Pervasive Computing Technologies for Maintaining Wellness and Healthy Lifestyle

Bert Arnrich

How I came to Pervasive Health …

Master in Computer Science, Bielefeld University, 2001
Autonomous Robotics, Bio-inspired Machine Learning, Medical Data Mining, Time Series Prediction Traffic / Energy / Stock

Doctor of Engineering Sciences, Bielefeld University, 2006
"Data Mining in Heart Surgery": Medical Data Warehouse, Heart Disease Pattern Mining, Real-time Risk Stratification in coop with a heart institute

Senior Researcher, Wearable Computing Lab, ETH Zurich, 2006-2013
Group Leader Pervasive Healthcare: acquisition and scientific management of 4 EU and 4 Swiss research projects, co-supervision 9 PhDs + 18 Master

Assistant Professor, CmpE, Bogazici University, since 2013
Pervasive Healthcare: Towards Computational Networked Life Science
Marie Curie / Tübitak Project
Ubihealth: International Research Staff Exchange Scheme Project

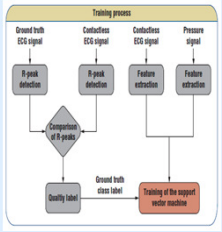
Pervasive Health in a Nutshell

Objective: Design, implement and evaluate pervasive computing technologies to support health and wellness in every-day life.

Example: *A personal stress assistant which* ***continuously monitors*** *your* ***stress level*** *and* ***proactively suggest*** *how to better deal with stress.*

Unobtrusive Sensing Technology

Data Processing and Modeling



Persuasive Human-Computer Interfaces

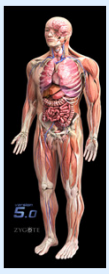
[Arnrich et al., 2010] Pervasive Healthcare - Paving the Way for a Pervasive, User-Centered and Preventive Healthcare Model

Stress: Definition, Causes, Responses and Effects

Definition
"Work-related stress is the response people may have when presented with **work demands and pressures that are not matched** to their knowledge and abilities and which challenge their ability to cope"

Causes
- Job Content
- Workload and pace
- Working Hours
- Participation/Control
- Career/Status/Pay
- Role in organization
- Personal relationships
- Organizational culture
- Home-Work interface

Responses



- Brain
- Lungs
- Liver
- Melt
- Muscles
- Hair
- Pupil
- Heart
- Kidney
- Stomach
- Blood

Effects of chronic stress

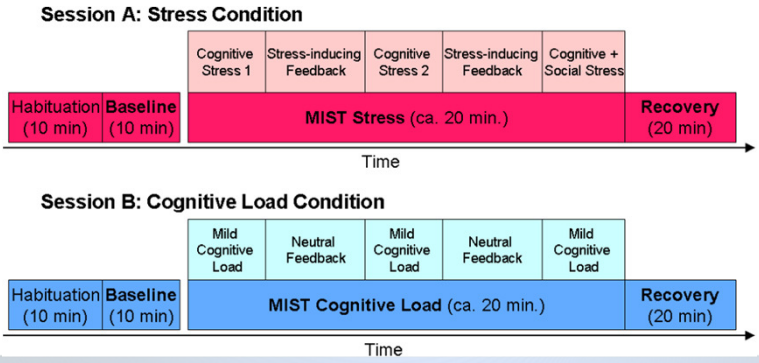
Serious physical and psychological diseases.

Decreased performance of organizations.

