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CACHET Research Platform CARP

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Background

Personal Health Technology

- the future of health is digital

Digital Phenotyping

- collection of a wide range of health and behavioral data

Research & Innovation

- need for a shared platform for collection, management, securing, and analyzing health data
- in research projects (in CACHET)
- in innovation w. industry

Secure and Approved Data Management

- DTU as “data controller”
- Secure hosting
- Regulatory (GDPR)

The Smartphone

- Ubiquitous
- Unobtrusive
- Intimate
- Powerful
- Sensor-rich
- Connected – always!

”... the mobile phone has become the most ubiquitous piece of technology in our recent history” – Oliver et. al. 2015

“Smartphones offer huge potential to gather **precise**, **objective**, **sustained**, and **ecologically valid** data on the **real-world behaviors** and experiences of **millions** of people where they **already are**” – Miller, 2015

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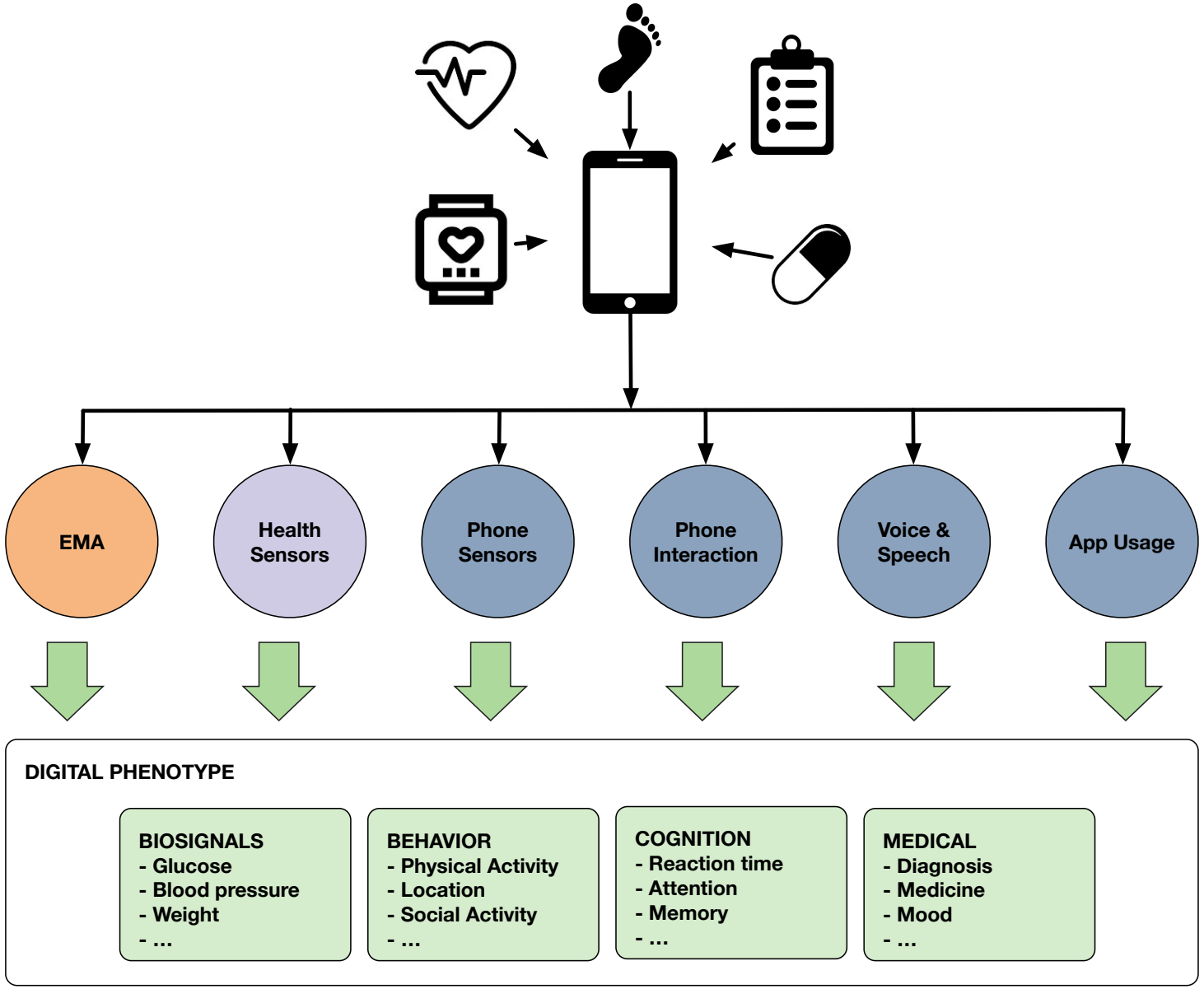
Digital Phenotyping

