# Sensing and Mining Urban Qualities in Smart Cities

AINA-S22: Internet of Things and Social Networking II

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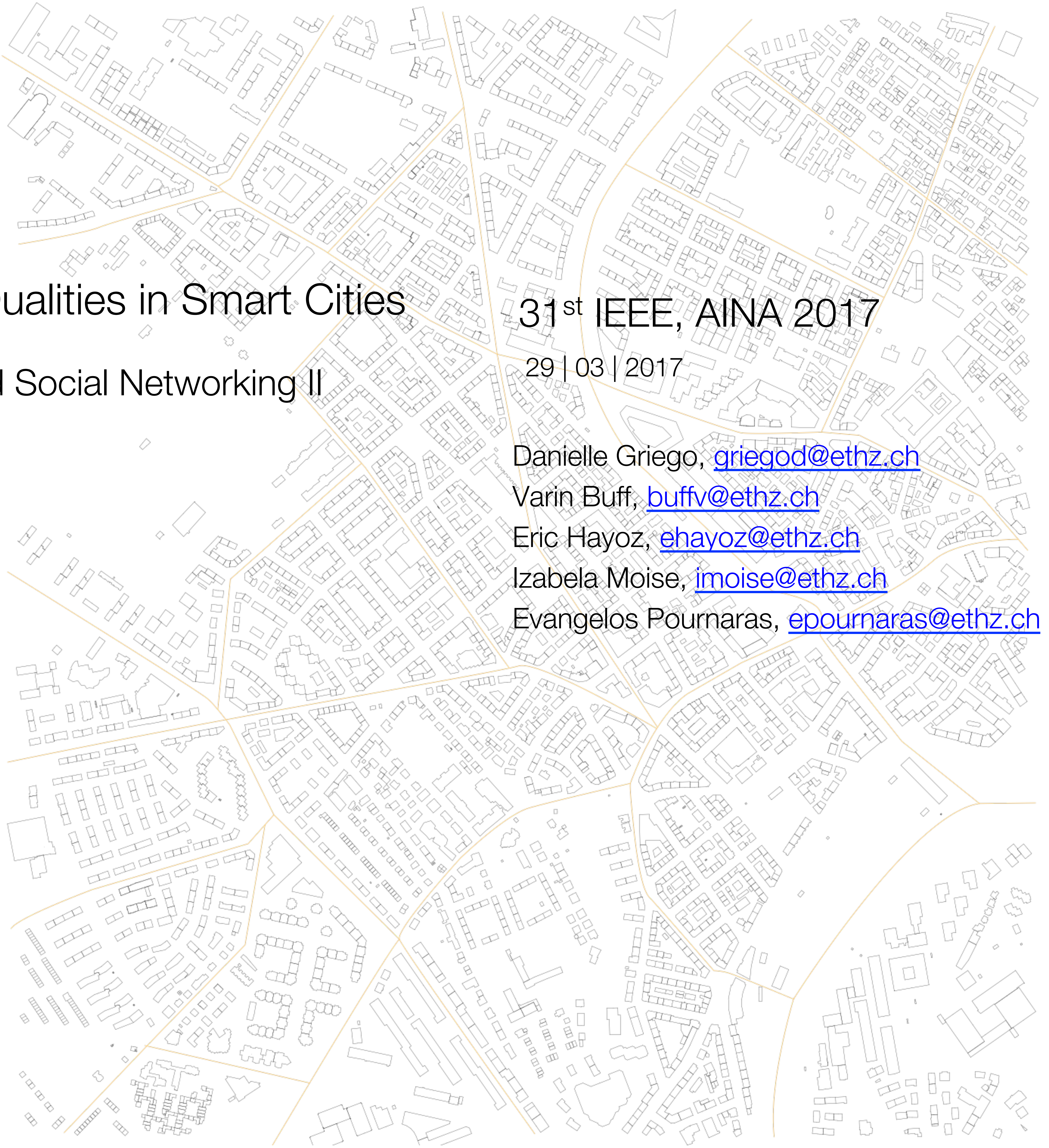

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# Context and motivation

Why cities and why perception?

- *Cities* areas are now the ***predominant living environment*** for the world population
- Important to consider how people ***feel in*** and ***perceive*** cities
- ***Which urban features*** influence perception?
- ***IoT*** and ***Smart City*** infrastructure to investigate this challenge

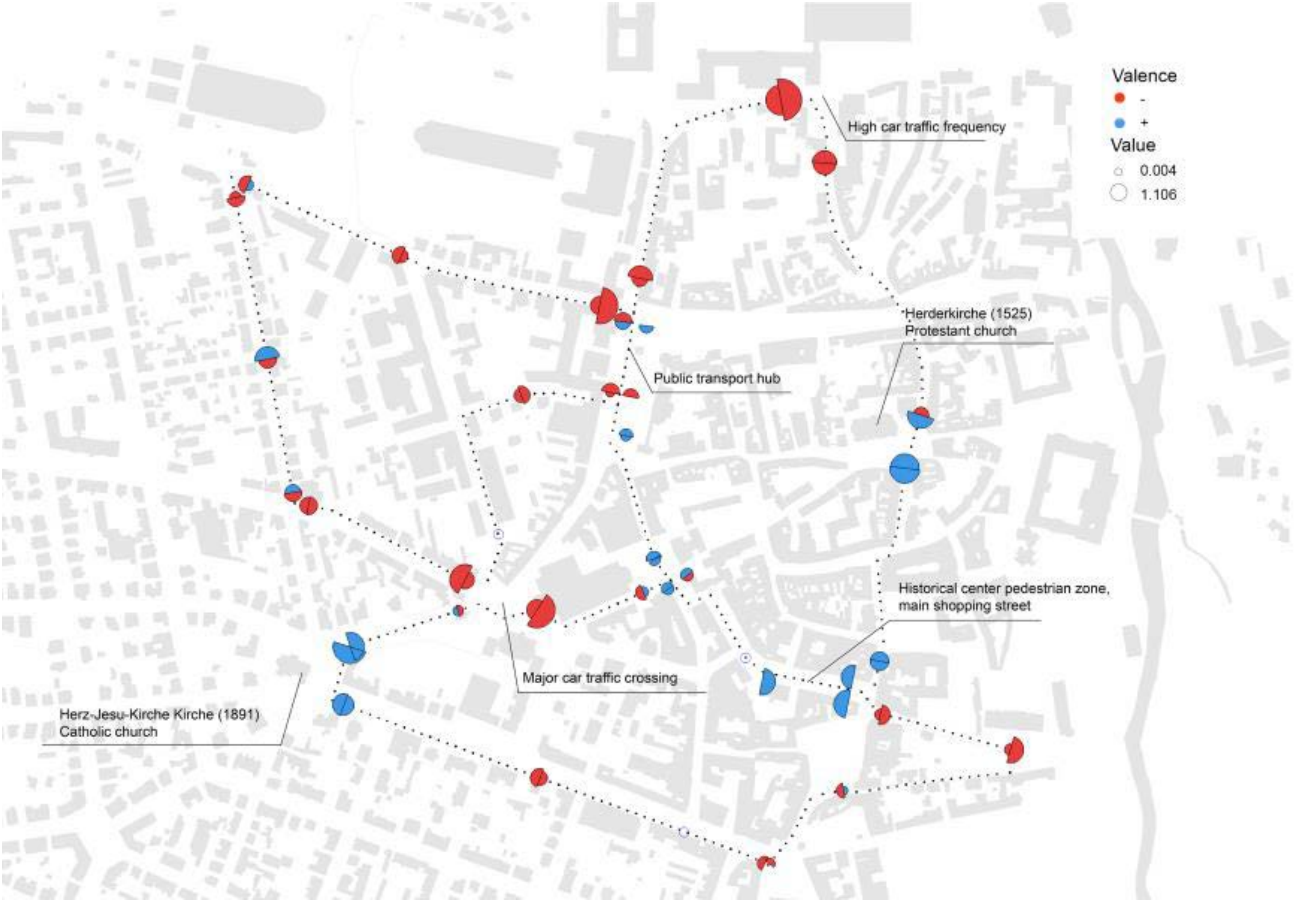
# Contributions

- A novel data collection process in a real-world urban context
- How data science techniques can improve the quality of smart city data analytics
- Mapping citizen’s perception using specific indicators
- Greater understanding of urban qualities by mining spatial correlations

# Background

Previous studies from urban planning focus on:

- Explicit perception of urban environments using subjective impression ratings (surveys)




M. Bielik, S. Schneider, S. Kuliga, M. Valasek, and D. Donath, "Investigating the effect of urban form on the environmental appraisal of streetscapes."

# Background

Previous studies from urban planning focus on:

- Explicit perception of urban environments using subjective impression ratings (surveys)
- Implicit perception of urban environments using biofeedback data


Fig 1
Locations of emotional arousal are colour-coded by Z-scores. Locations surrounded by locations with similarly positive or negative values are shown in red or blue.

*S. I. H. Hijazi, R. Koenig, S. Schneider, X. Li, M. Bielik, G. N. J. Schmit, and D. Donath, "Geostatistical analysis for the study of relationships between the emotional responses of urban walkers to urban spaces," International Journal of E-Planning Research (IJEPR), vol. 5, no. 1, pp. 1–19, 2016.*

# Background

Previous studies from urban planning focus on:

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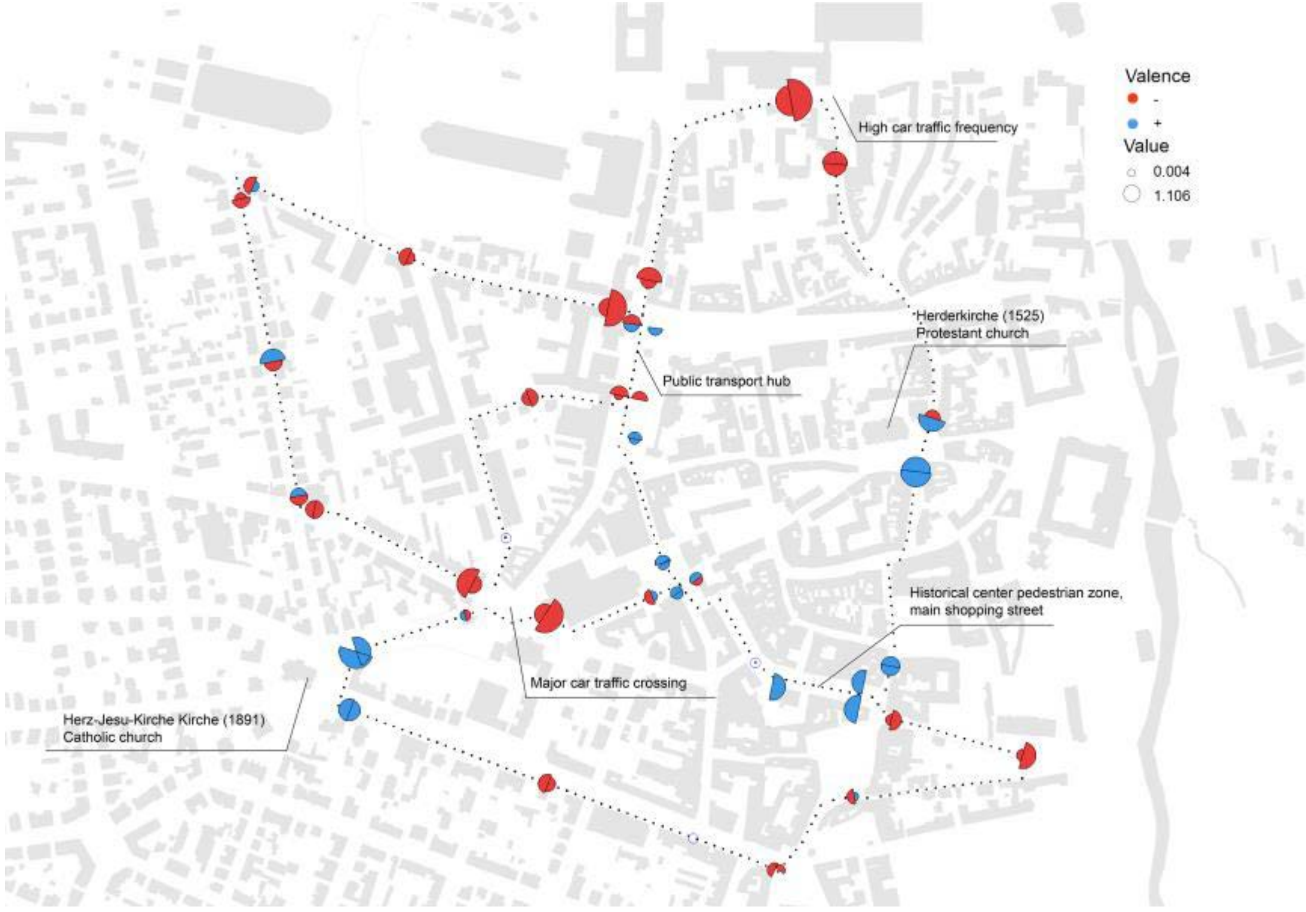
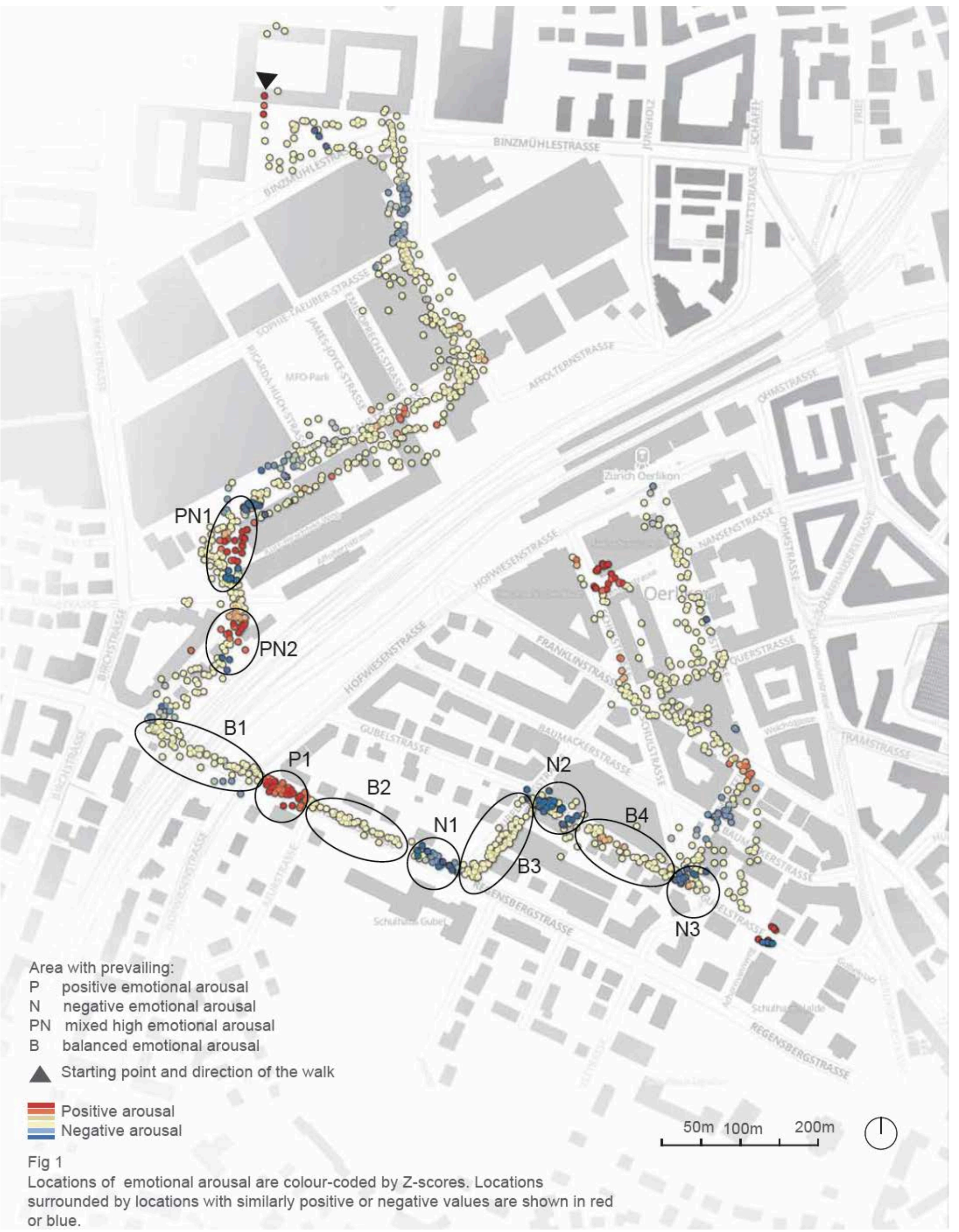


