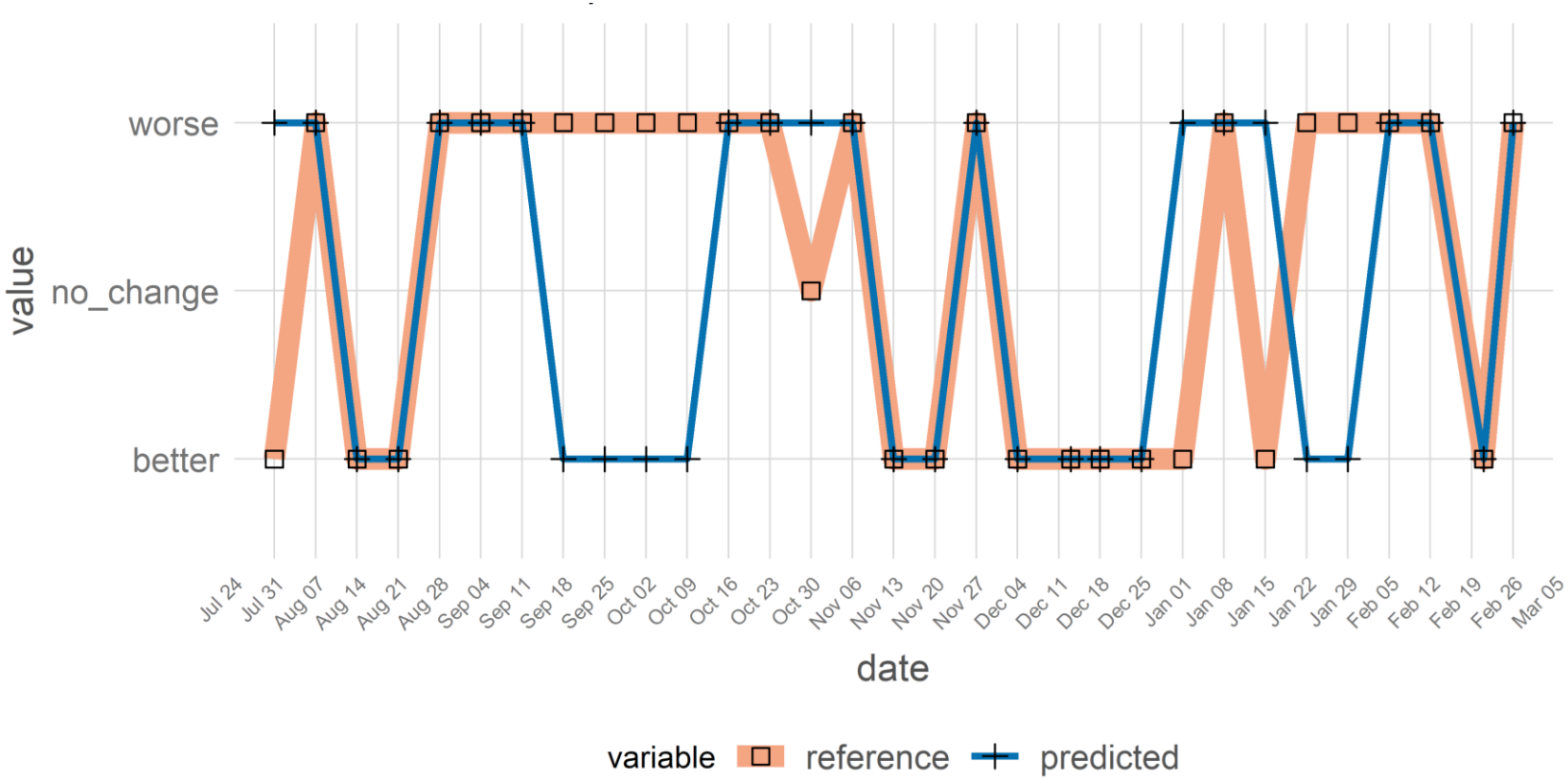
Compare adapted features to a random baseline

Example of prediction



What features are relevant to each person?