Continuous and unobtrusive measurement and inference of health, behavior, and other parameters from wearable and mobile technology



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- Insel, T. R. (2017). Digital phenotyping: Technology for a new science of behavior. *JAMA*, *318*(13), 1215–1216.

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MONARCA

- Bipolar disorder (manio-depressive)
- EU STREP project | 2010-2014 | 13 partners
- Copenhagen team
  - The Copenhagen Clinic for Affective Disorder, Rigshospitalet, Psychiatric Center Copenhagen,
  - The Pervasive Interaction Technology Laboratory (PIT Lab), IT University of Copenhagen

- MONARCA system
  - Self-assessment
    - mood | sleep | stress | medicine | ...
  - Auto-assessment
    - physical activity | mobility | social activity | phone usage
  - Feedback
    - visualizations | medication | actions-to-take | triggers | early-warning-signs | impact factors
  - Mood forecast
    - predict mood for next 5 days

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Clinical Evidence

Clinical evaluations have shown strong correlations between

- self-rated and clinically-rated mood
- objectively colle
  rated mood

"Smartphones provide an easy and objective way to monitor illness activity and could serve as an electronic biomarker for depressive and manic symptoms in patients with bipolar disorder."

Table 2. Correlations between self-monitored data[a] collected using smartphones and depr
17 and YMRS, respectively[b]

	Unadjusted		
	Coefficient	95% CI	p-value
Mood (scale: −3 to +3)			
HDRS-17	−0.055	−0.067 to −0.042	<0.001
HDRS-17 sub-item 1 (mood)	−0.38	−0.45 to −0.30	<0.001
YMRS	0.39	0.016–0.062	<0.001
YMRS sub-item 1 (mood)	0.38	0.24–0.53	<0.001

Table 3. Correlations between automatically generated objective data[a] collected u
using the HDRS-17 and YMRS, respectively[b]

	Unadjusted		
	oefficient	95% CI	p-value
/day)			
	0.022	−0.010 to 0.054	0.18
	0.060	0.016–0.100	0.007
ng calls (sec/day)			
	19.96	4.12–35.80	0.014
	28.54	5.17–51.90	0.017
sages (no./day)			
	−0.037	−0.18 to 0.14	0.61
	0.087	−0.10 to 0.28	0.37
/day)			
HDRS-17	0.031	−0.047 to 0.110	0.44
YMRS	0.15	0.045–0.250	0.005
Duration of outgoing calls (sec/day)			
HDRS-17	28.27	10.15–46.40	0.002
YMRS	23.87	−3.08 to 50.83	0.083
Outgoing text messages (no./day)			
HDRS-17	0.014	−0.16 to 0.19	0.88
YMRS	0.22	−0.006 to 0.450	0.057

M Faurholt-Jepsen et al. Smartphone data as an electronic biomarker of illness activity in bipolar disorder. Bipolar Disorders, 2015.

Voice & Mood

Collection of voice features in naturalistic setting

- N=28 | 12 week
- HDRS-17 (depre
- 179 clinical ratir
- openSMILE (em

Classification resu
(s.d.)