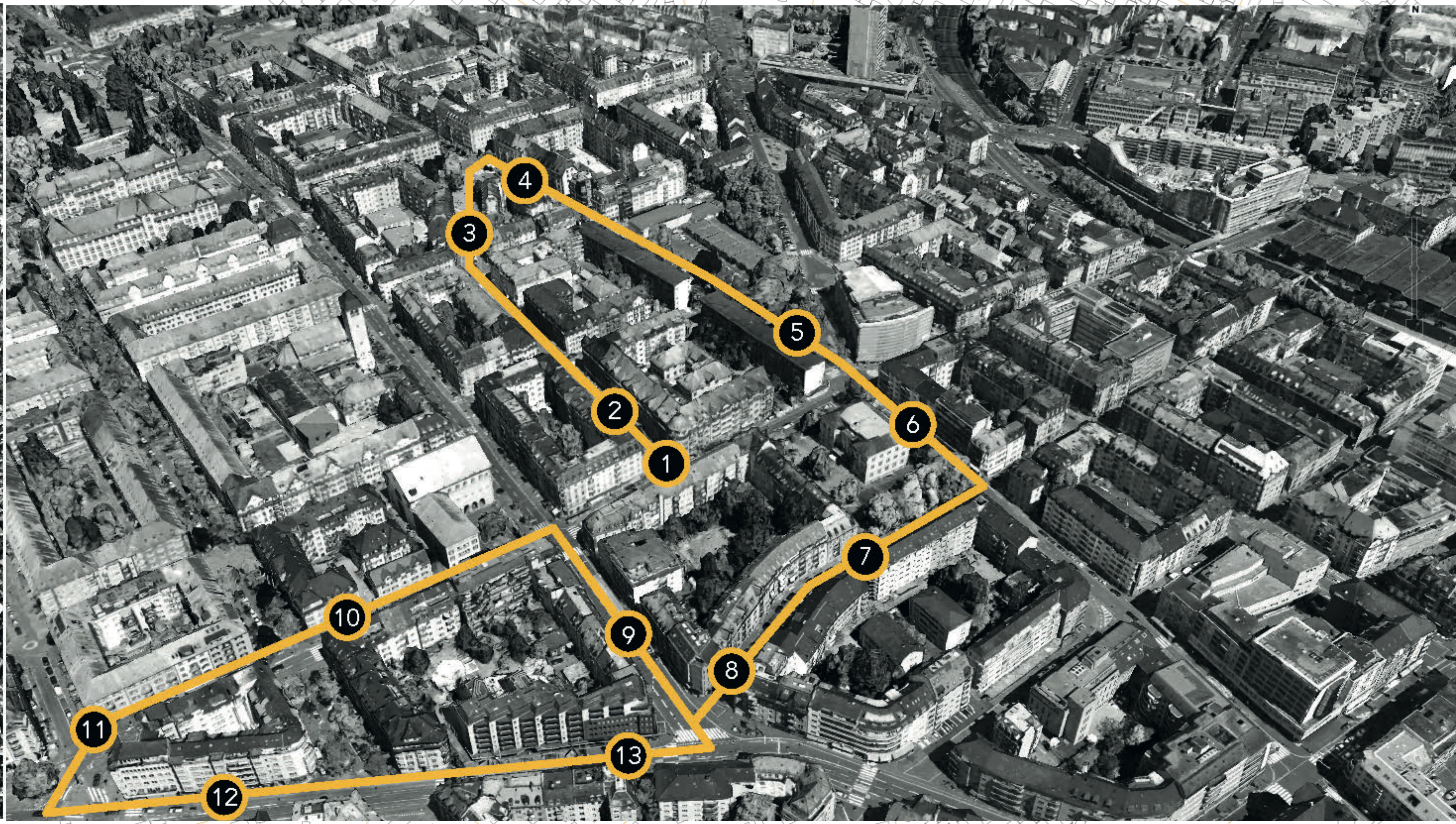




→neither approach consider effects of externalities from the environment such as temp, RH, pollutants, sound, light, etc.

# Case study

Zurich, Switzerland

Alt-Wiedikon Zürich




14 survey checkpoints along experimental path

*Graphics: Brigitte Clements, briclleme@student.ethz.ch*

# Experimental setup

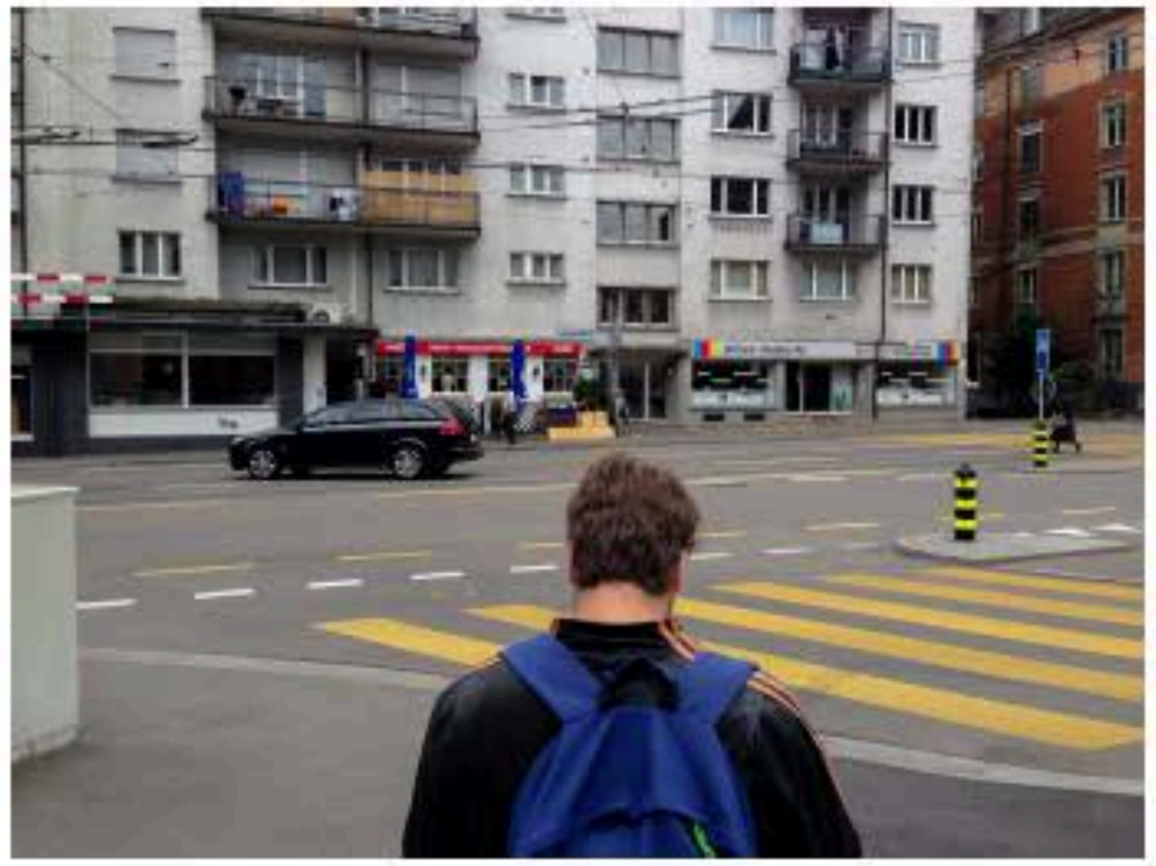
Data collection from 37 participants

- Investigate perception of:
    - Select urban morphological configurations (narrow, spacious)

