The Role of Non-Intrusive Approaches in the Development of People-Aware Systems

PAULO NOVAIS

Intelligent Systems Lab/ALGORITMI CENTER

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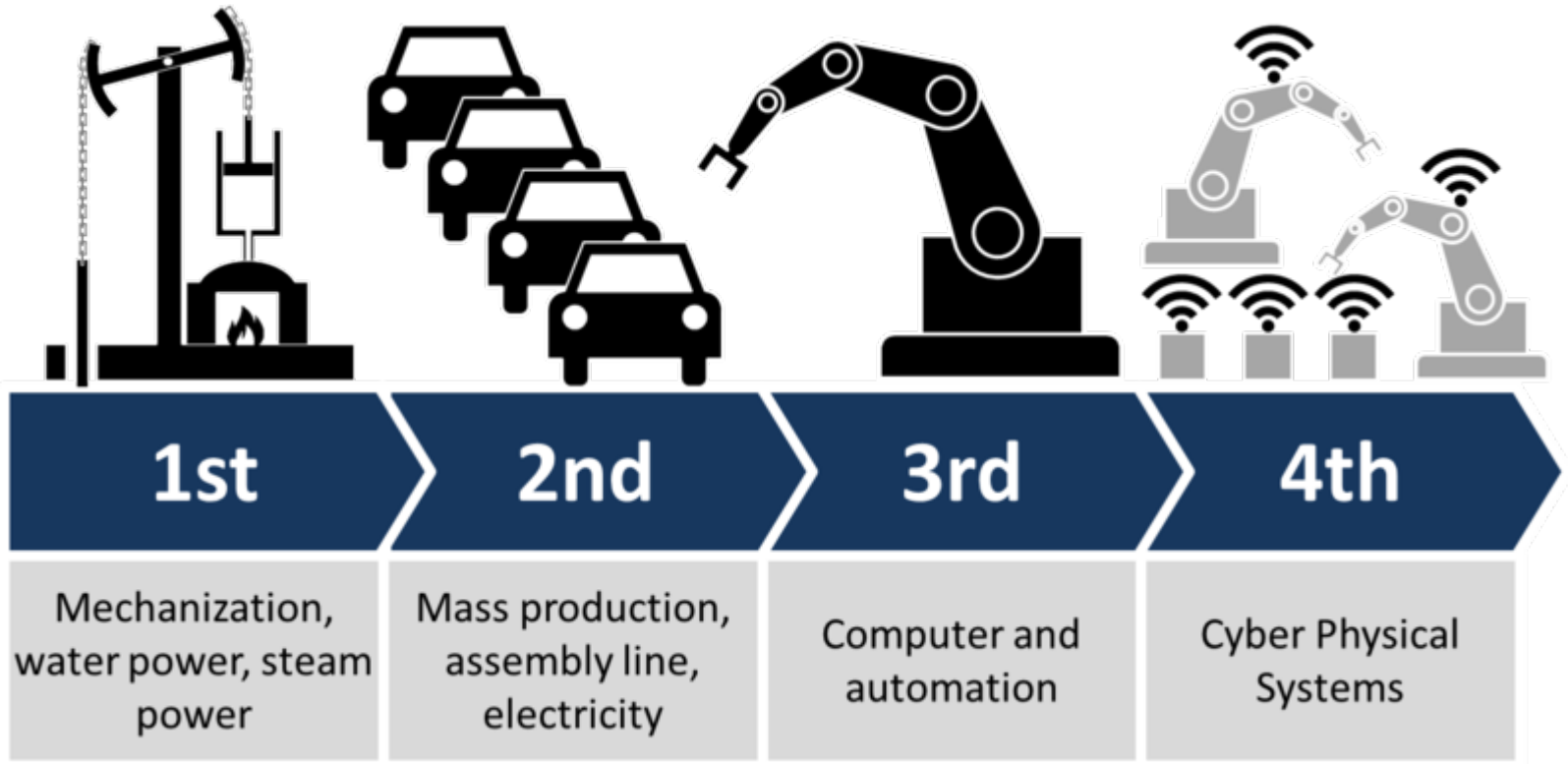
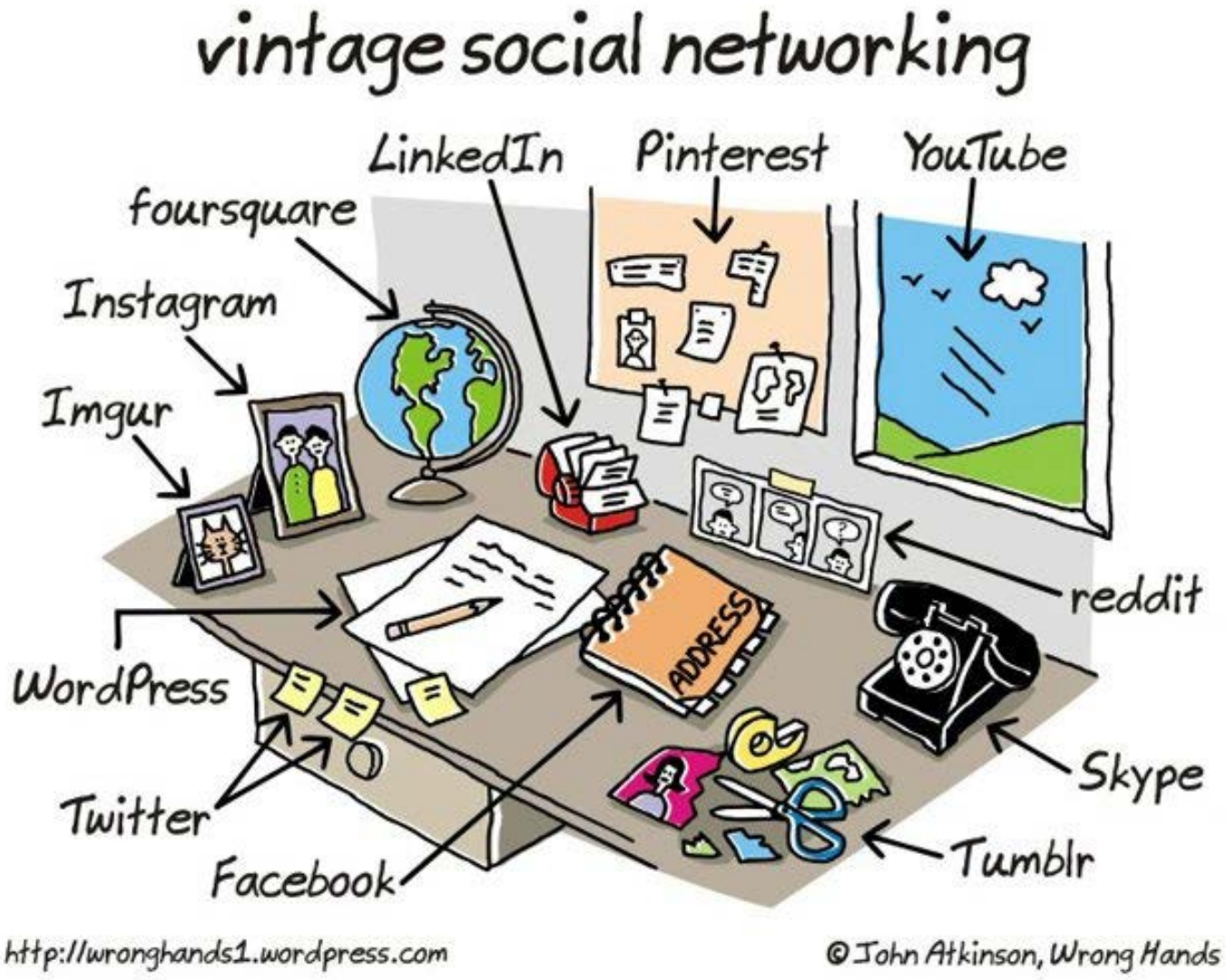
The New Revolution



The 4 Industrial Revolutions (by Christoph Roser at AllAboutLean.com)

The New Real World

New "smarter" Tools



Digital Lifestyle

"In the years ahead, further exciting innovations will unify the software, hardware and services in people's lives, offering them even richer, more engaging and deeply connected experiences."