- depressive state : 70% (0.13)
- manic state : 61% (0.04)

Classification accuracy were not significantly increased when combining voice features with automatically generated objective data

"Voice features collected in naturalistic settings using smartphones may be used as objective state markers in patients with bipolar disorder. "

OPEN

Citation: Transl Psychiatry (2016) **6**, e856; doi:10.1038/tp.2016.123
www.nature.com/tp

ORIGINAL ARTICLE

Voice analysis as an objective state marker in bipolar disorder

M Faurholt-Jepsen[1], J Busk[2], M Frost[3], M Vinberg[1], EM Christensen[1], O Winther[2], JE Bardram[2] and LV Kessing[1]

Changes in speech have been suggested as sensitive and valid measures of depression and mania in bipolar disorder. The present study aimed at investigating (1) voice features collected during phone calls as objective markers of affective states in bipolar disorder and (2) if combining voice features with automatically generated objective smartphone data on behavioral activities (for example, number of text messages and phone calls per day) and electronic self-monitored data (mood) on illness activity would increase the accuracy as a marker of affective states. Using smartphones, voice features, automatically generated objective smartphone data on behavioral activities and electronic self-monitored data were collected from 28 outpatients with bipolar daily basis during a period of 12 weeks. Depressive and manic symptoms were assessed Scale 17-item and the Young Mania Rating Scale, respectively, by a researcher blinded zed using random forest algorithms. Affective states were classified using voice features calls. Voice features were found to be more accurate, sensitive and specific in the classification under the curve (AUC) = 0.89 compared with an AUC = 0.78 for the classification of depressive automatically generated objective smartphone data on behavioral activities and electronic curacy, sensitivity and specificity of classification of affective states slightly. Voice features smartphones may be used as objective state markers in patients with bipolar disorder.

6; doi:10.1038/tp.2016.123; published online 19 July 2016

such as the Hamilton and the Young Mania standards to assess the mptoms when treating using these clinical rating er. Further, the severity of termined by a subjective nterview with the risk of bjective and continuous t the clinical assessment ods using continuous and servable data on illness be able to discriminate linicians to improve the ons for early intervention r close and continuous monitoring and collection of real-time data on depressive and manic symptoms outside clinical settings between outpatient visits.

Studies analyzing the spoken language in affective disorders date back as early as 1938.[5] A number of clinical observations suggest that reduced speech activity and changes in voice features such as pitch may be sensitive and valid measures of prodromal symptoms of depression and effect of treatment.[6–12] Conversely, it has been suggested that increased speech activity may predict a switch to hypomania.[13] Item number eight on the HAMD (psychomotor retardation) and item number six on the YMRS (speech amount and rate) are both related to changes in speech, illustrating that factors related to speech activity are important aspects to evaluate in the assessment of symptoms' severity in bipolar disorder. Based on these clinical observations there is an increasing interest in electronic systems for speech emotion recognition that can be used to extract useful semantics from speech and thereby provide information on the emotional state of the speaker (for example, information on pitch of the voice).[14]

Software for ecologically extracting data on multiple voice features during phone calls made in naturalistic settings over prolonged time-periods has been developed[15] and a few preliminary studies have been published.[16–20] One study extracted voice features in six patients with bipolar disorder type I using software on smartphones and demonstrated that changes in speech data were able to detect the presence of depressive and hypomanic symptoms assessed with weekly phone-based clinicians administrated ratings using the HAMD and the YMRS, respectively.[17] However, none of the patients in the study presented with manic symptoms during the study period, and the clinical assessments were phone-based. Another study on six patients with bipolar disorder showed that combining statistics on objectively collected duration of phone calls per day and extracted voice features on variance of pitch increased the accuracy of classification of affective states compared with solely using variance of pitch for classification.[18,19] The study did not state if and how the affective states were assessed during the monitoring period.

In addition to voice features, changes in behavioral activities such as physical activity/psychomotor activity[21–24] and the level of engagement in social activities[25] represent central aspects of

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E-mail: maria@faurholt-jepsen.dk
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M Faurholt-Jepsen, J Busk, M Frost, M Vinberg, EM Christensen, O Winther, JE Bardram, LV Kessing (2016,). Voice analysis as an objective state marker in bipolar disorder. *Transl Psychiatry.* Macmillan Publishers Limited.