(a) Pathpoint 2, narrow

(b) Pathpoint 3, spacious

(e) Pathpoint 7, narrow



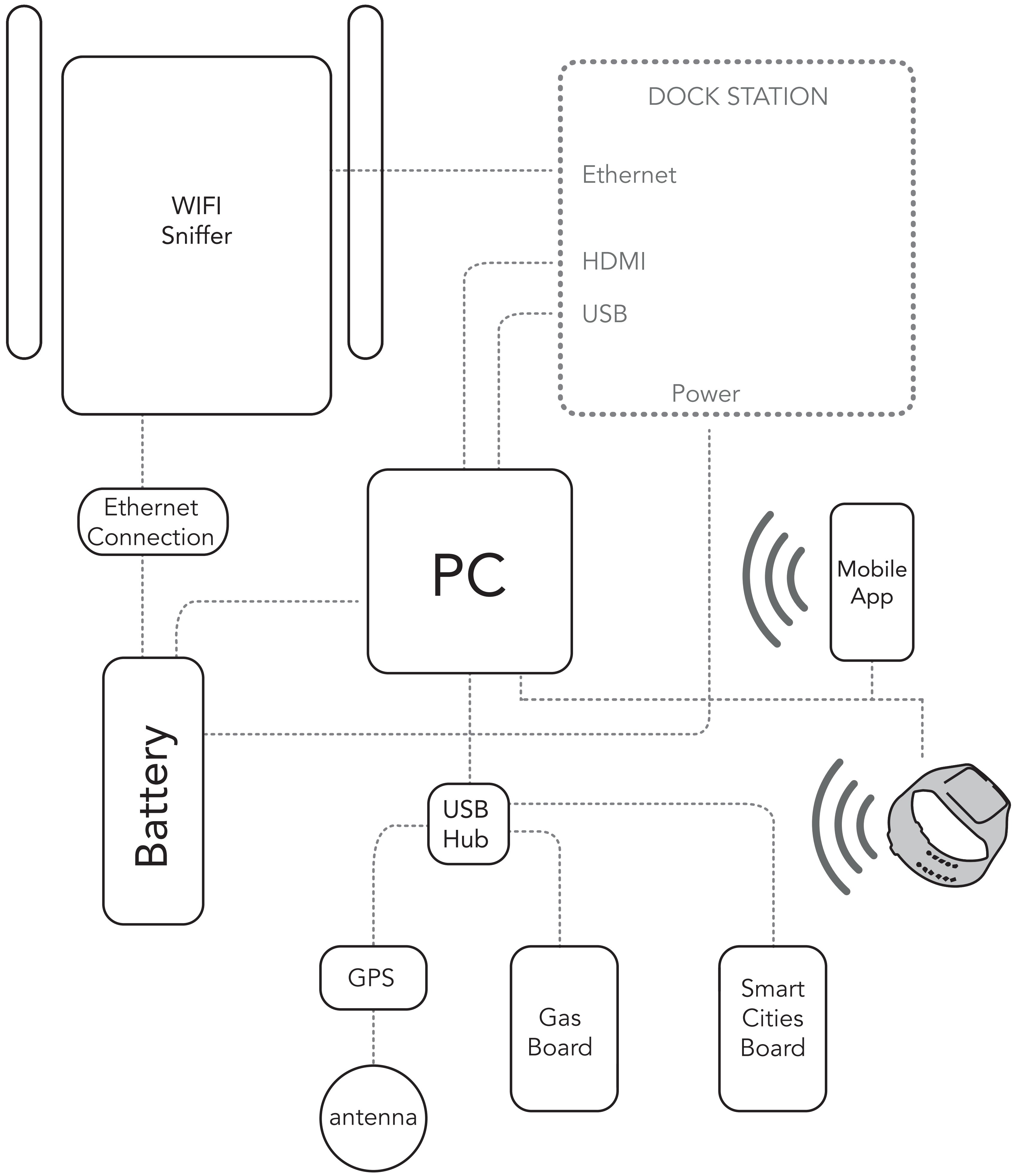
(f) Pathpoint 8, spacious

*Graphics: Brigitte Clements, bricllem e@student.ethz.ch*

# Experimental setup

Data collection from 37 participants

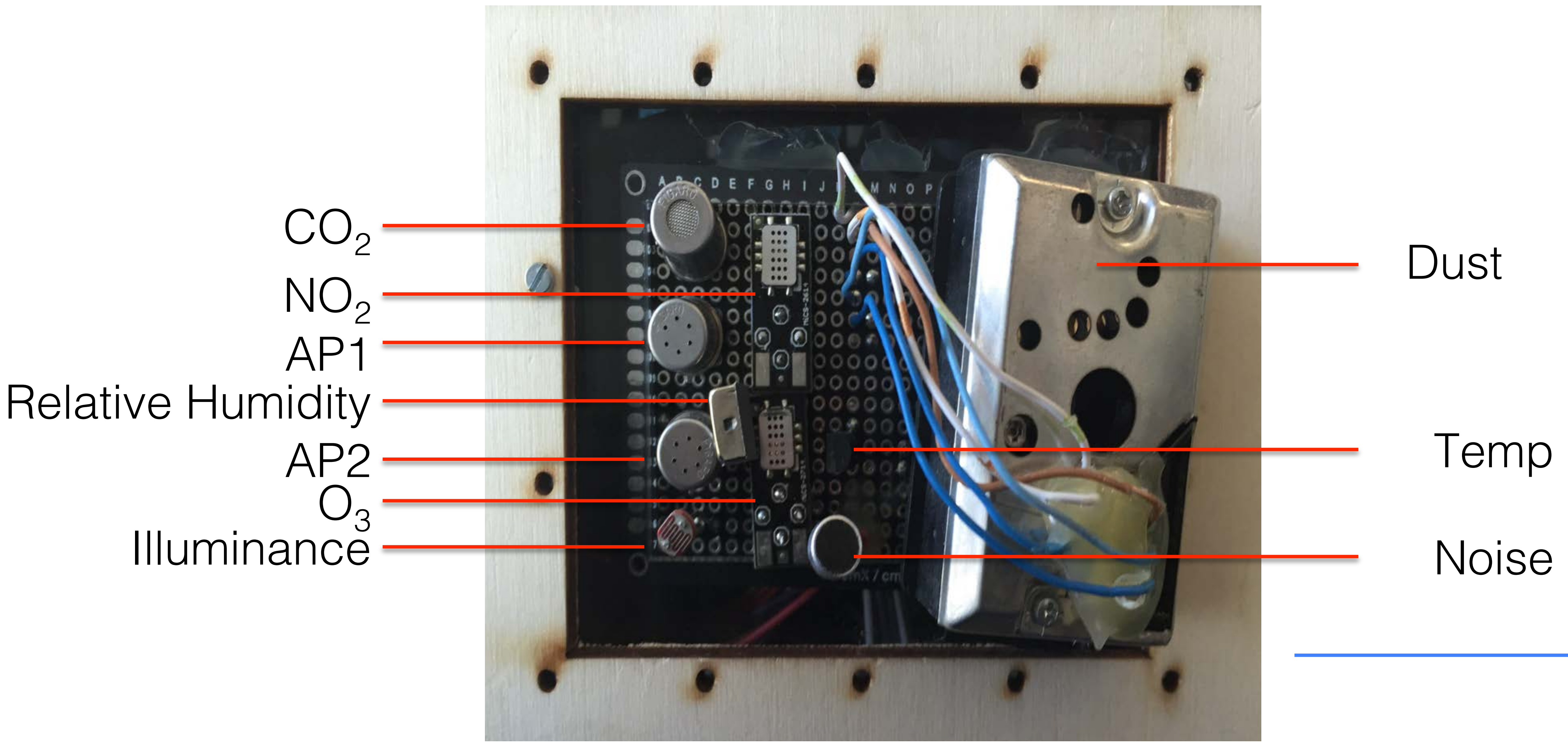
- Investigate perception of:
  - select urban morphological configurations (narrow, spacious)
  - Environmental conditions as measured by (environmental sensors)