Results

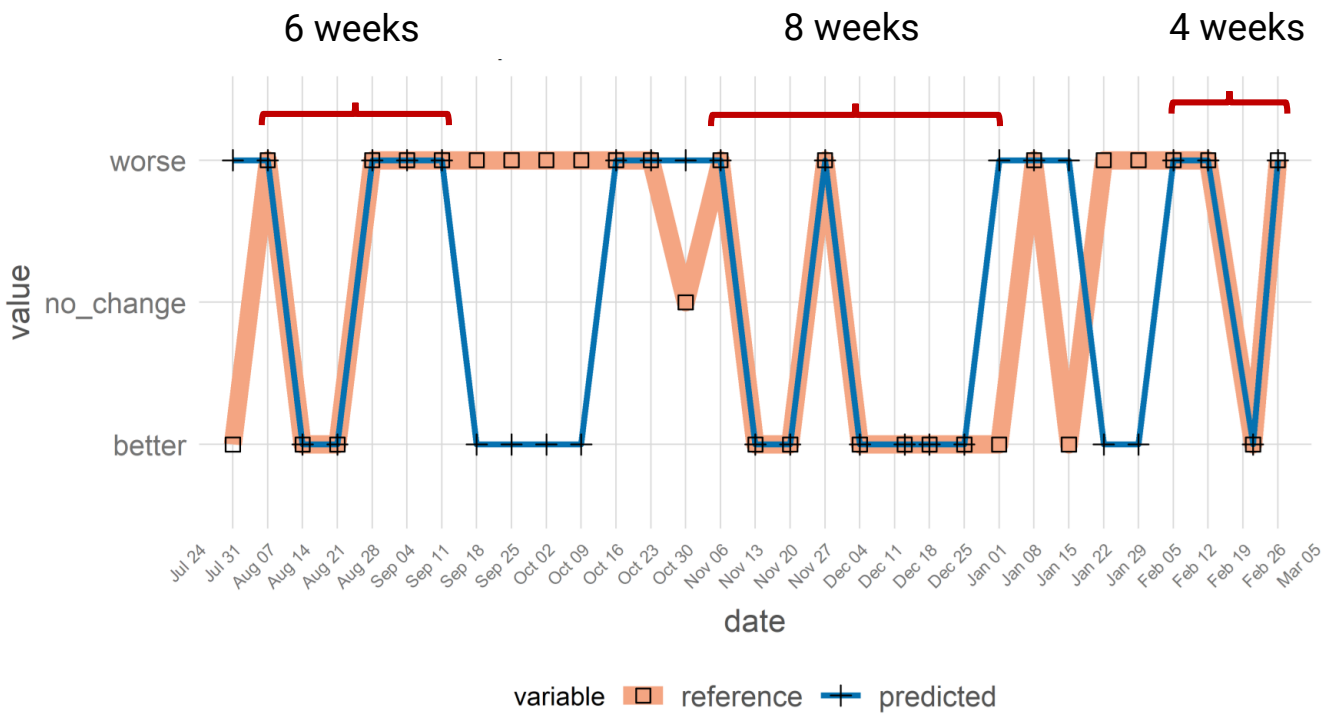


P01 - Fatigue

Personal Prediction on 100% of data

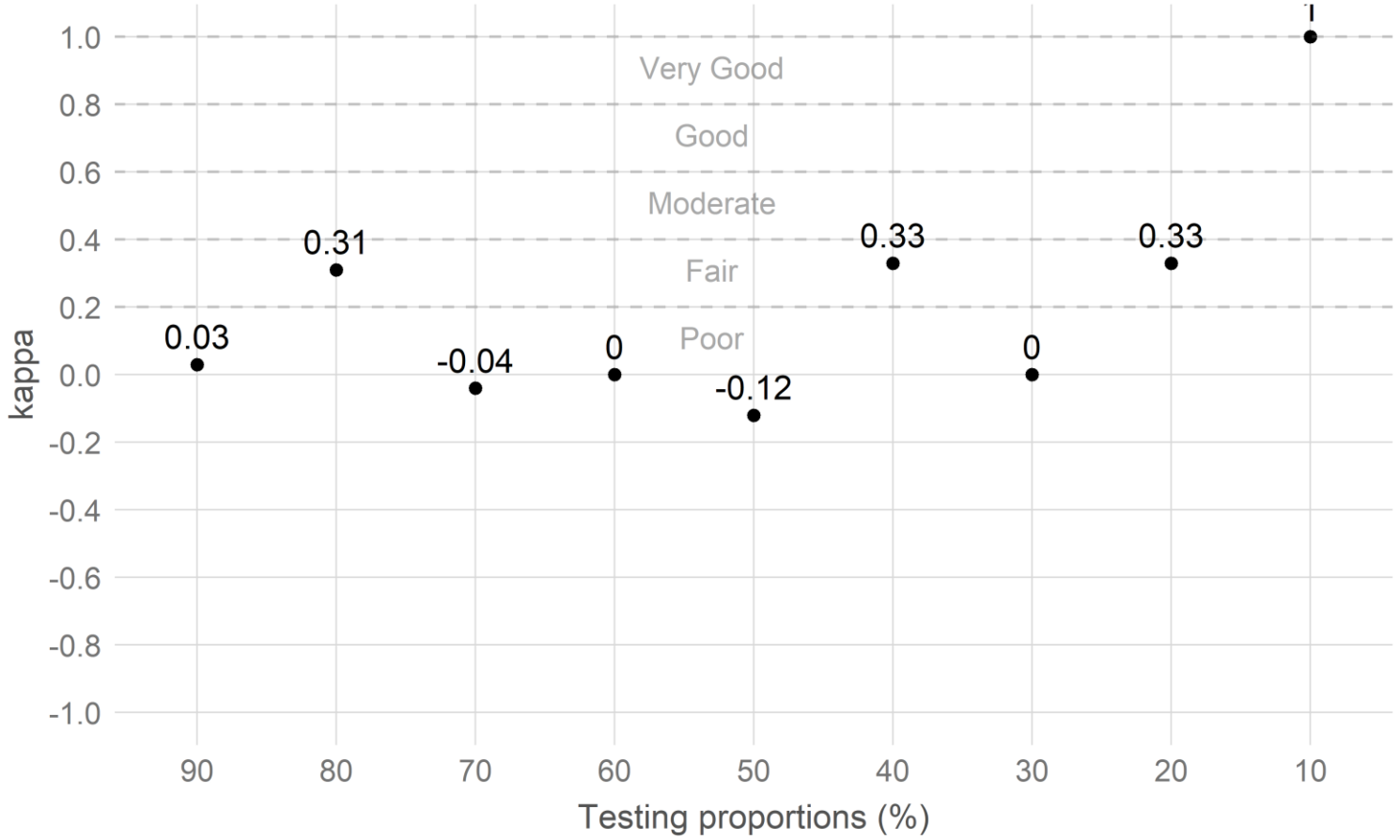
Participant	Groundtruth	weeks	Agreement
P01	Slow Walk	31	0.53
P01	Fatigue	31	0.37
P03	Low Energy	31	0.29
P03	Pain	31	0.35
P03	Freezing	31	0.23
P04	Fatigue	37	0.45
P06	Gait	42	0.18
P07	Low Energy	46	0.21
P08	Gait	43	0.34
P08	Pain	43	0.35