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CARP – CACHET Research Platform

Standardization

- part of open international standards
- FHIR, IEEE 1752, ORK, ORS, ...

Sharing

- multi-study platform
- analysis of data across multiple studies

Privacy & Security

- enabling privacy & security as part of platform (GDPR)
- secure local hosting @DTU Computerome

Multi-project platform used in

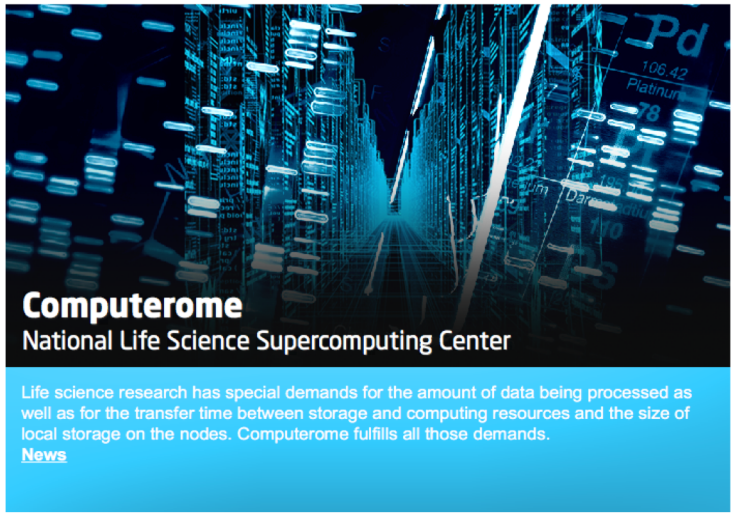
- REAFEL
- BHRP
- PhyPsy Trial
- ...