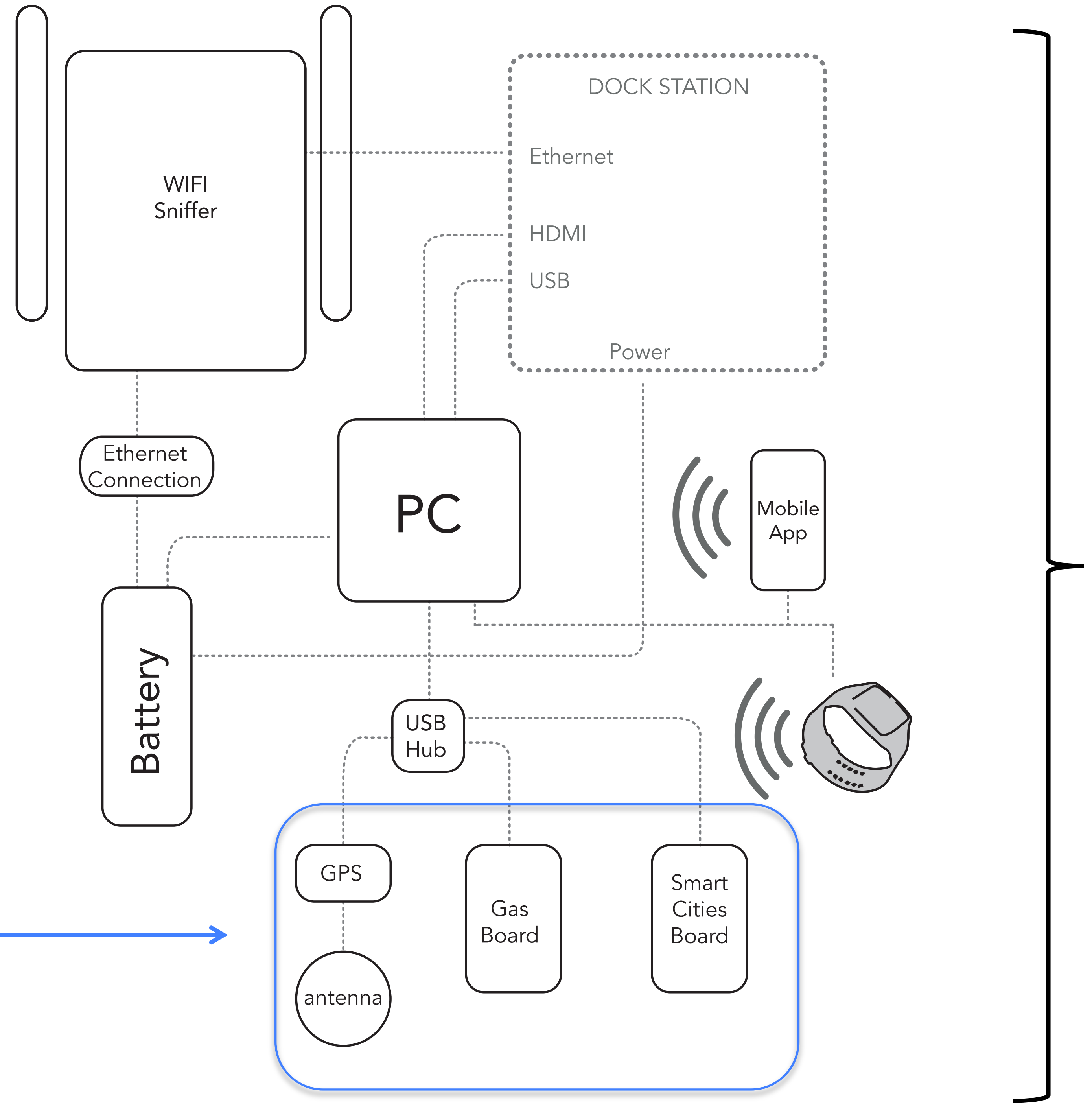



Graphics: Brigitte Clements, bricleme@student.ethz.ch

# Mobile sensing equipment

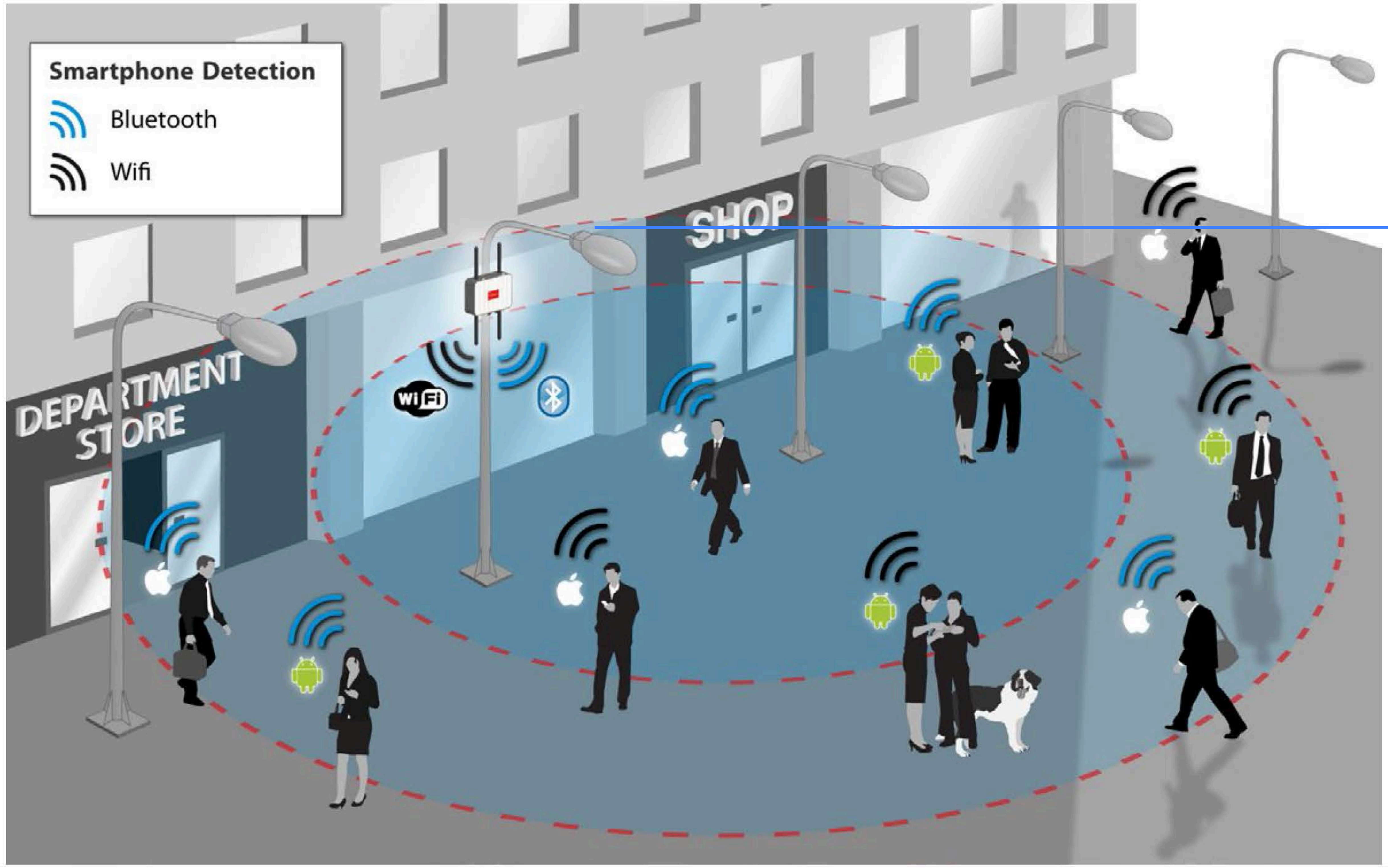
## Environmental sensors

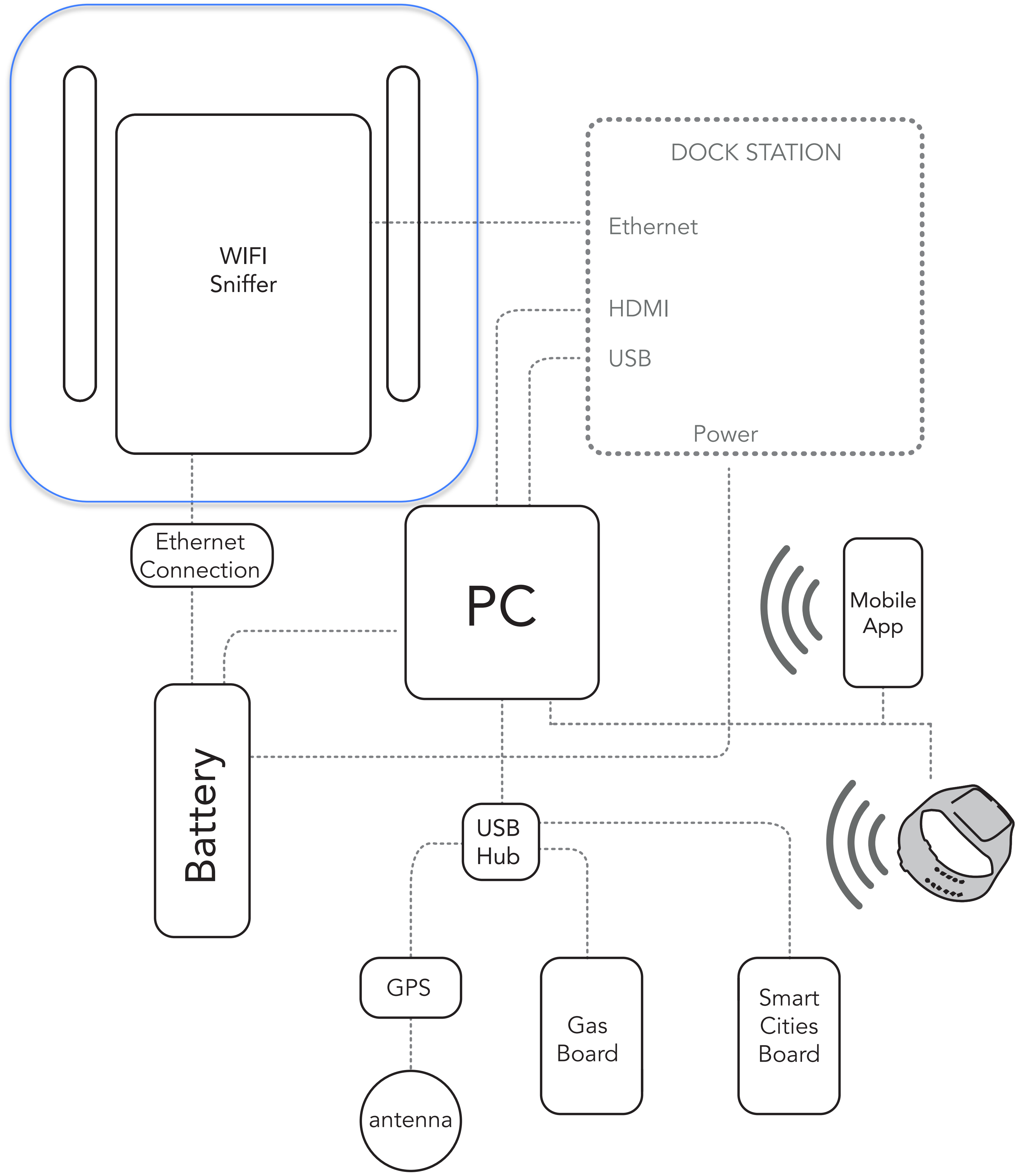



# Mobile sensing equipment

## Wifi-sniffer

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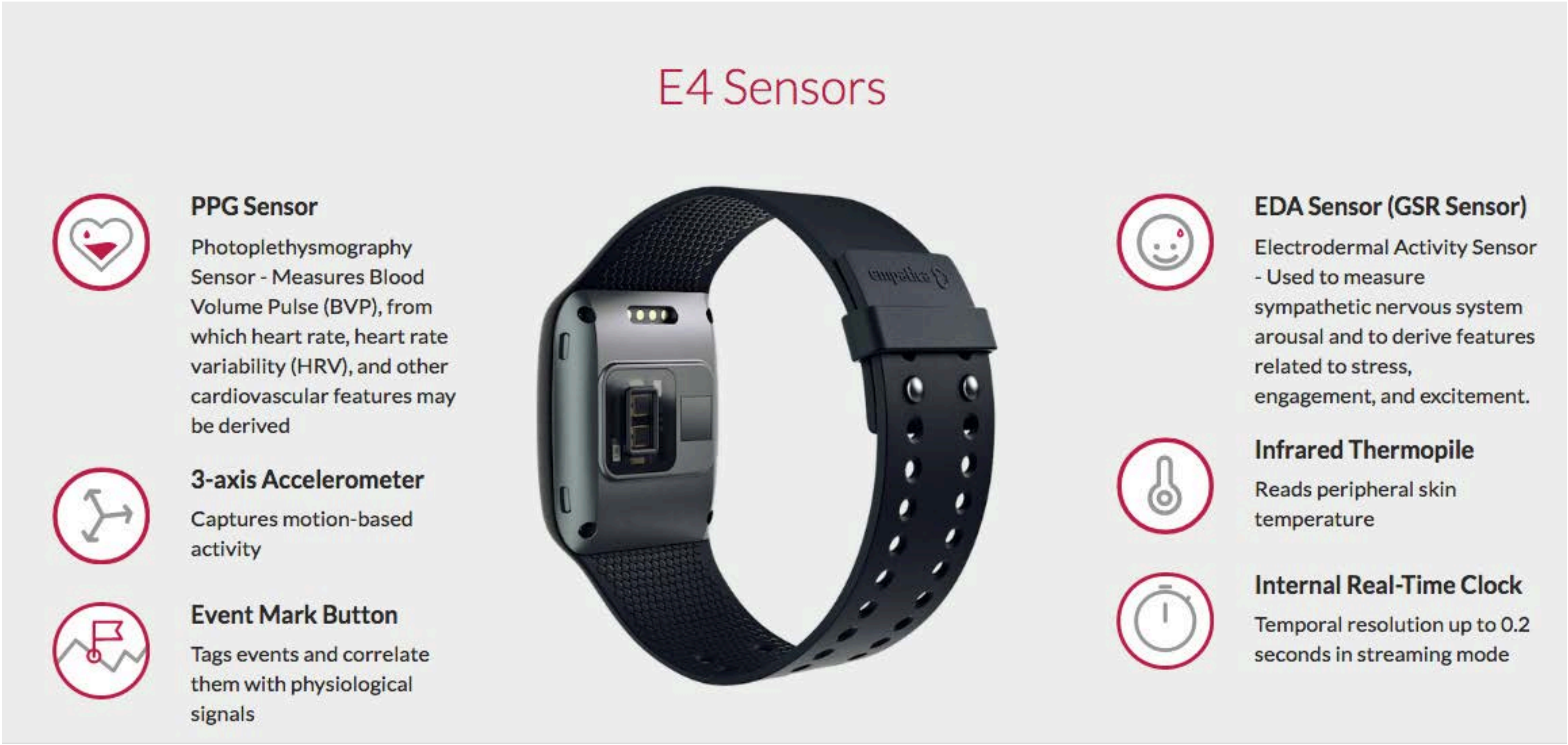
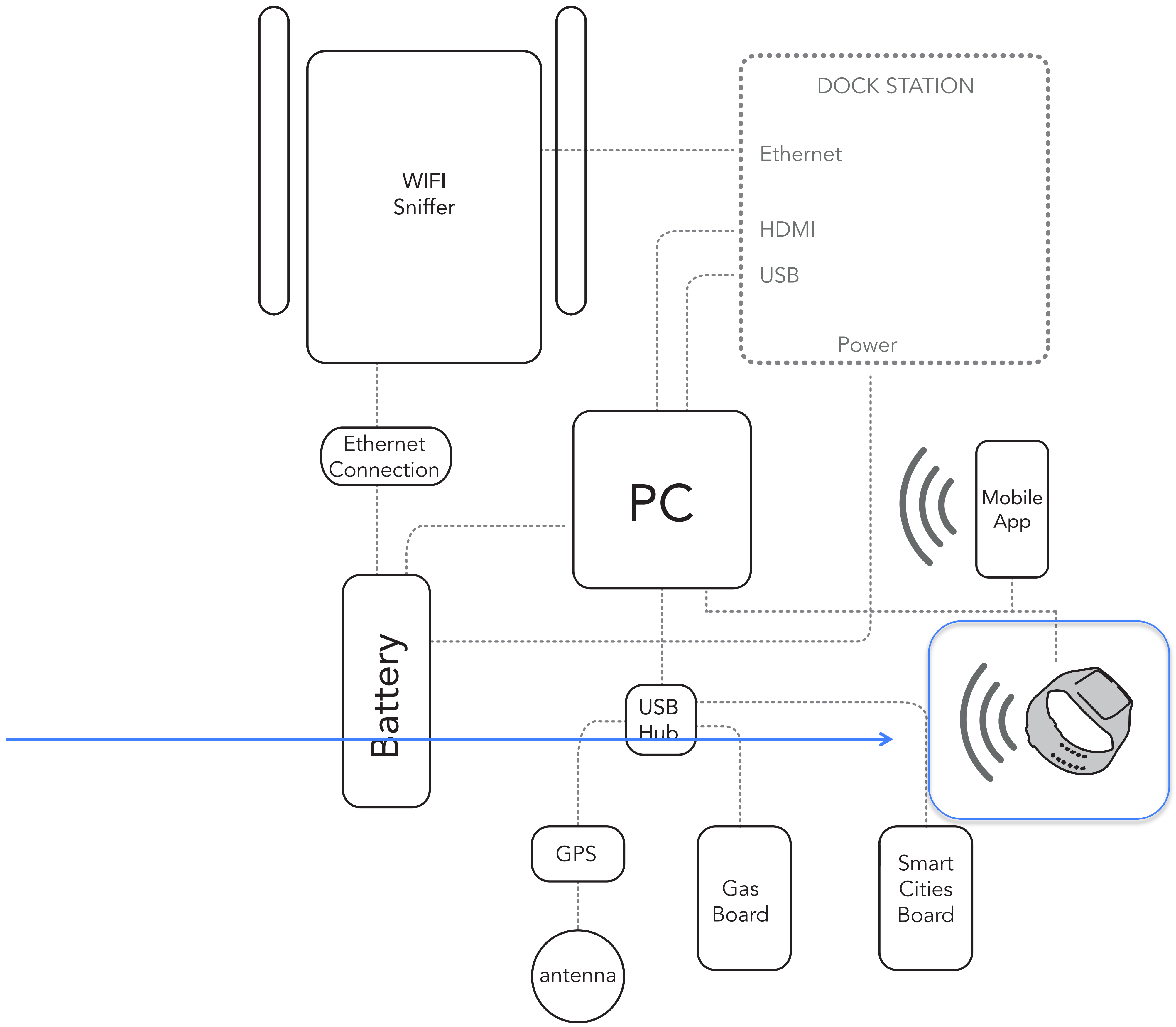
# Mobile sensing equipment