Bill Gates, Outlines Vision for the Digital Lifestyle (2006)

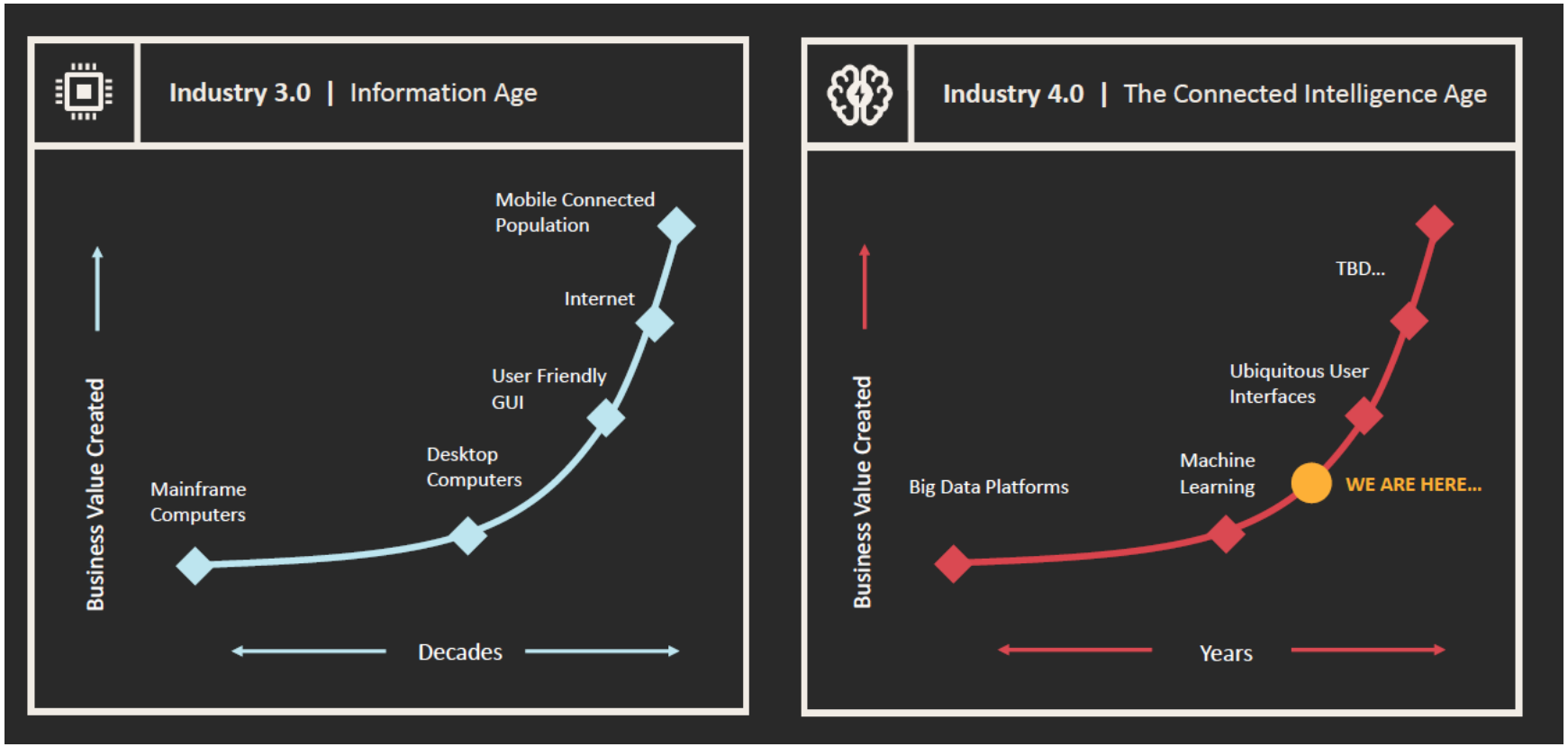
New ways

“Computing is not about computers any more.