P01 Fatigue vs Max Home Distance

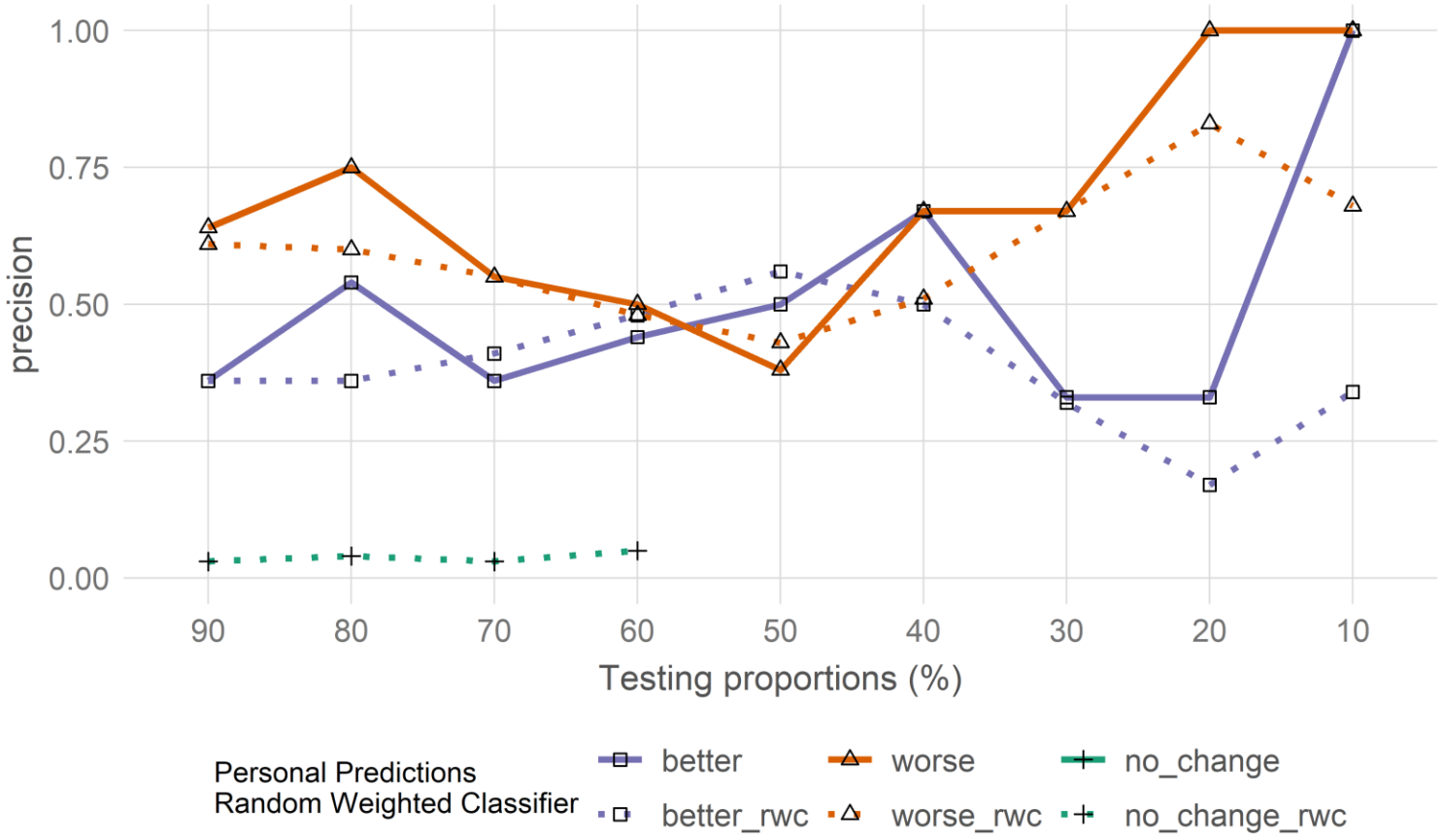


Class	Precision (diff over chance)	Recall (diff over chance)
worse	0.75 (+0.17)	0.67 (+0.09)
no change	0.03 (NA)	0.04 (-0.04)
better	0.60 (+0.22)	0.75 (+0.38)

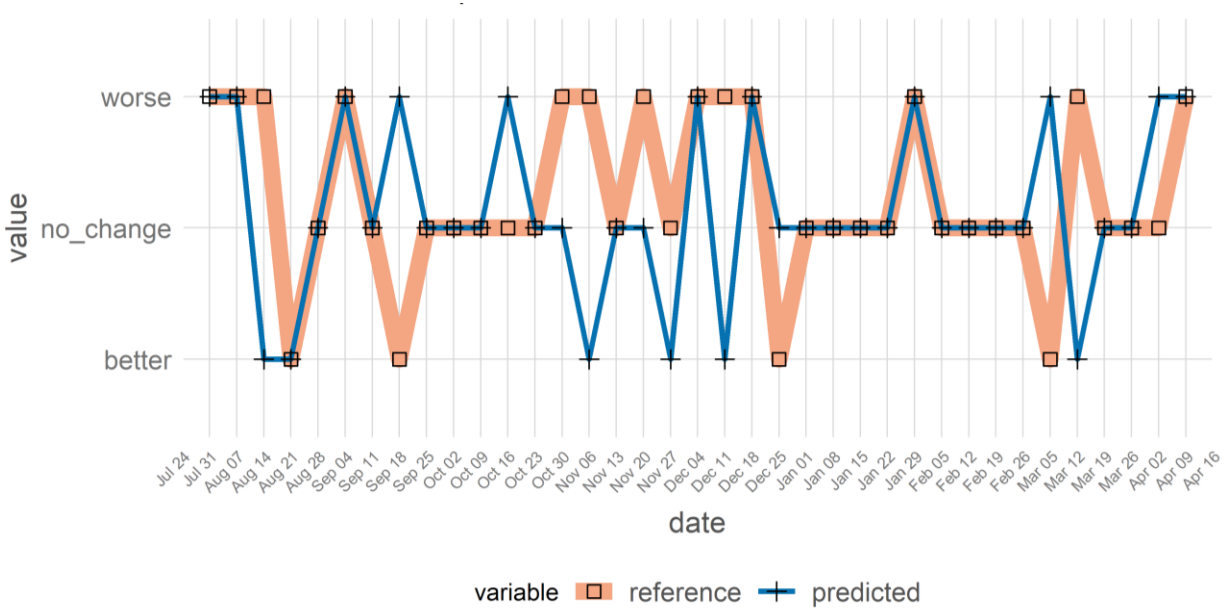
P01 Fatigue (agreement)