## Biofeedback sensors

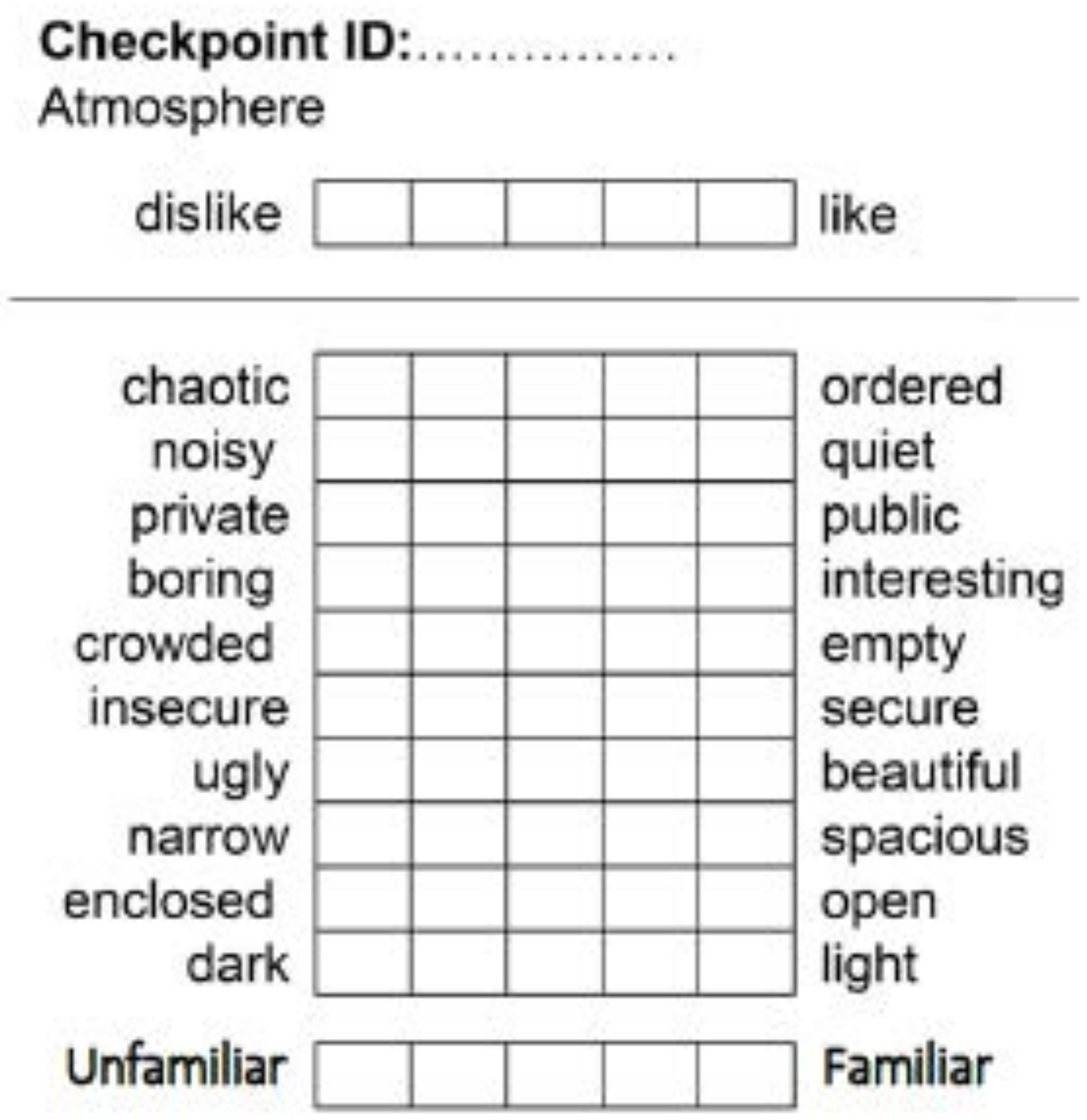


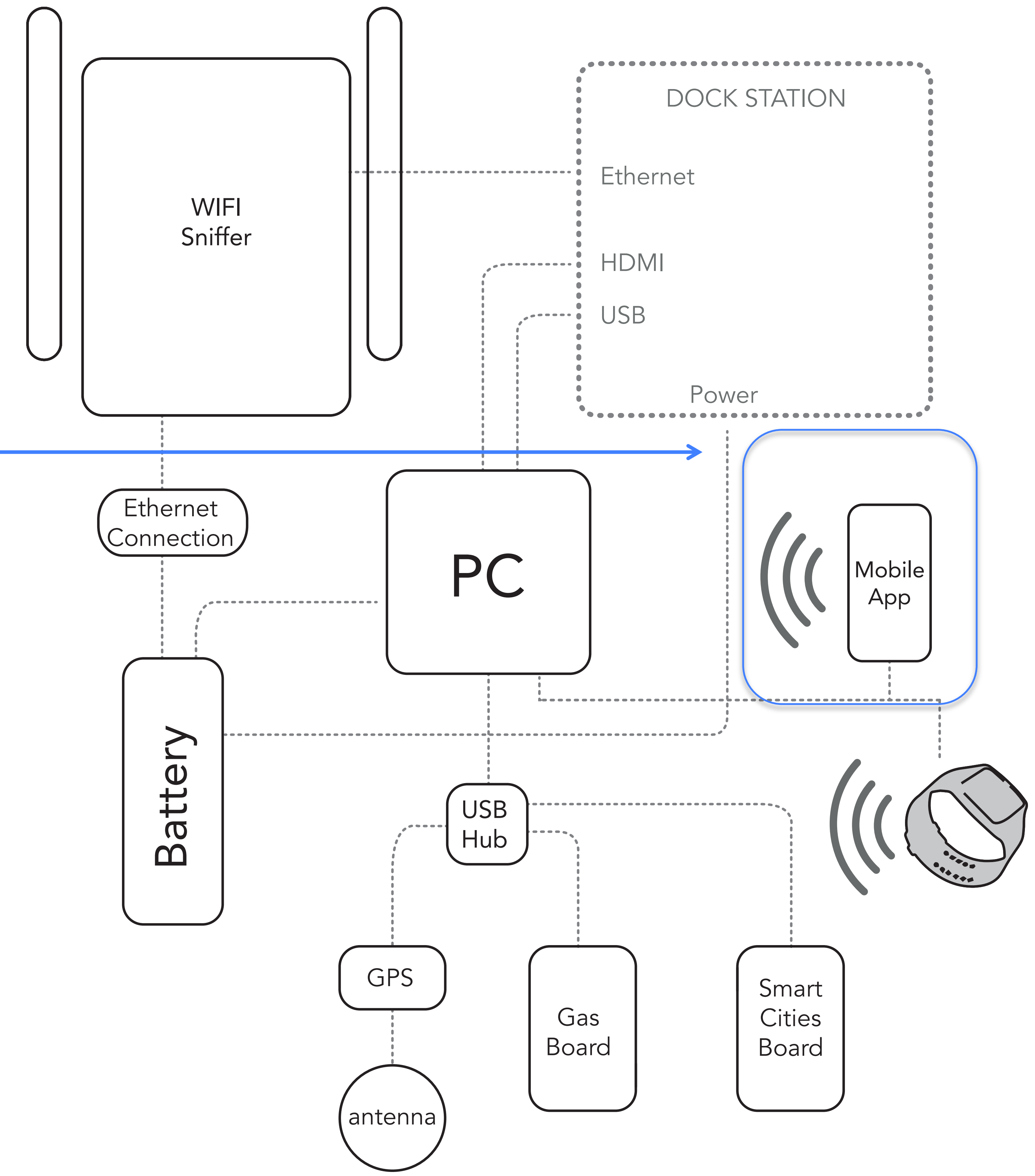

https://www.empatica.com/e4-wristband

# Mobile Sensing equipment

Mobile phone application for virtual sensors







# Virtual Sensors

Greenery detection

- Analyzed RGB pixels of Google satellite images using the C++ library “Cimg”
- False positive green pixels excluded by cross referencing neighbor pixels

# Virtual Sensors

Appeal, activity, experience


| Question # | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Question Range | Beautiful  Ugly | Empty - Crowded | Familiar - Unfamiliar | Interesting  Boring | Light - Dark | Like - Dislike |
| Used in virtual sensor: | APP | - | APP | ACT | ACT | APP |
| | | | | | | |
| Question # | 7 | 8 | 9 | 10 | 11 | 12 |
| Question Range | Open - Enclosed | Ordered  Chaotic | Public  Private | Quiet  Noisy | Secure - Insecure | Spacious  Narrow |
| Used in virtual sensor: | ACT | APP | APP | EXP | EXP | EXP |

$$v_j = \sum_{i=1}^{k} \frac{w_i(q_{i,j} + 2)}{k},$$

$v_j$ =virtual sensor at path point $j$

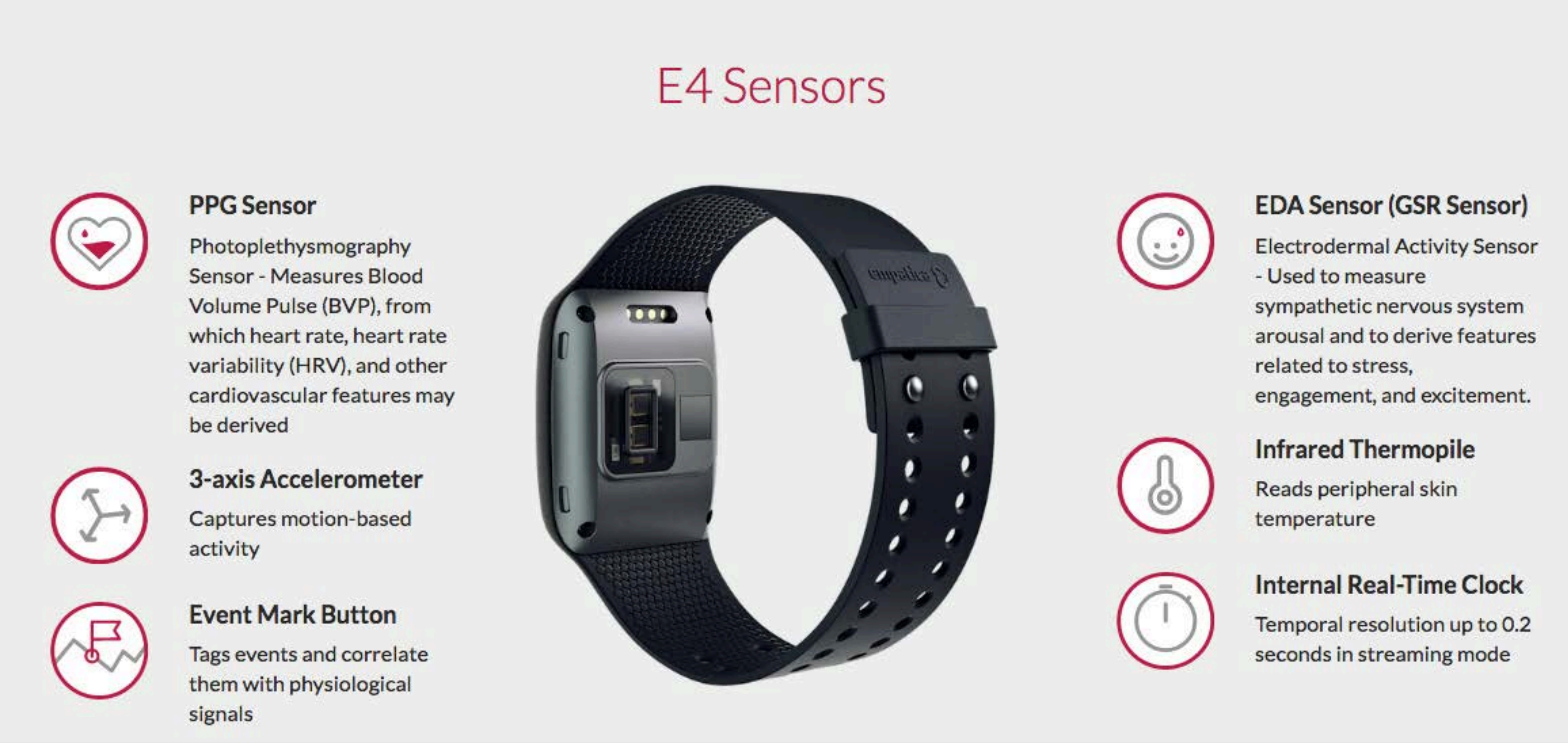
$k$=the number of questions

$q_{i,j}$= survey responses $i$ of range [-2, 2] at path point $j$

$w_i$= weighing factor of sensor $i$

# Virtual Sensor

"Stress level"




$$v_j = \sum_{i=1}^{l-1} \frac{w_i s_{i,j}}{l-1},$$

$v_j$ =Stress Level

$l$=number of biofeedback sensors (including HR, $T_{BF}$, EDA)

$S_{i,j}$=normalized biofeedback sensor *i* at pathpont *j*

$w_i$= weighing factor of sensor *i*

# Overview of all sensors

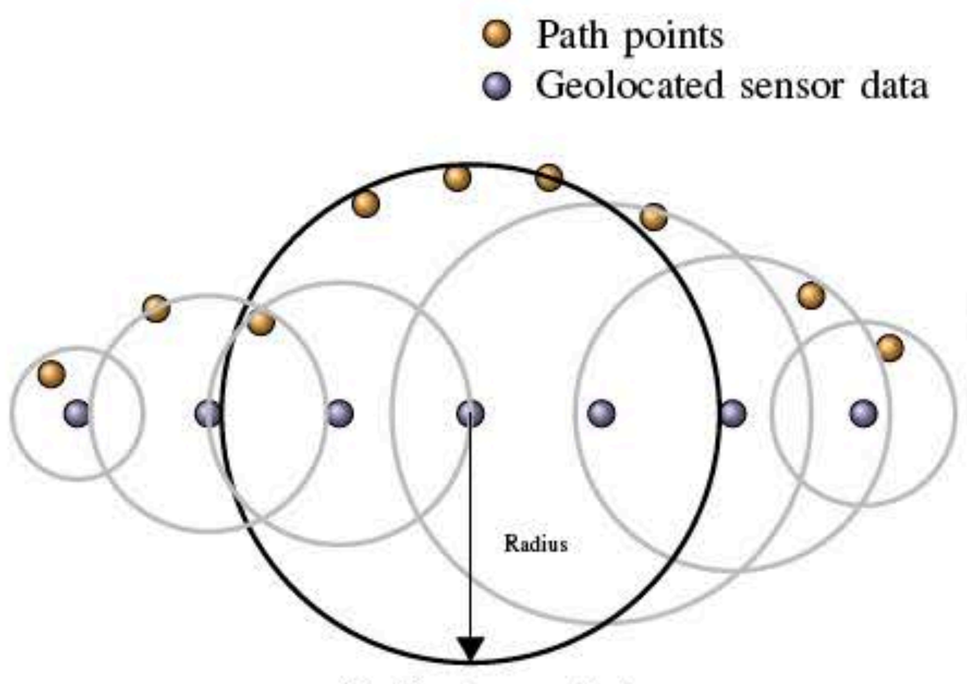
A total of 19 variables,  and 12 measurements and 5 virtual sensors and 2 additional location descriptors

| Acronym | Sensor description |
|---|---|
| PP | Path Point |
| HR, dHR | Heart Rate |
| BVP, dBVP | Blood Volume Pressure |
| EDA, dEDA | Electrodermal Activity |
| T-BF, dT-BF | Bio Feedback Temperature |
| S, dS | Sound |
| D, dD | Dust |
| T-EN, dT-EN | Environmental Temperature |
| RH, dRH | Relative Humidity |
| IL, dIL | Illuminance |
| ACC, dACC | Acceleration |
| PD | People Density |
| LON | Longitude |
| LAT | Latitude |
| GR | Greenery |
| APP | Appeal |
| ACT | Activity |
| EXP | Experience |
| SL | Stress Level |