It is about living.”

Nicholas Negroponte

The AI time



Josh Sutton, Publicis.Sapient, 2016

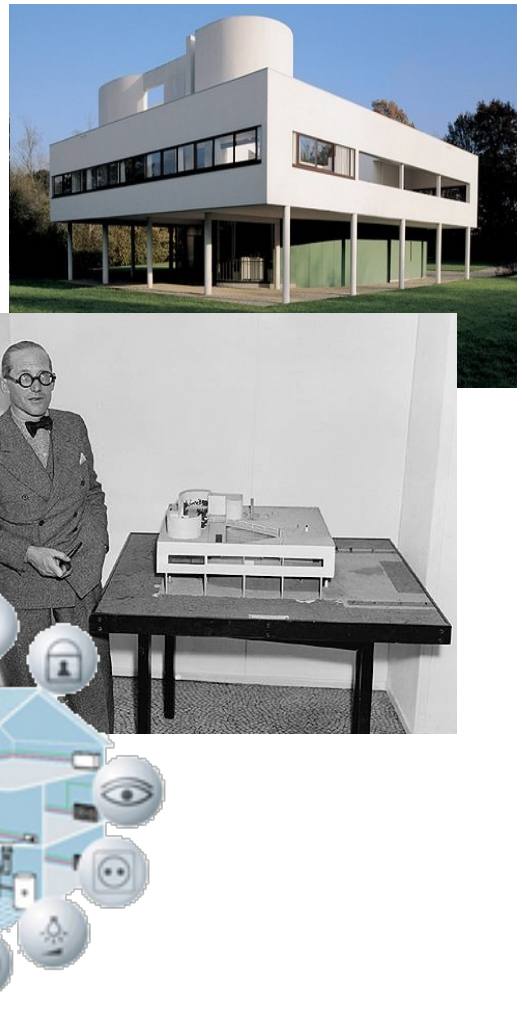
Live in machines

Le Corbusier (architect 1887-1963)

"A house is a machine for living in"

Vic Callaghan (UEssex 2000)

"A building is a robot we live inside"



Ambient Intelligence

Pattie Maes (MIT)

"Ambient Intelligence envisions a world where people are surronded by Intelligence and intuitive interfaces embedded in the everyday objects arround them"

Elisabetta Farella (University of Bologna)

“These interfaces recognize and respond to the presence and behavior of an individual in a personalized and relevant way”

Juan Carlos Augusto (University of Ulster)