Open mHealth

FHIR

IEEE Advancing Technology for Humanity

ResearchKit



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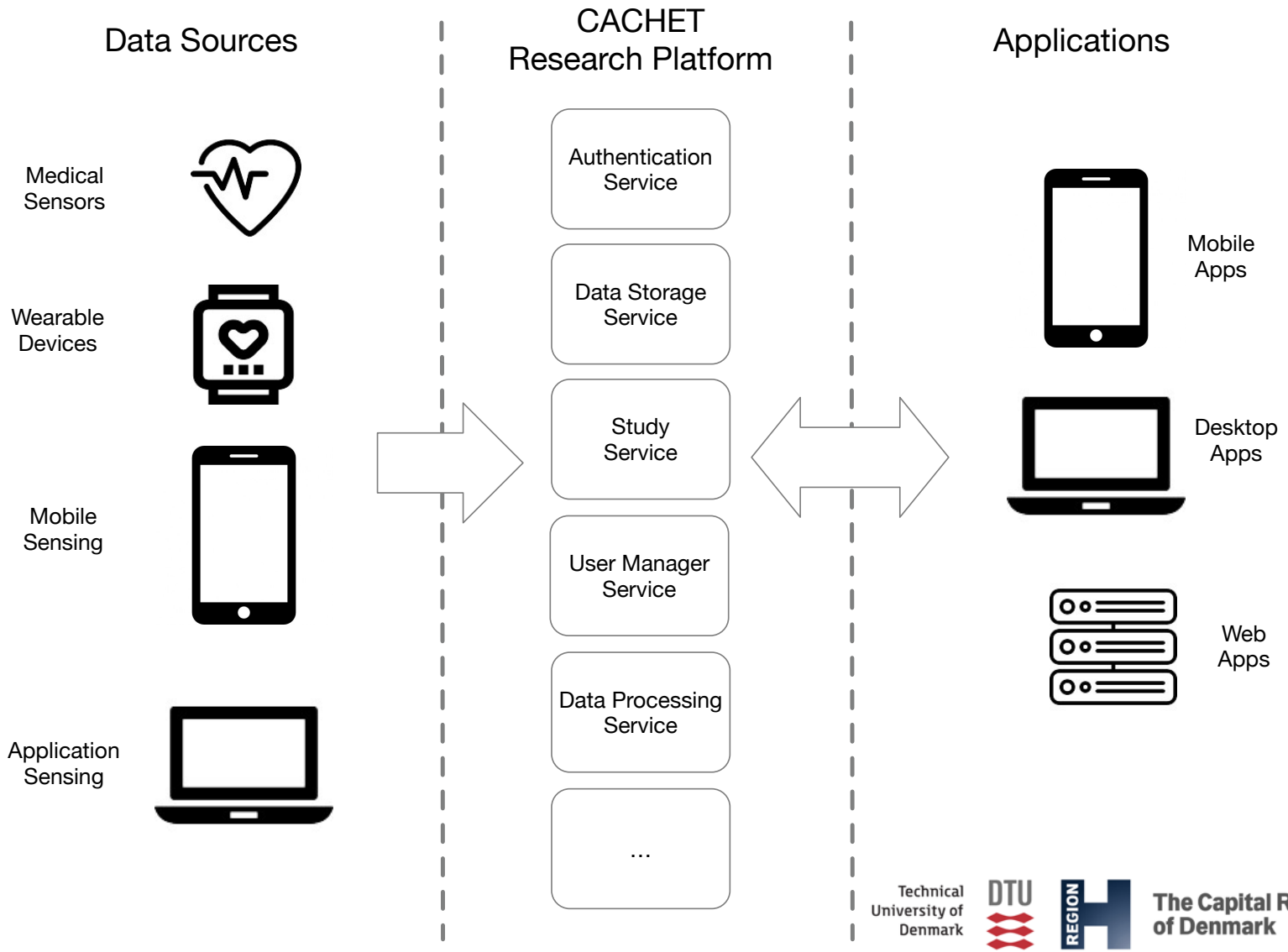
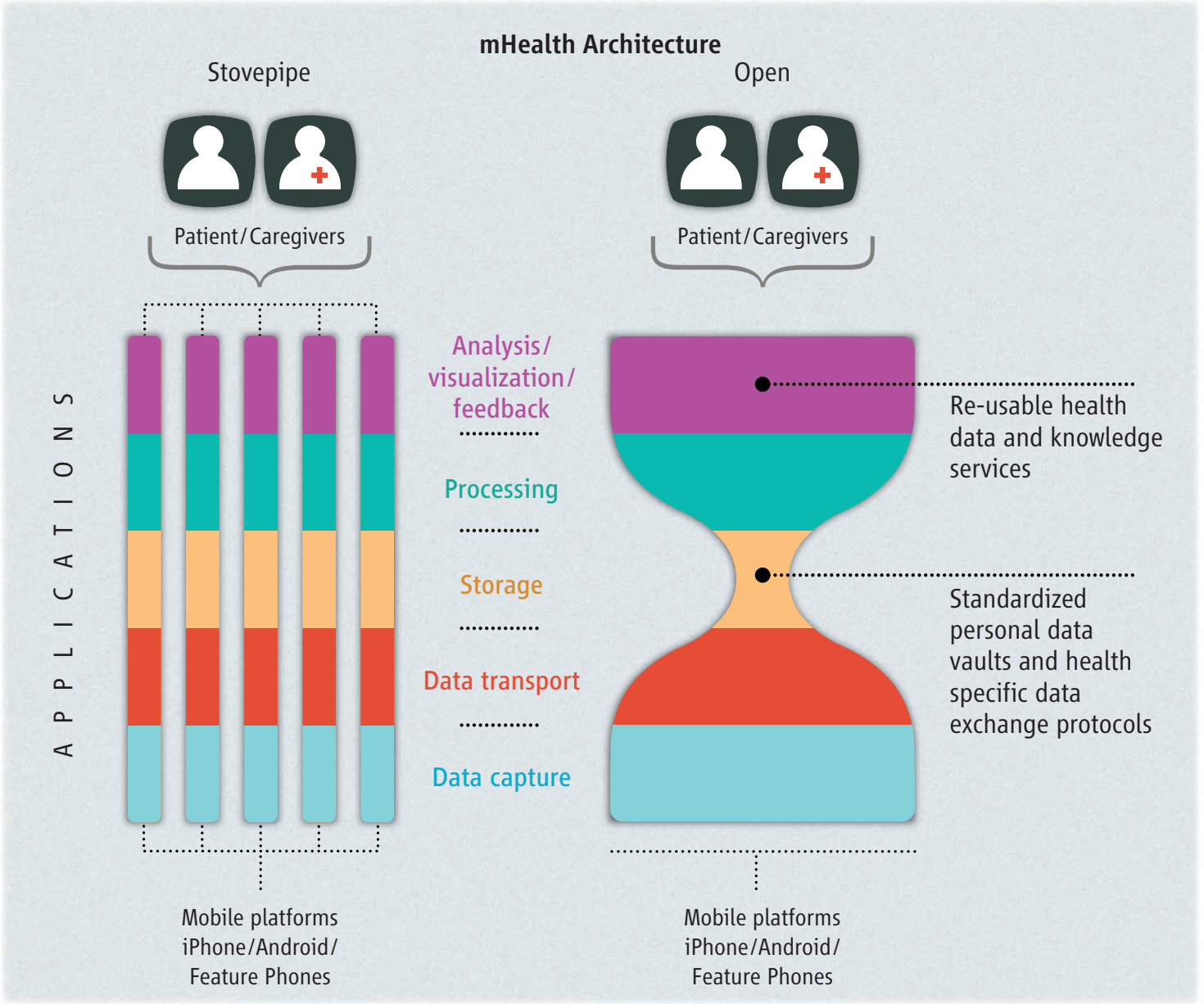
CARP Architecture