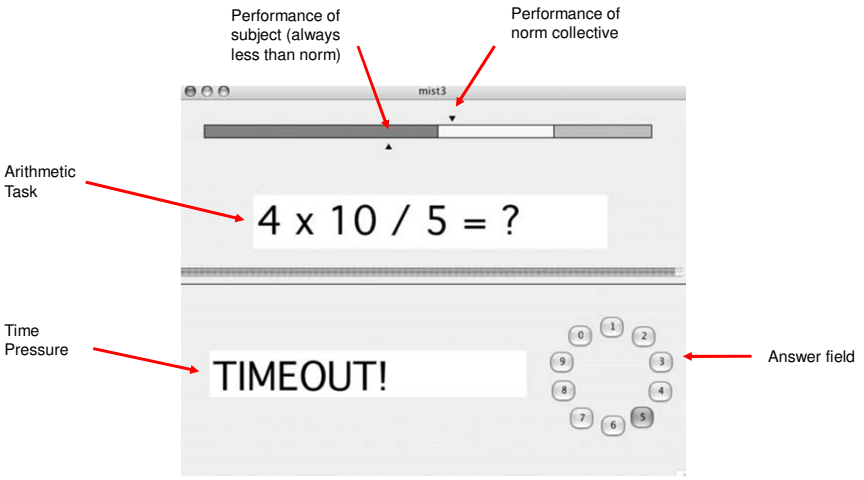
[World Health Organization, 2004] Work Organization and Stress

How to perform a stress experiment ?

- Interdisciplinary Cooperation with Psychological Institute University Zurich
- 33 subjects participating in stress and control condition



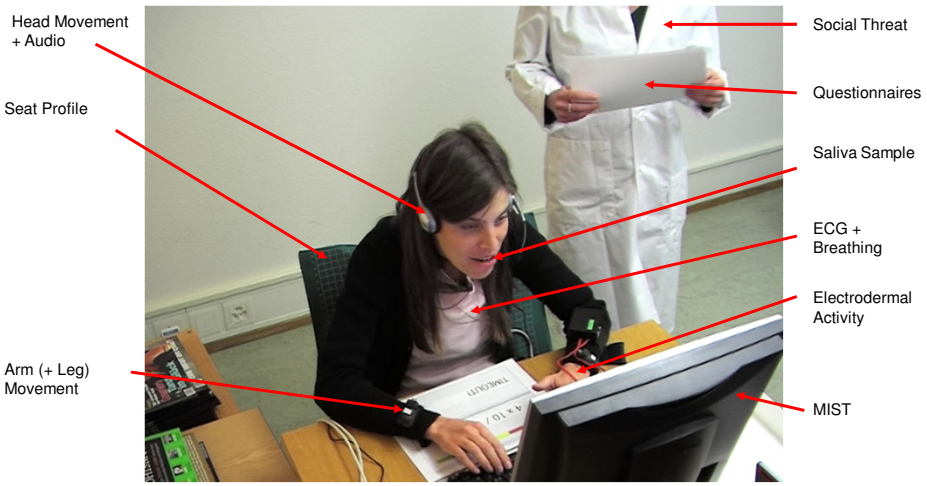
Cognitive Stress



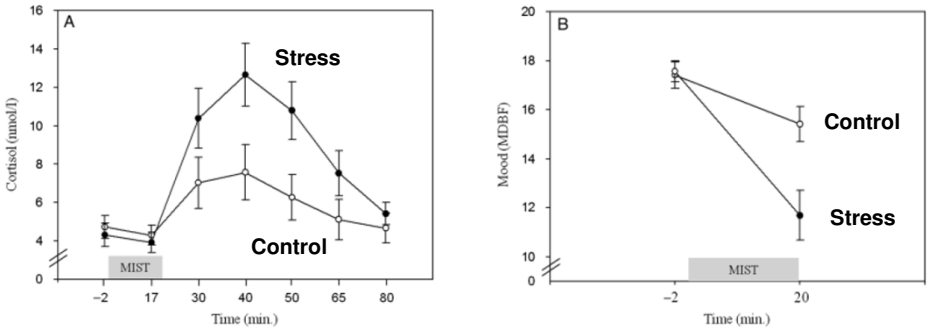
Social Stress

1. Mild
   - Do you have problems with the keyboard?
   - Can you read the tasks on the screen well?
2. Moderate
   - Did you sleep bad?
   - Are you feeling bad today?
3. Strong
   - Do you take drugs?
   - Did you already had math problems in school?