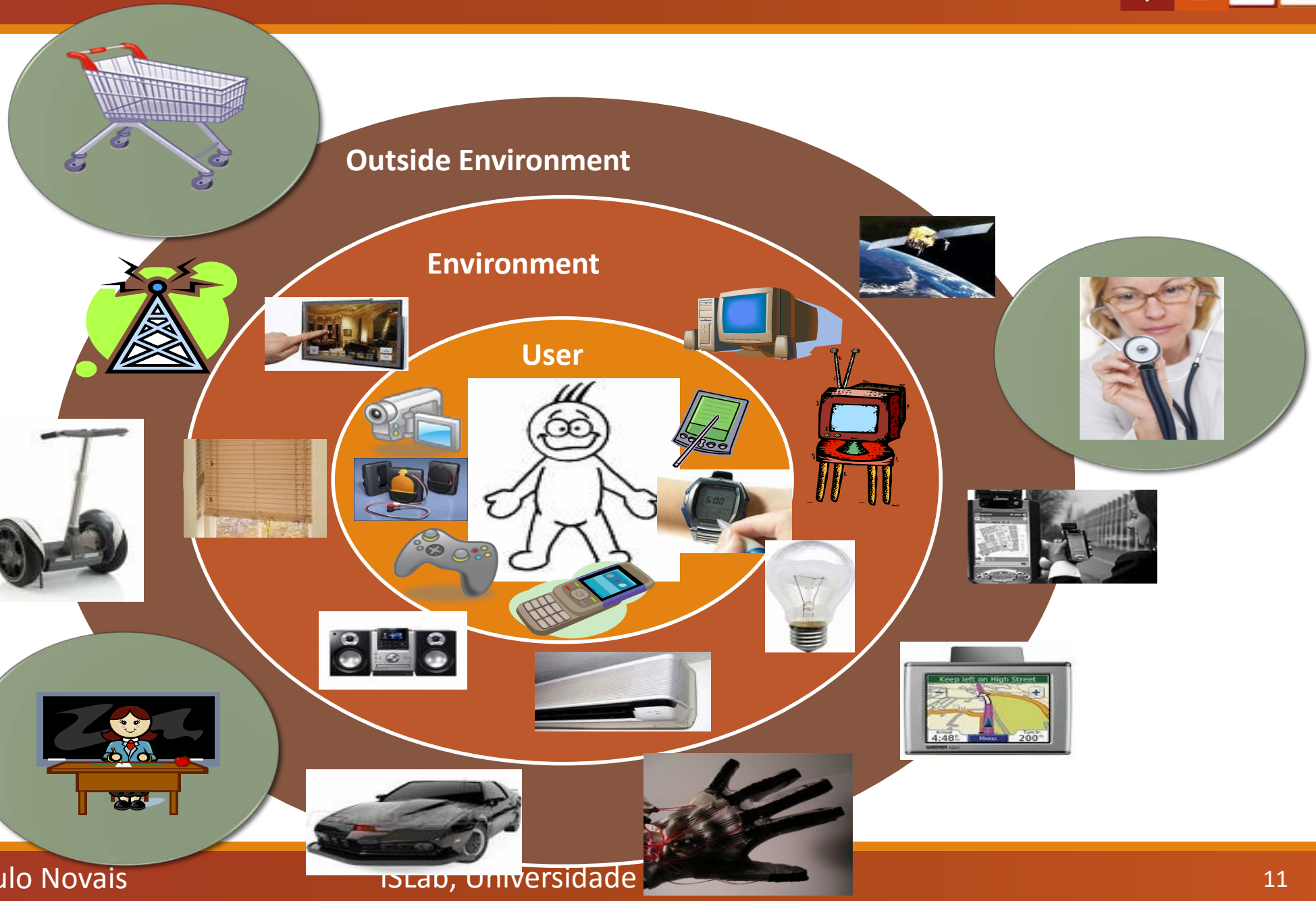
“A digital environment that helps people in their daily lives, in a sensible way”

Ambient Intelligence

Ambient Intelligence presents a new approach to the surrounding environment, where devices are spread everywhere (ubiquity), eventually included in objects (embedded systems), allowing the human being to interact in the real world in an intelligent and discrete way (pervasive computing).

These environments should be aware of people's needs (contextual awareness), with custom requirements and forecasting behaviours.