# Data processing

## Data localization methodology

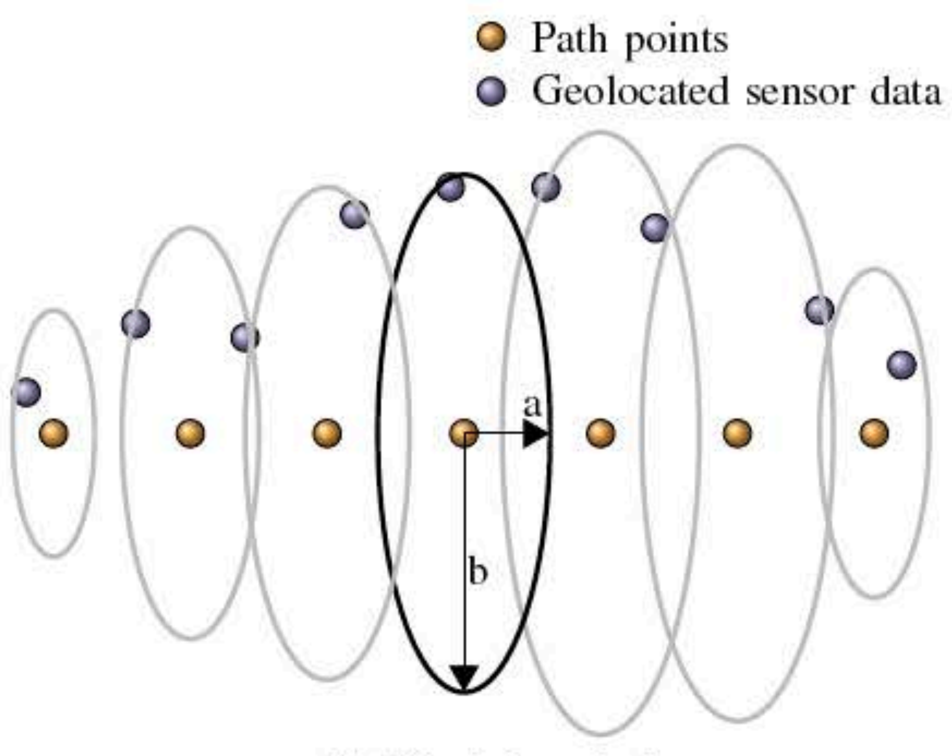
### Circular method




Initial condition:

$r$= 5 meters

### Ellipse method

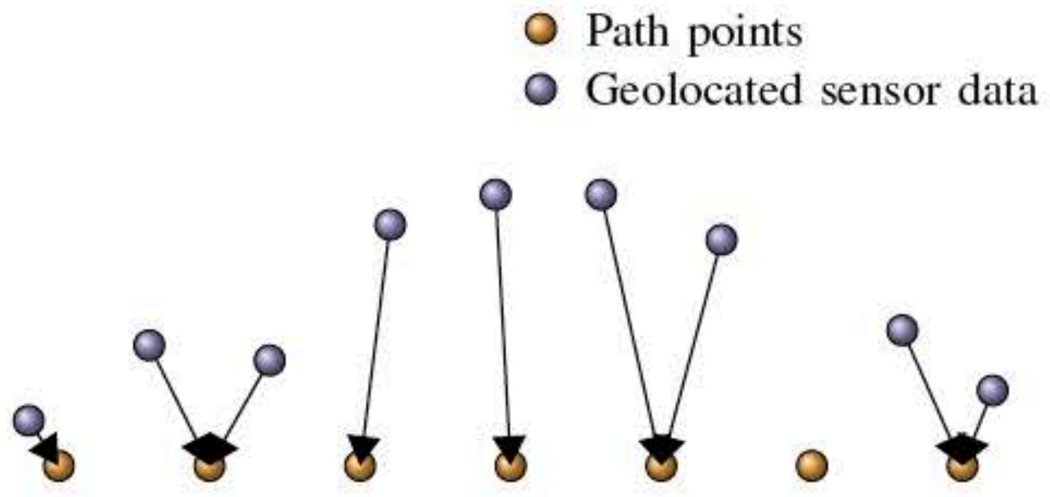



Initial condition:

$a$= 3 meters

$b$=12 meters

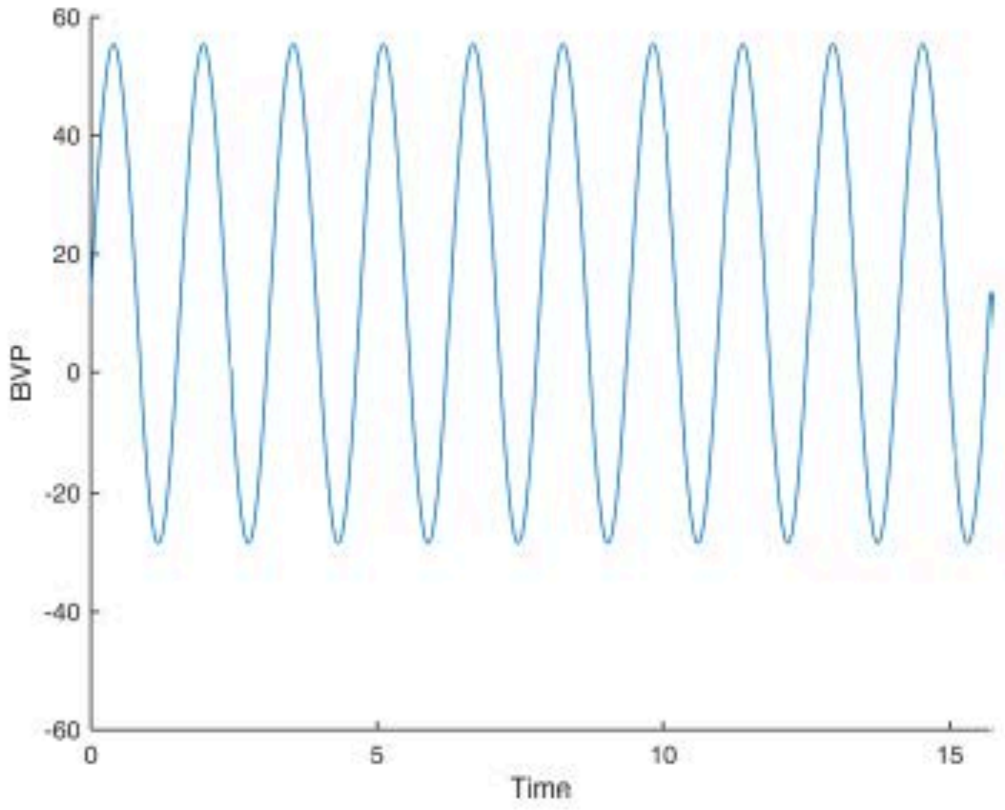
### Minimum distance method



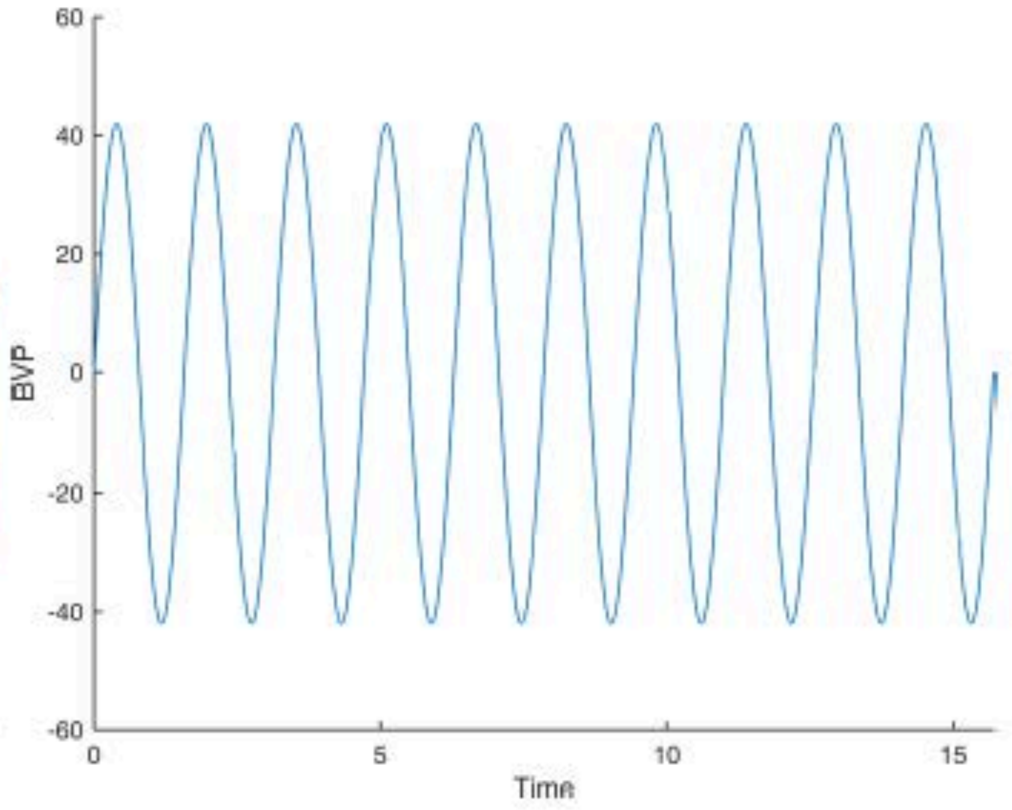

# Data Processing

Data integration and frequency reduction and from multiple data sources

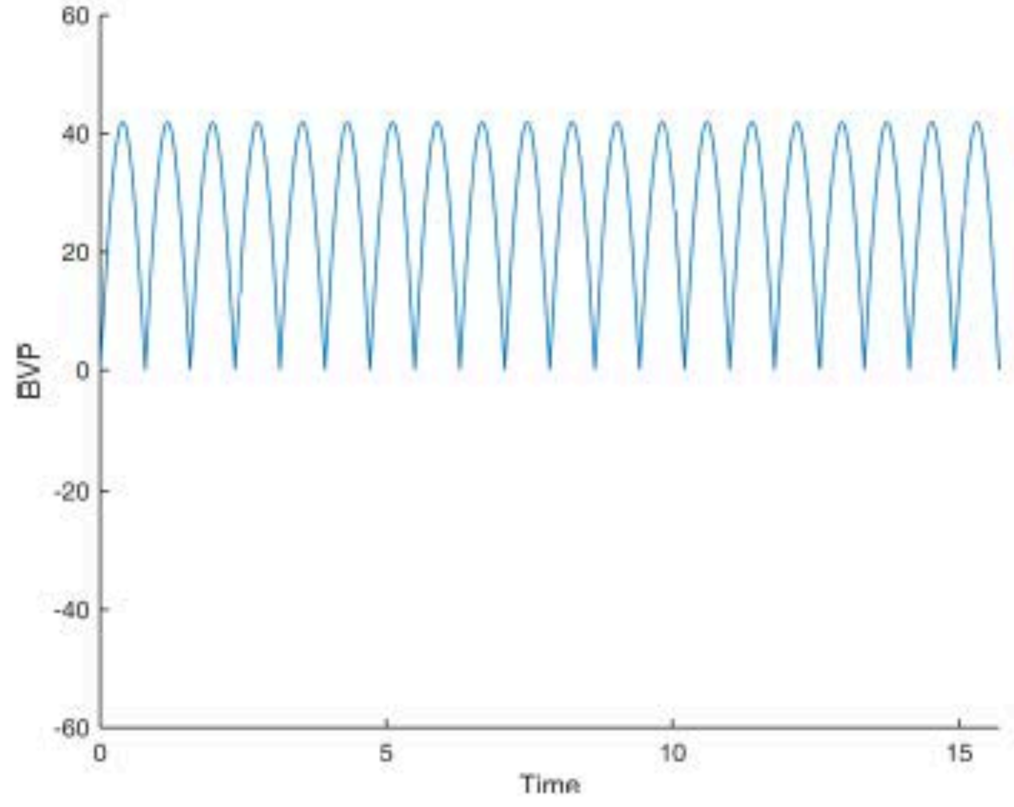
| Sensor description | Frequency [Hz] |
|---:|---:|
| Heart rate (HR) | 1 |
| Blood volume pressure (BVP) | 64 |
| Electrodermal activity (EDA) | 4 |
| Biofeedback temperature (T-BF) | 1 |
| Sound level (S) | 0.3 |
| Dust (D) | 0.3 |
| Environment temperature (T-EN) | 1 |
| Relative humidity (RH) | 1 |
| Illuminance (IL) | 1 |
| People density (PD) | 1 (if many), 0.024 (if few) |
| Longitude (LON) | 1 |
| Latitude (LAT) | 1 |
| Survey answers | In each of the 14 checkpoints |




(a) Raw signal.




(b) Signal after adding average offset.