Experimental Data Collection



Was the stress induction successful?

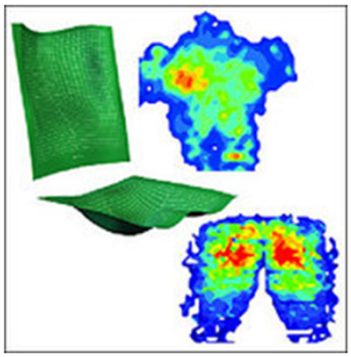


(A) Cortisol levels were significantly increased during stress (p<0.01)

(B) Subjective mood was significantly decreased during stress (p<0.01)

[La Marca et al., 2009] Vagal functionality as indicator for biopsychological stress responsiveness

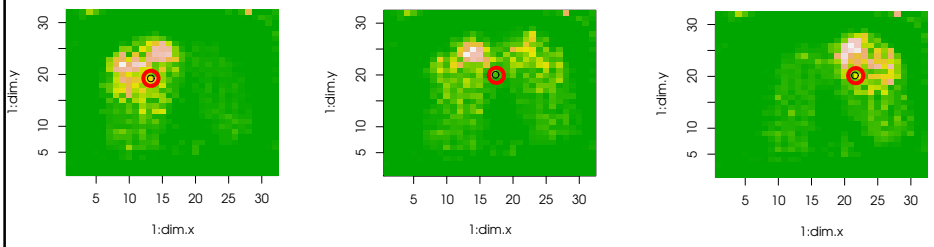
What does your chair know about your stress ?



- Motivation:
  - Body movements carry information about affective states.
- Chair Sensor:
  - Tekscan pressure mat
  - 32x32 senor elements
  - Sampling 25Hz

[Arnrich et al., 2010] What does your chair know about your stress level?

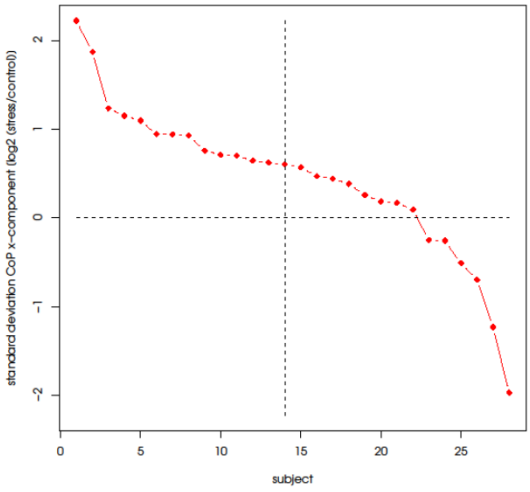
How to compute meaningful features ?



Compute Center of Pressure (CoP) out of each pressure frame and investigate CoP movements.

[Arnrich et al., 2010] What does your chair know about your stress level?

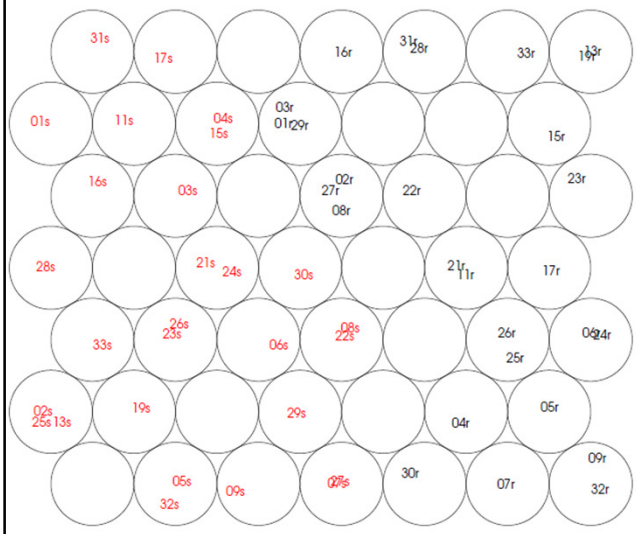
Variance of sideward moves: Stress/Control



- Variation of the x-CoP is higher during stress for most of the subjects ($p<0.05$)
- Might be a measure of nervousness
- 6 subjects behave differently to stress

[Arnrich et al., 2010] What does your chair know about your stress level?