Open mHealth

- mHealth is emerging as a patchwork of **incompatible** applications serving narrow, albeit valuable, needs, and thus could benefit from more coordinated development

- Open architecture
  - standardized interfaces
  - standardized components
  - standardized data formats



mHealth architecture: Stovepipe versus Open. The narrow waist of the open hourglass will include at least health-specific syntactic and semantic data standards; patient identity standards; core data processing functions such as feature extraction and analytics; and data stores that allow for selective, patient-controlled sharing. Standards should be common with broader health IT standards whenever possible.

OMH Schemas

- A set of JSON standard for various mHealth data points
- Semantic standardization

- Design principles
- Templates
- Library

Sample Data

With descriptive statistic

```
{
    "systolic_blood_pressure": {
        "value": 160,
        "unit": "mmHg"
    },
    "diastolic_blood_pressure": {
        "value": 60,
        "unit": "mmHg"
```

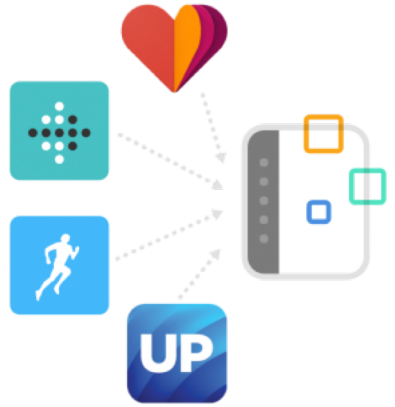
Sample Data

Valid geoposition

```
{
    "latitude": {
        "value": 40.0596923828125,
        "unit": "deg"
    },
    "longitude": {
        "value": -105.21440124511719,
        "unit": "deg"
    },
    "effective_time_frame": {
        "date_time": "2013-02-05T07:25:00Z"
    },
    "positioning_system": "GPS"
}
```

Shimmer

- Can pull health data from popular third-party APIs like Runkeeper and Fitbit.
- Converts data into OMH valid schemas
- Supports
  - Fitbit
  - Google Fit
  - iHealth
  - Jawbone UP
  - Misfit
  - Moves
  - RunKeeper
  - Withings



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Standardization

- IEEE P1752 – Open mHealth is now part of an IEEE standardization effort

- Standardization of
  - schemas
  - end-point APIs

- Relation to other (IEEE) standards
  - HL7 / FHIR
  - ISO/IEEE 11073 Personal Health Data (PHD)