Ambient Intelligence



Introduction

Most of our actions generate data

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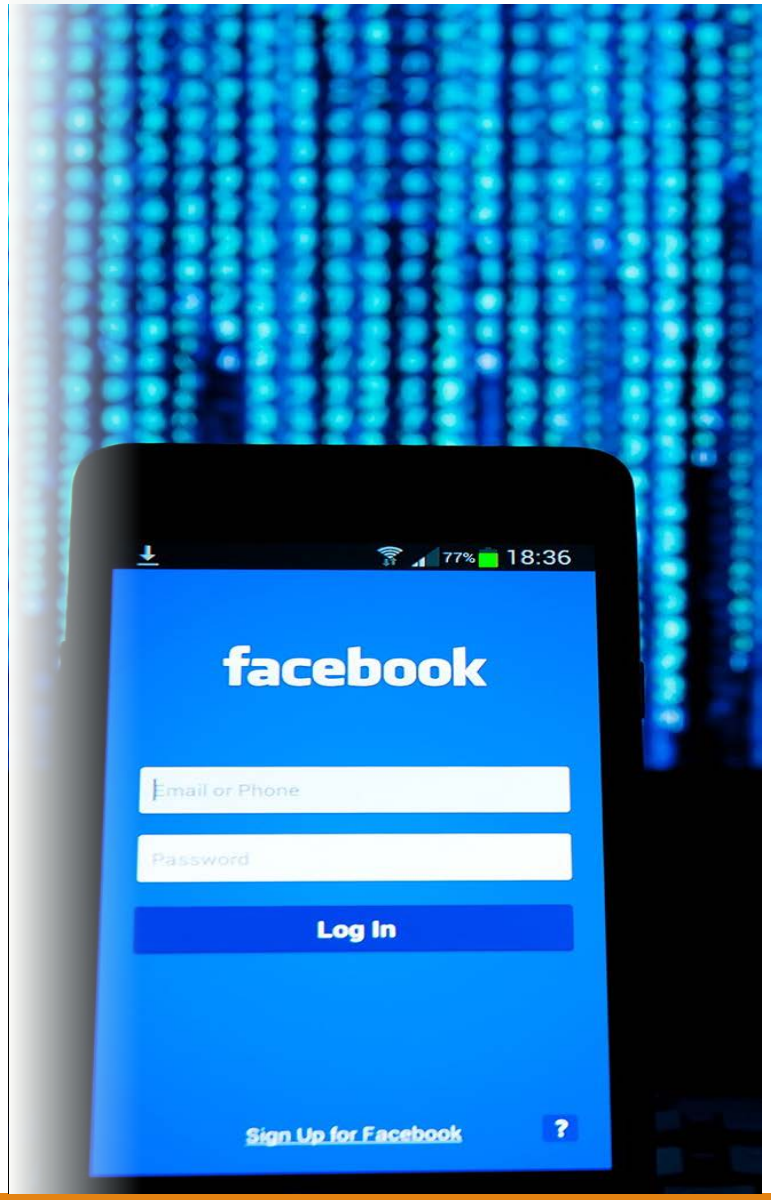