Self Organizing Map (SOM) Classification



XYs	Stress
XYr	Control

- Good separation in control and stress condition
- Go on with leave-one-person-out cross validation

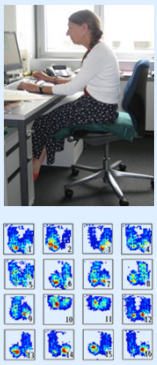
SOM Classification Results

Method	Grid size	Accuracy training	Accuracy CV
SOM	3x3	71.14 ± 2.04	61.25 ± 3.48
SOM	5x5	83.48 ± 2.47	68.39 ± 3.04
SOM	7x7	92.43 ± 2.51	70.89 ± 2.92
XY-fused	3x3	78.95 ± 2.93	66.25 ± 2.59
XY-fused	5x5	97.66 ± 2.44	71.43 ± 2.23
XY-fused	7x7	99.66 ± 0.75	73.75 ± 2.53

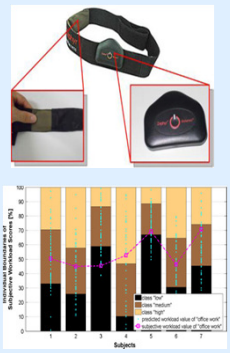
- Increase in training performance with rising grid size
- Best overall accuracy of 73.75% for unseen subjects

Towards Real Life: Measuring Stress Responses

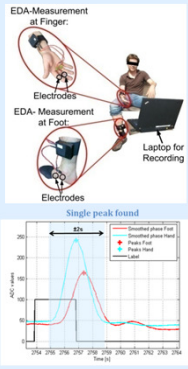
[Tessendorf et al., 2009]



[Cinaz et al., 2011]



[Setz et al., 2011]

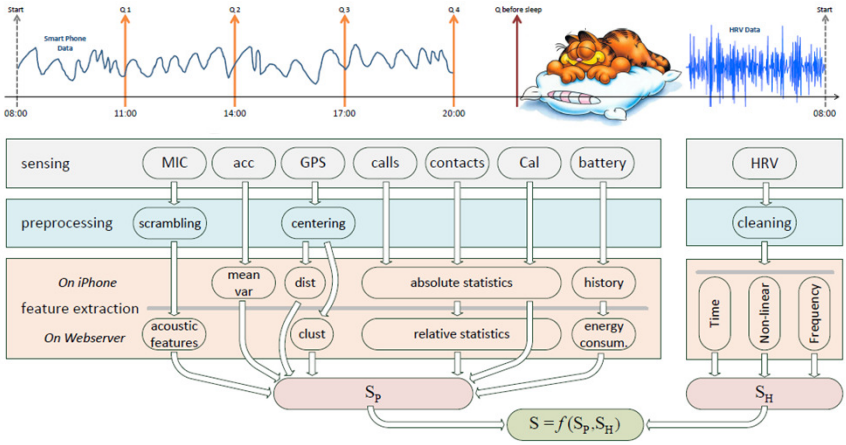


[Tessendorf et al., 2009] Unsupervised Monitoring of Sitting Behavior.
[Cinaz et al., 2011] Monitoring of mental workload levels during an everyday life office-work scenario.
[Setz et al., 2011] Towards long term monitoring of electrodermal activity in daily life.
[Arnrich et al., 2011] Mental health and the impact of ubiquitous technologies.