IEEE P1752 Working Group IEEE

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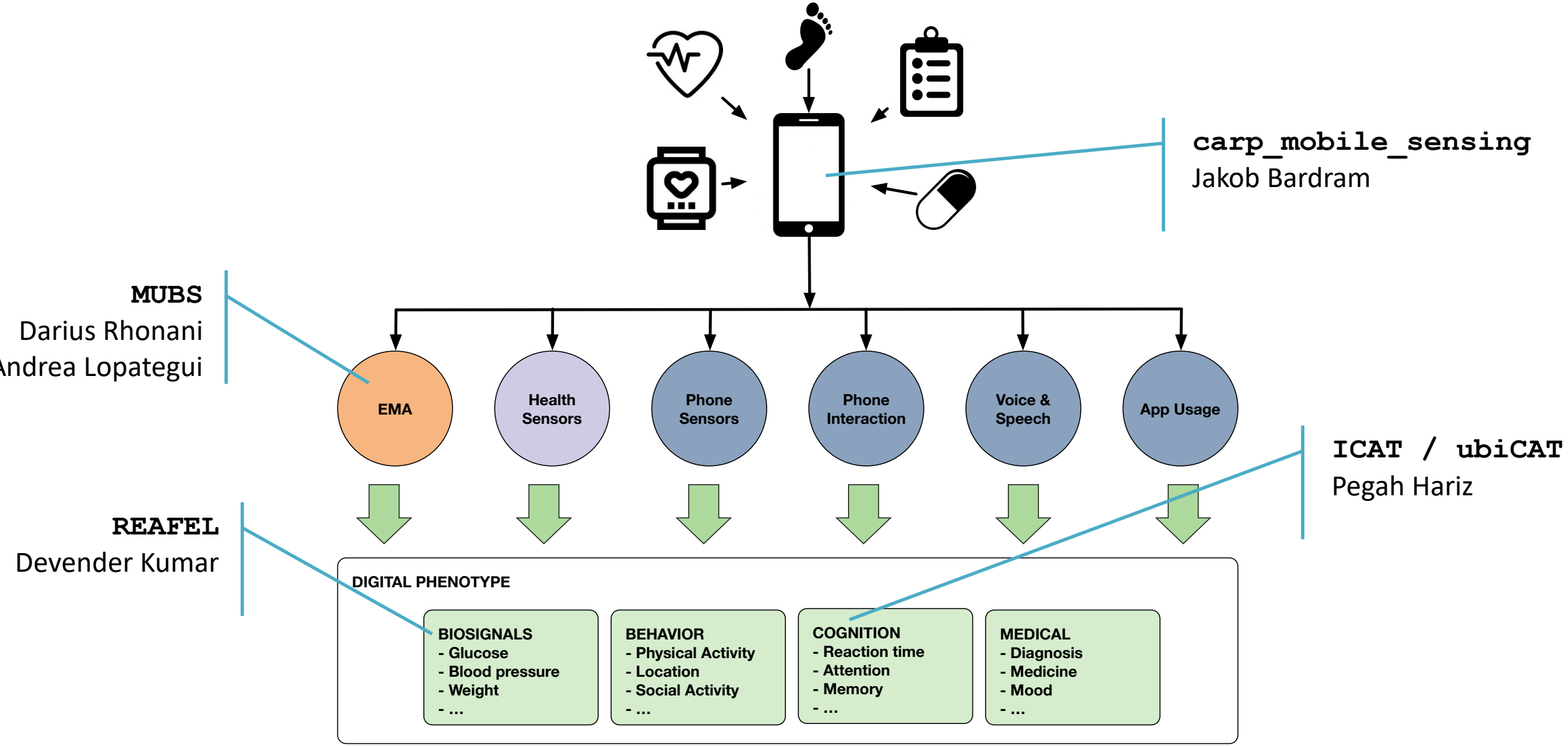