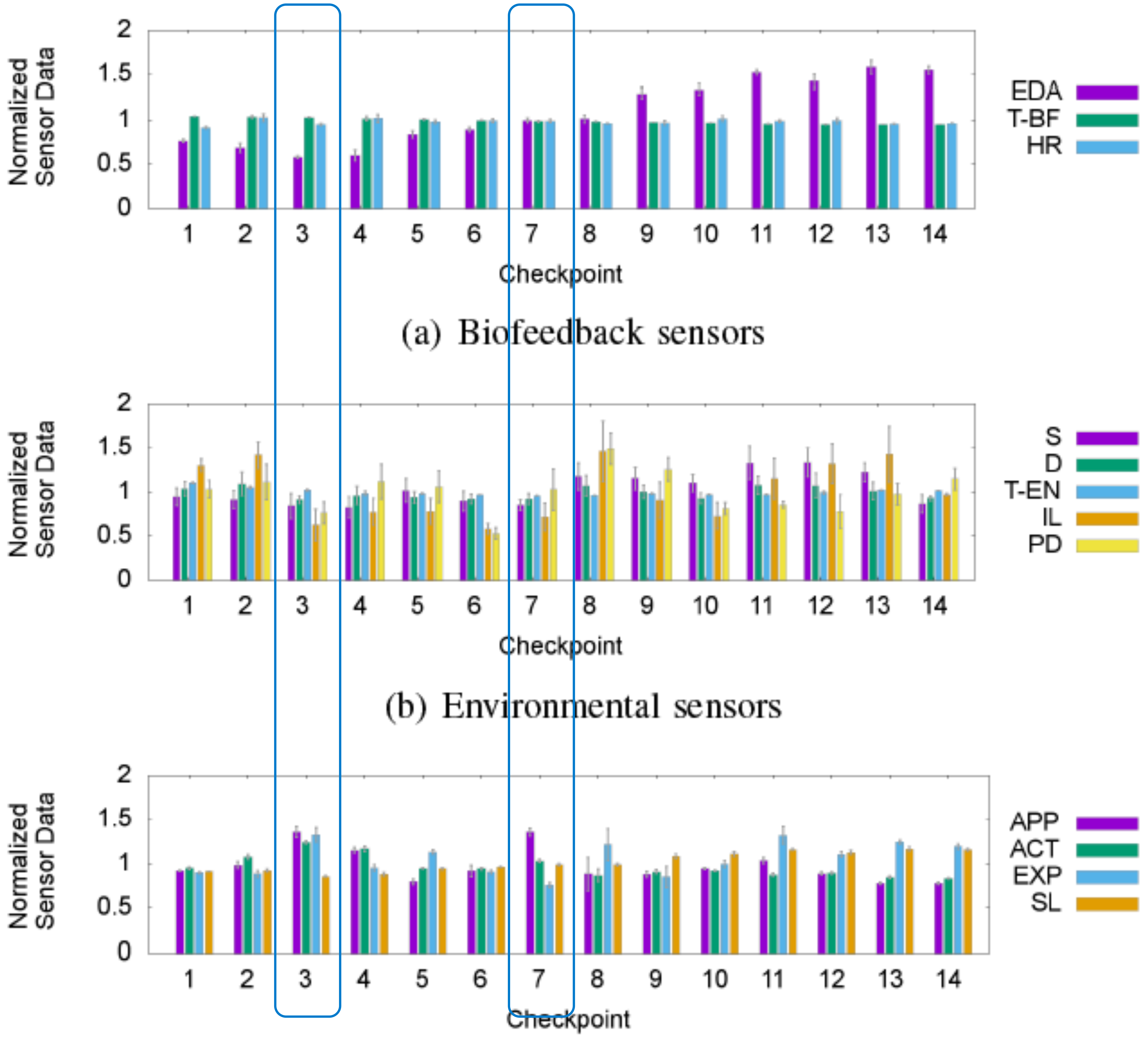



(c) Absolute positive signal.

# Initial results

Normalized sensor values at each check point

- Most likable check points are 3 and 7
- Increased EDA along the path
  - People sweat more as the experiment progresses
  - It is also noisier from checkpoints 8 to 13




(a) Biofeedback sensors

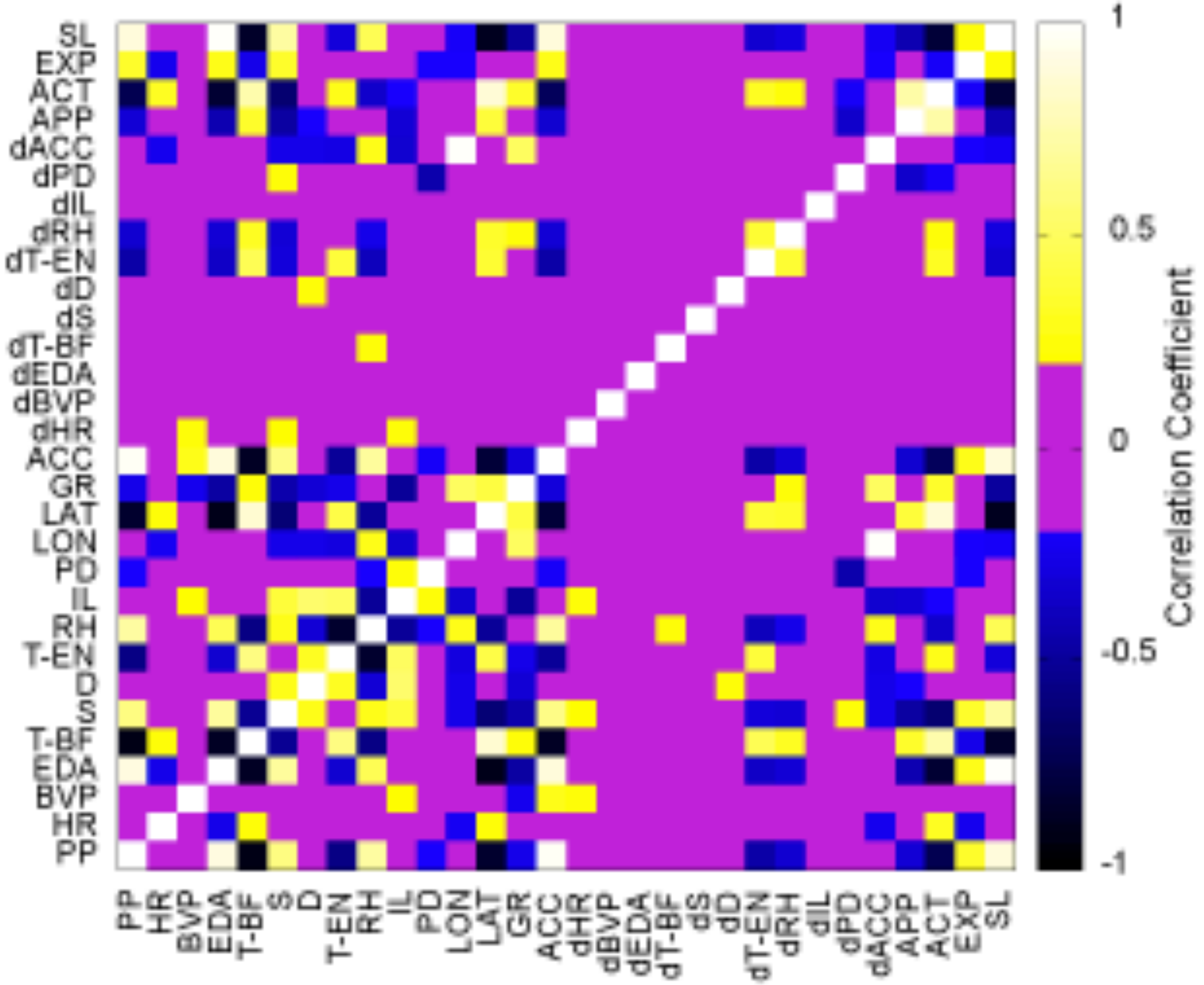
(b) Environmental sensors

(c) Virtual sensors

# Initial results

Correlation coefficient of all variable pair combinations

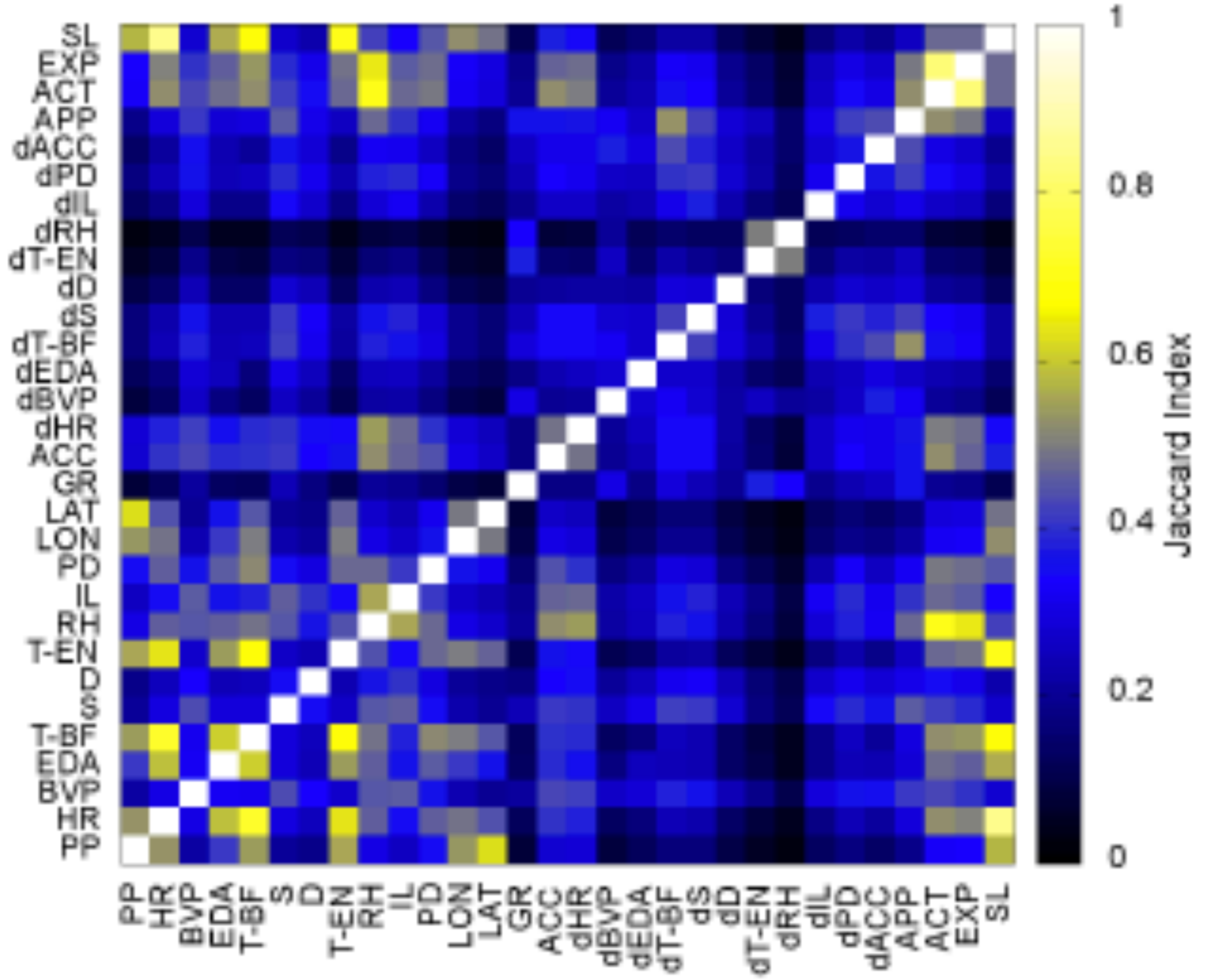
- Sound positively correlates with EDA and acceleration:
  - More stress in noisy conditions
  - People walk faster when it's noisy
- Greenery negatively correlates with acceleration and illumination:
  - Greenery indicates that there is more shade
  - Greenery indicates enjoyment (slower walking pace)