Towards Real Life: "Stress-o-Meter" app

Work-related causes of stress	Smart Phone Measures
Workload: number of meetings, business trips, …	WLAN, GPS, Bluetooth, Calendar, …
Interpersonal relations: social interaction with colleagues and leader	Voice, Emails, Bluetooth, …
Home vs. Work: sleep duration, sport, …	GPS, activity level, …
…	…

Feasibility “Stress-o-Meter”



[Muaremi et al., 2013] Towards Measuring Stress with Smartphones and Wearable Devices During Workday and Sleep

Lifestyle in Urban and Rural Environments

[Arnrich et al., 2014] Sensing Healthy Lifestyle in Urban and Rural Environments

Urban Turkey

Rural Turkey

Funf Open Sensing Framework

- Android-based extensible framework for collecting smartphone probes
  - Supports collection of over 30 modalities
  - Configuration via server synchronization
  - Local data storage, encryption and data upload to server
  - Basic data processing methods

www.funf.org

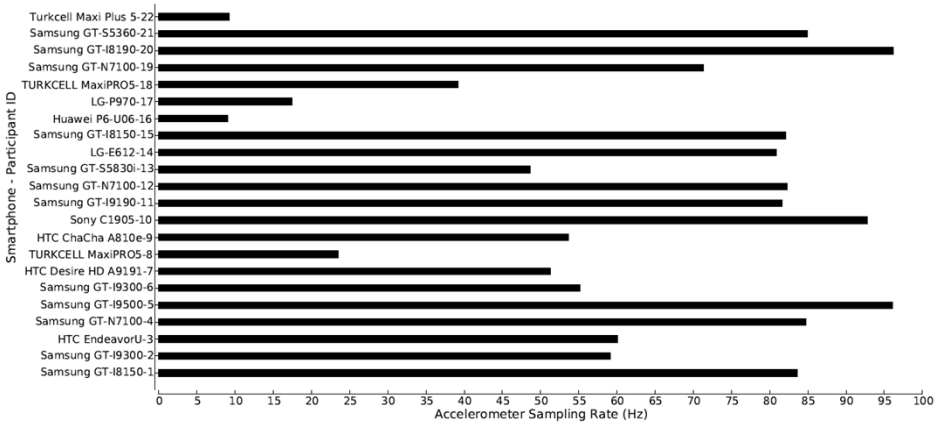
Challenge: Platform Diversity

ID	Age	Occupation	Smartphone Model	Android Version
1	21	Student (BS)	Samsung GT-I8150	4.0.4
2	21	Student (BS)	Samsung GT-I9300	4.3
3	21	Student (BS)	HTC EndeavorU	4.3.1
4	22	Student (BS)	Samsung GT-N7100	4.3
5	23	Student (BS)	Samsung GT-I9500	4.4.2
6	23	Student (BS)	Samsung GT-I9300	4.3
7	23	Student (MS)	HTC Desire HD A9191	2.3.5
8	23	Student (BS)	TURKCELL MaxiPRO5	4.0.3
9	24	Student (BS)	HTC ChaCha A810e	2.3.5
10	26	Student (MS)	Sony C1905	4.1.2
11	30	Researcher	Samsung GT-I9190	4.2.2
12	33	Student (PhD)	Samsung GT-N7100	4.3
13	50	Retired	Samsung GT-S5830i	2.3.6
14	52	Retired	LG-E612	4.0.3
15	52	Housewife	Samsung GT-I8150	2.3.6
16	52	Self-employed	Huawei P6-U06	4.2.2
17	53	Teacher	LG-P970	4.0.4
18	54	Housewife	TURKCELL MaxiPRO5	4.0.3
19	56	Academician	Samsung GT-N7100	4.3
20	57	Retired	Samsung GT-I8190	4.1.2
21	63	Self-employed	Samsung GT-S5360	2.3.6
22	63	Education Inspector	Turkcell Maxi Plus 5	4.0.4