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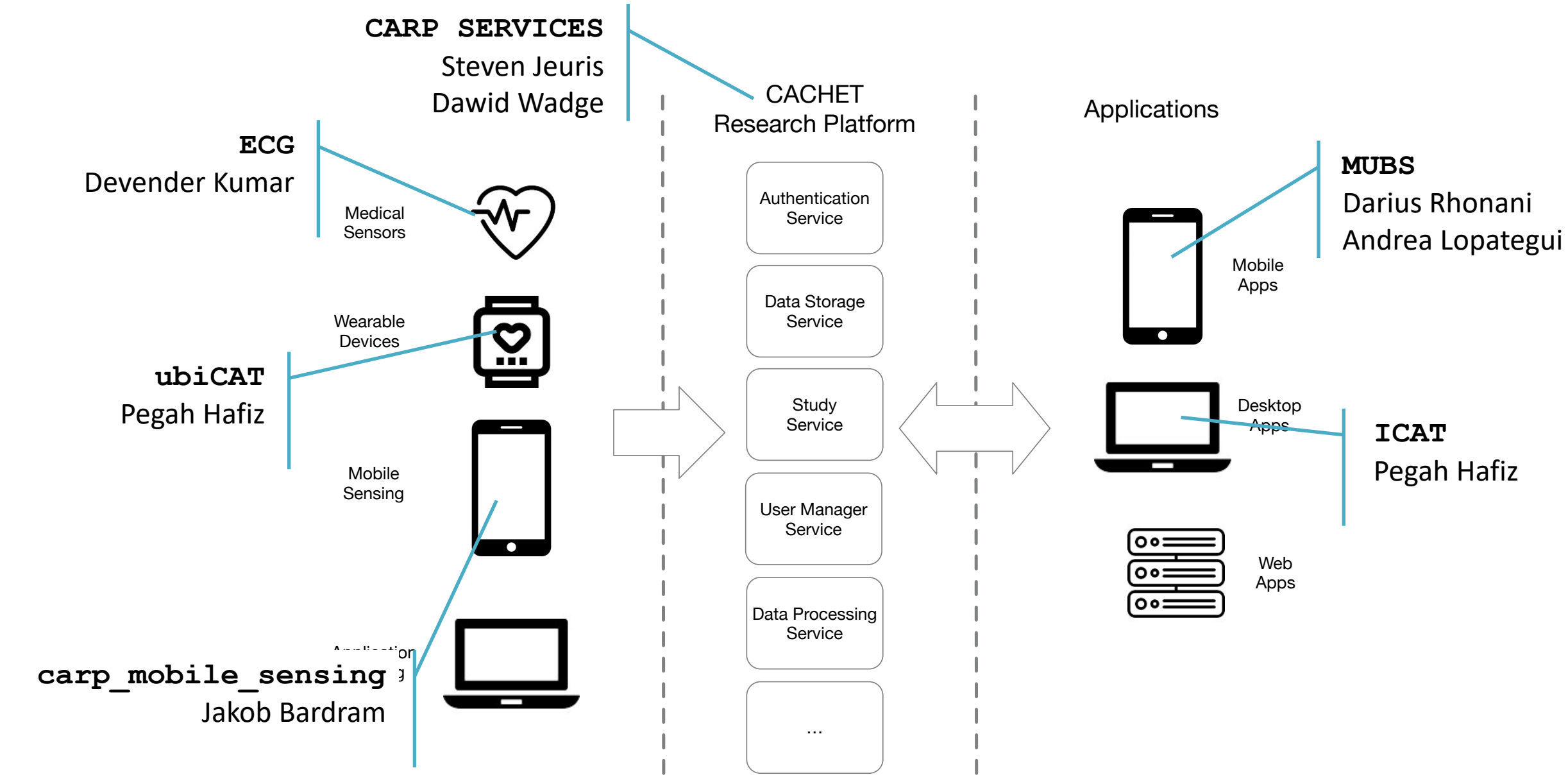

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Outline of Talk

Copenhagen Center for Health Technology

- background & vision
- research & innovation

Digital Phenotyping in Mental Health

- background
- systematic review of correlations between 'objective' features and depression

Outlook

- technology for digital phenotyping
- standards for mobile health (mHealth)

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