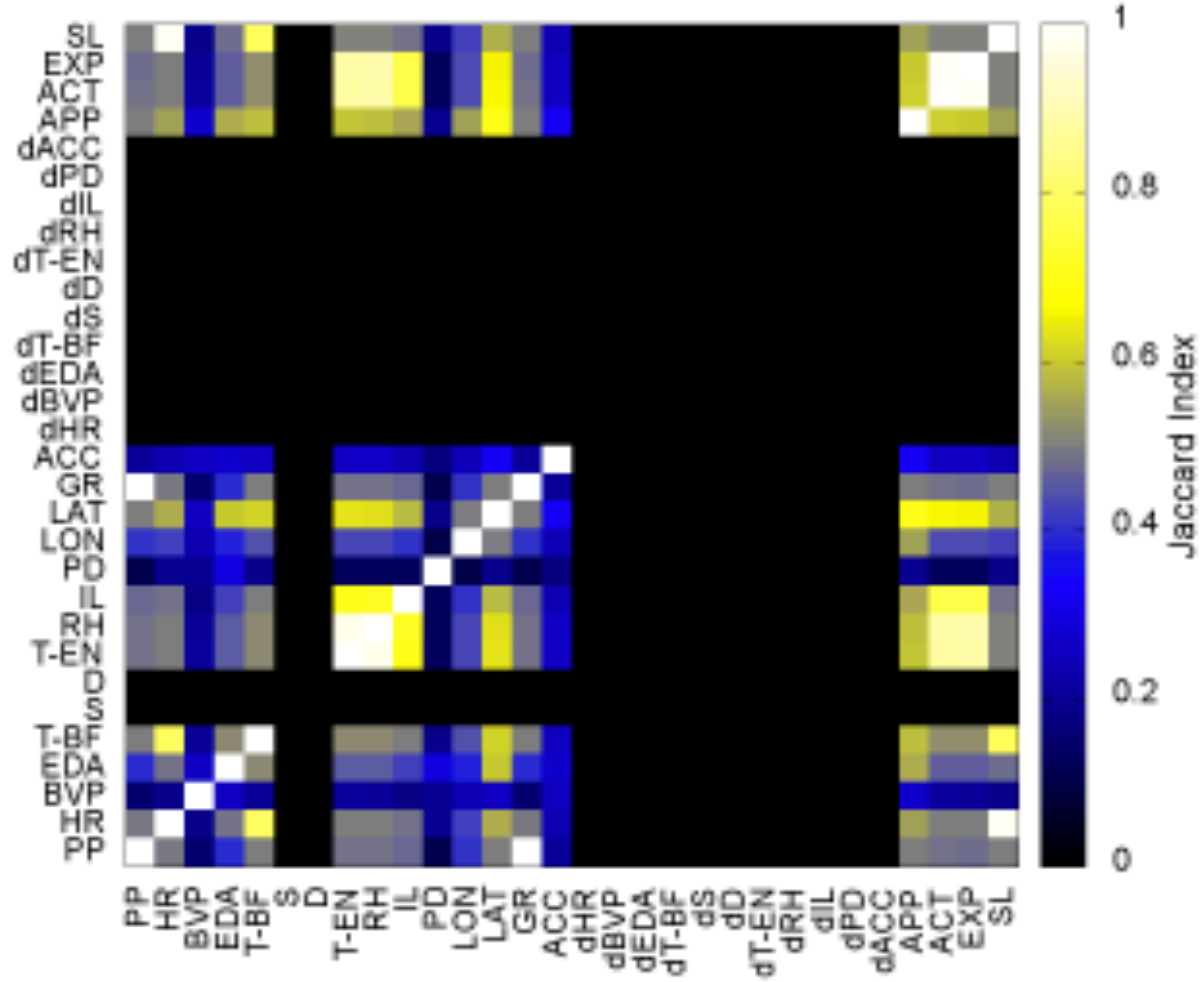
# Initial results

Mean jaccard index between all cluster pairs to indicate similarity from k-means and DBSCAN clustering analysis

k-means




DBSCAN



# Ongoing and future work

Data Analysis of existing data set

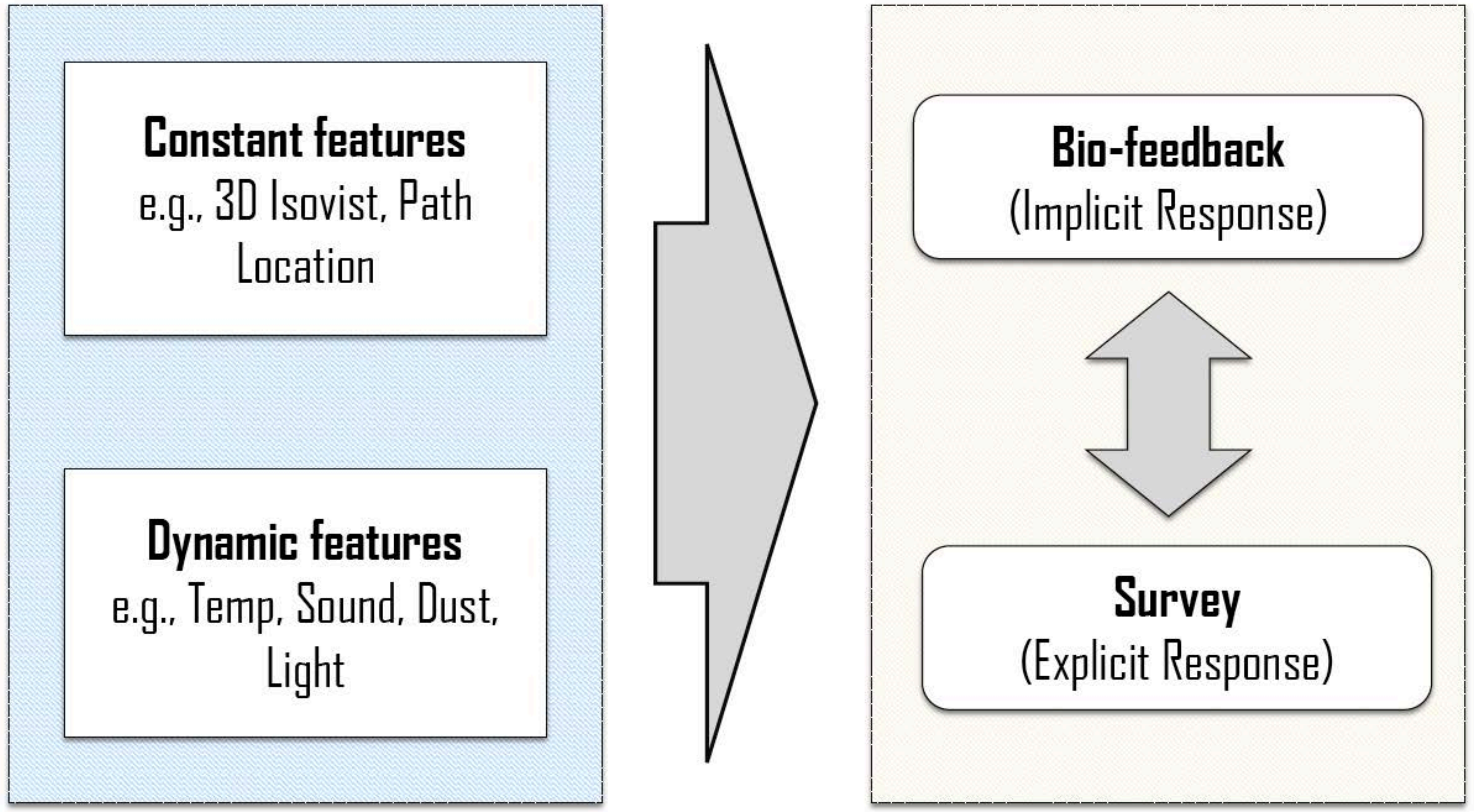
- Automatic clustering using Self Organizing Maps
- Neural Tree or NN: to finds if the participants behavior can be predicted: to perform Feature Selection and Analysis
- Fuzzy Tree or Fuzzy Inference Models: to find inferential (rule based) predictive models to understand if there are certain rule pattern emerge
- Evolutionary Feature Selection of Isovit Features
- Associated Rule Mining: to find pattern in the relationship
- Model survey questions as classification and fuzzy modeling

Future experiments

- VR studies with participants to avoid artifacts in the Biofeedback data

Wide-scale implementation

- Nervousnet framework for privacy protection of greater number of participants (Evangelos Pournaras)



# Questions?

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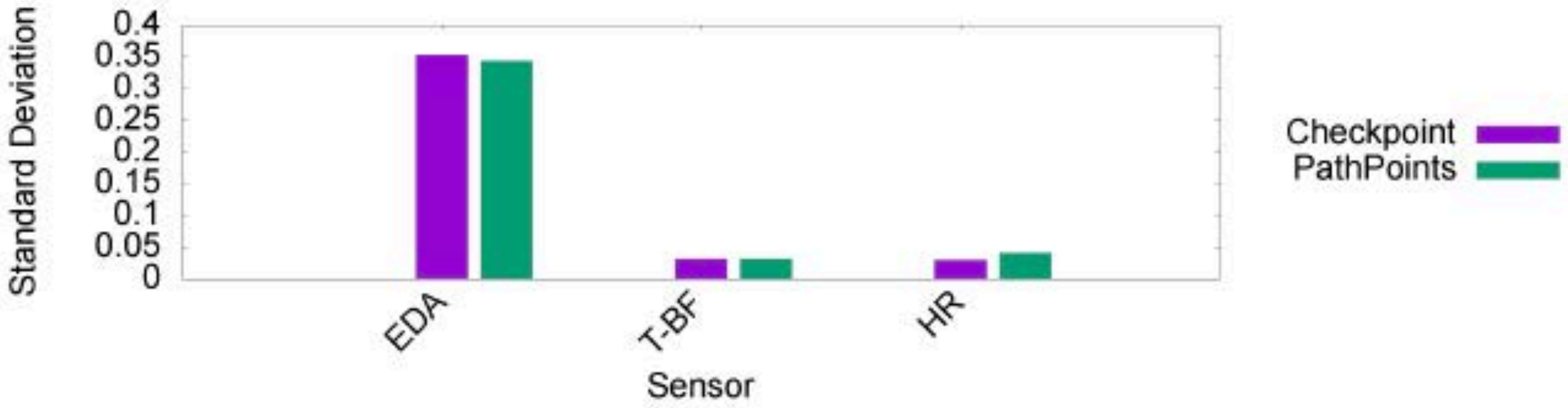
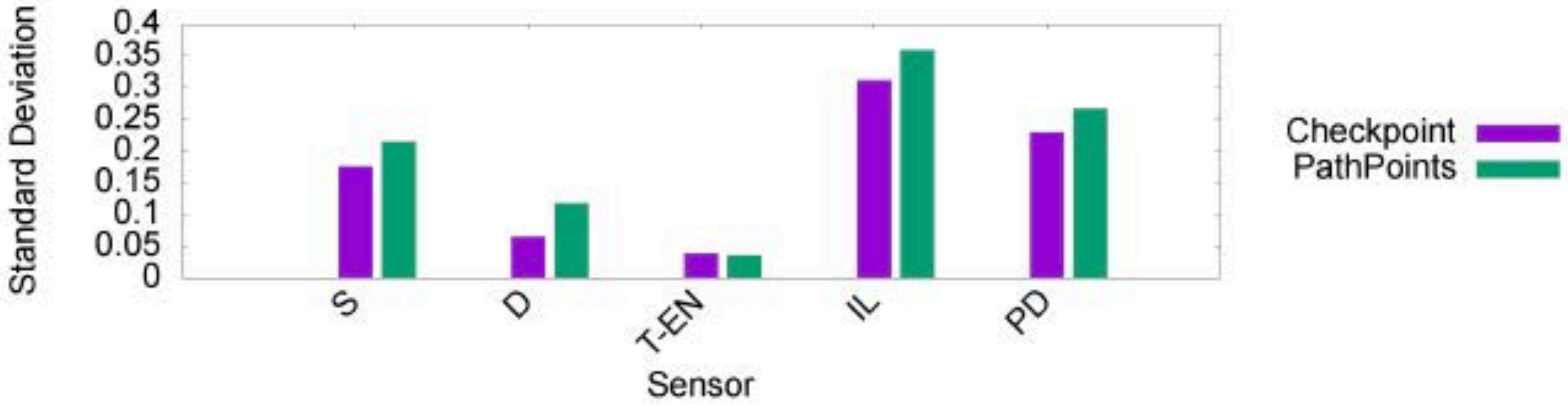
# Initial Results

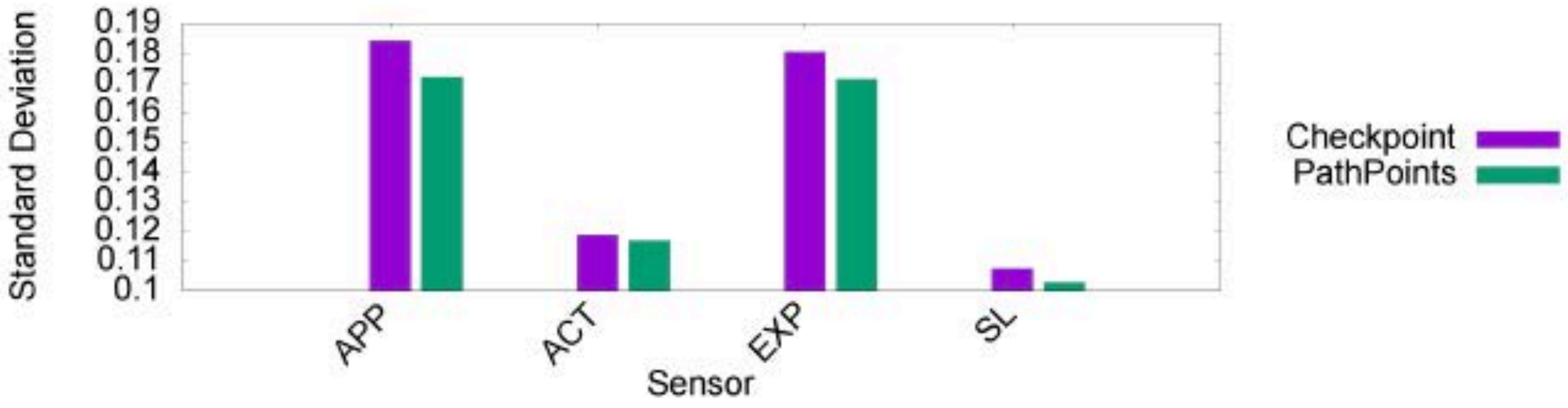
Standard deviation of normalized values for checkpoints and path




(a) Biofeedback sensors




(b) Environmental sensors




(c) Virtual sensors