22 participants, 17 different smartphone models

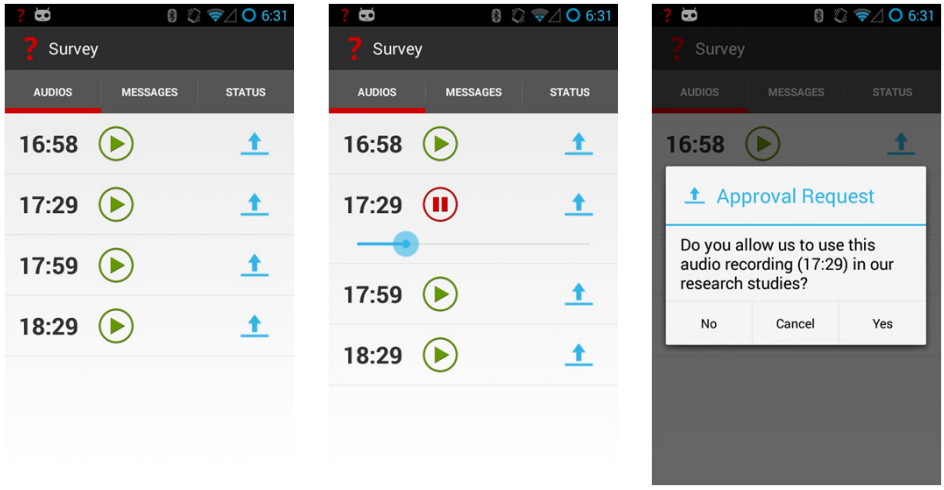
[Hasan Faik Alan, 2014] Context-Aware Mobile Diary

Platform Diversity: Average Accelerometer Sampling Rates



[Hasan Faik Alan, 2014] Context-Aware Mobile Diary

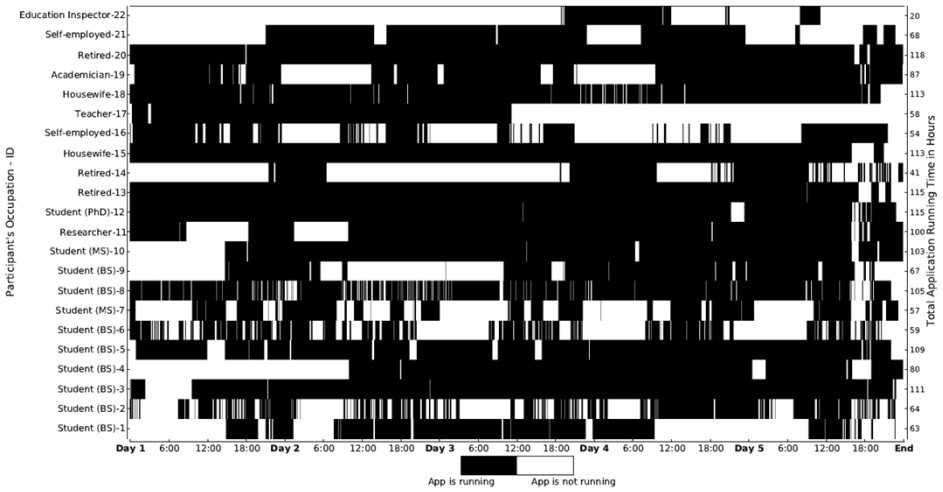
Usability: Privacy Preserving Audio Recording



Participants felt comfortable with this kind of controlled sharing of audio recordings

[Hasan Faik Alan, 2014] Context-Aware Mobile Diary

Data Completeness



On average 82 out of 120 hours were successfully collected from a person

[Hasan Faik Alan, 2014] Context-Aware Mobile Diary

Conclusion

- There has never been a more exciting time for research that overlaps pervasive technology and health
- What's next?
  - Develop and employ large-scale available sensor systems into the daily life of individuals.
  - Develop privacy-aware data interpretation schemes for capturing, connecting and interpreting various health-related dimensions.
  - Develop and evaluate objective benchmarks to provide evidence on the effectiveness of persuasive recommenders.

Pervasive Health Conference 2015 in Istanbul

- Premier international forum on ubiquitous technologies and human factors in healthcare and wellbeing
- Istanbul – The Capital of Capital Cities
- Important Dates
  - Submission: December 19
  - Conference: May 20-23
- http://pervasivehealth.org