P01 Fatigue (precision vs chance)

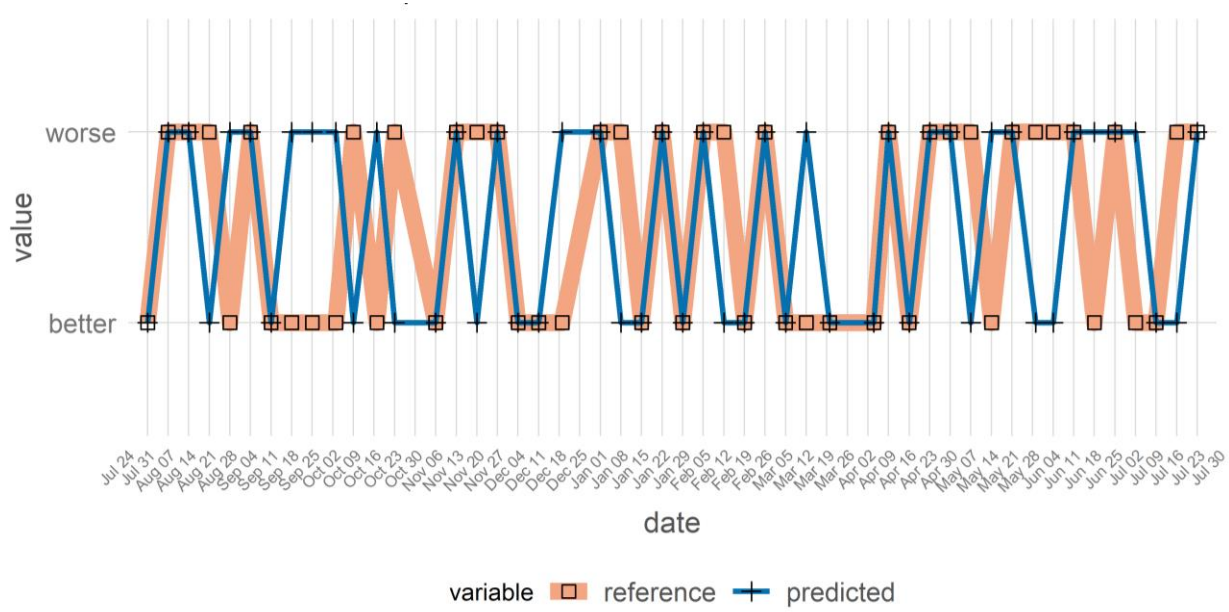


Other participants



P04 - Fatigue

P06 - Gait



Insights

Our method **personalised** smartphone features to people's symptoms (not on unseen data)

Our method **adapted** to patients with different weekly trends

Our method **tracked contiguous fluctuations** (blocks of behaviour)

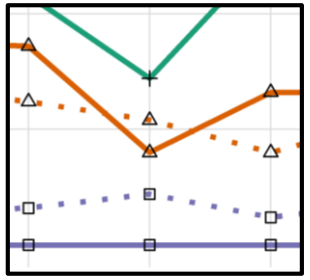
The personalisation/testing split **is not suitable** for a real-world deployment

Limitations (opportunities)

Validity of smartphone features

Confounding factors in people's behaviour

Self-reporting drawbacks



Clinical validity and usefulness of weekly trends

Creating new questions is as good as getting answers

MANCHESTER 1824
The University of Manchester

IAMlab

Unobtrusive and Personalised Monitoring of Parkinson's Disease Using Smartphones

julio.vega@manchester.ac.uk

juliovega.info