Big Data

Things one can do at a large scale that cannot be done at a smaller one

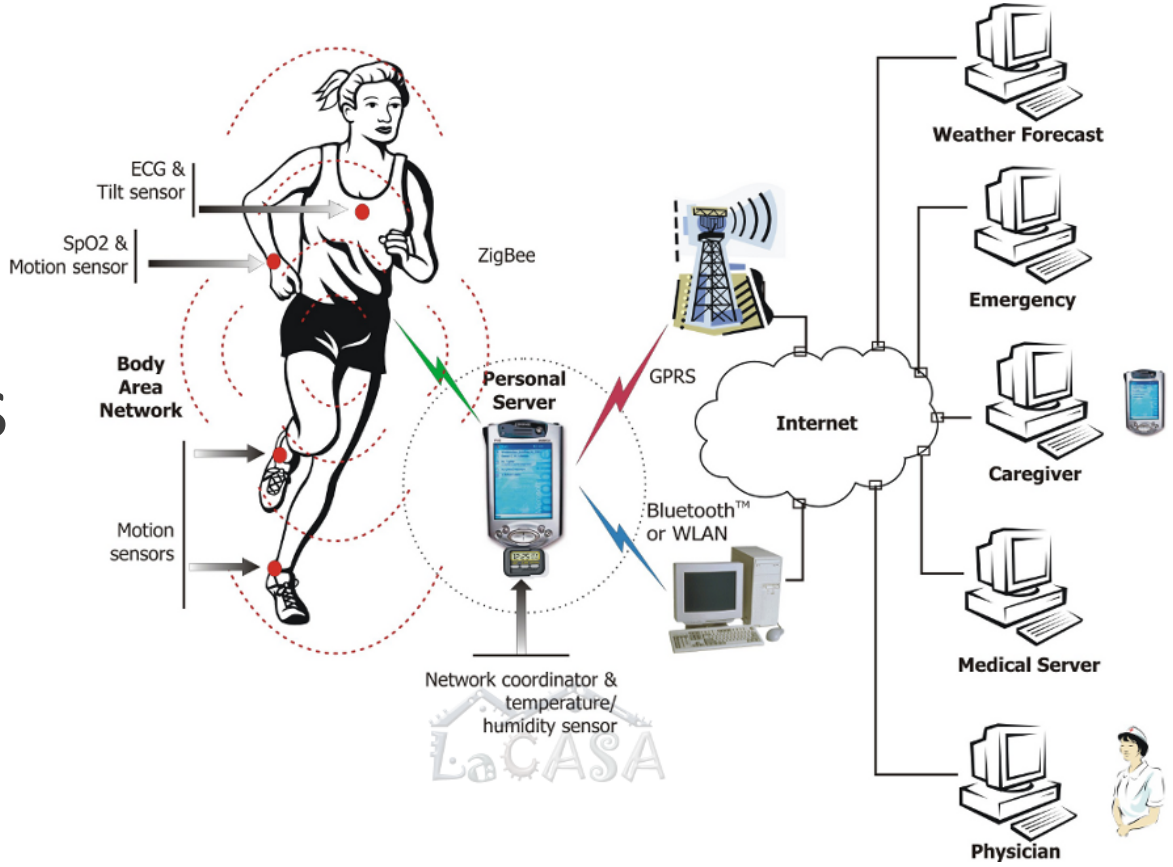
Big Data & HCI

Extract data from our interaction patterns

How do people interact?

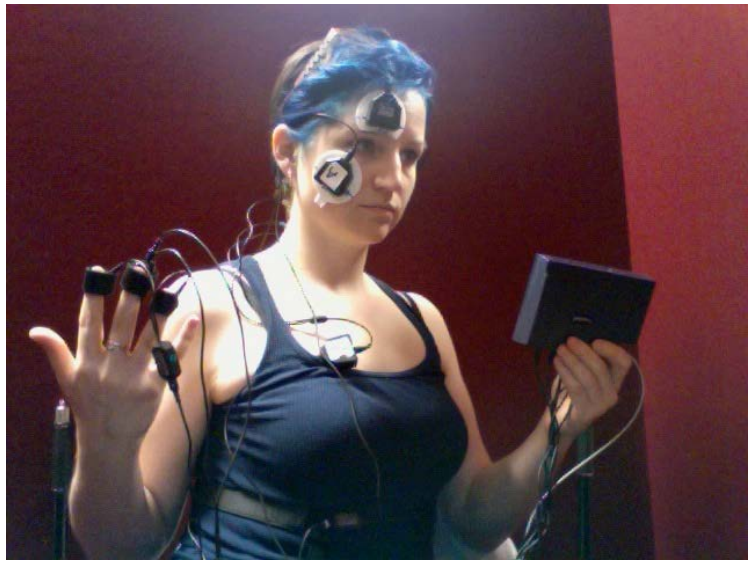
Introduction

There is, currently, a significant interest in consumer electronics in applications and devices that monitor and improve the user's well-being



Introduction

Nonetheless, existing approaches are generally based on physiological sensors



Introduction

We propose a new approach to the problem in which user behavioral cues are used as an input to assess inner state.

Our reactions to everyday events, our behavior, are a result of our inner state.

If we interpret someone's behavior, we are able to "guess" how she/he feels.

Introduction

Main goal: a non-intrusive system for acquiring contextual information about human users;

This will allow the development of unobstrusive, pervasive and sensitive Ambient Intelligent Systems;

This innovative approach has been validated by research in the last years.

Current State

Scenarios for 2010

The ISTAG proposed 4 scenarios that would be reality by 2010

One describes 'D-Me‘: an avatar of the user, which constantly monitors the user's behaviors, so as to build a complete and up-to-date prolfie

This avatar, embodied in the clothes of the user, can then take some decisions that resemble the ones that would be (and were) taken by the user, in similar situations

AmI Systems

Main characteristics: sensitive, responsive, adaptive, transparent, ubiquitous, and inteligente

Some of these characteristics depend on technological evolution

AmI Systems

On what does the *sensitive* characteristic depends?

Traditional answer: on the development of sensors, especially physiological sensors (hard sensors)

Our answer: on the development of soft-sensors, especially behavioral ones

Traditional approaches

Acquisition of information for

Stress

Fatigue

Performance

Traditional Approaches

Traditionally, two main approaches can be followed to acquire information about an individual

(1) Questionnaires or surveys, used mostly by psychology

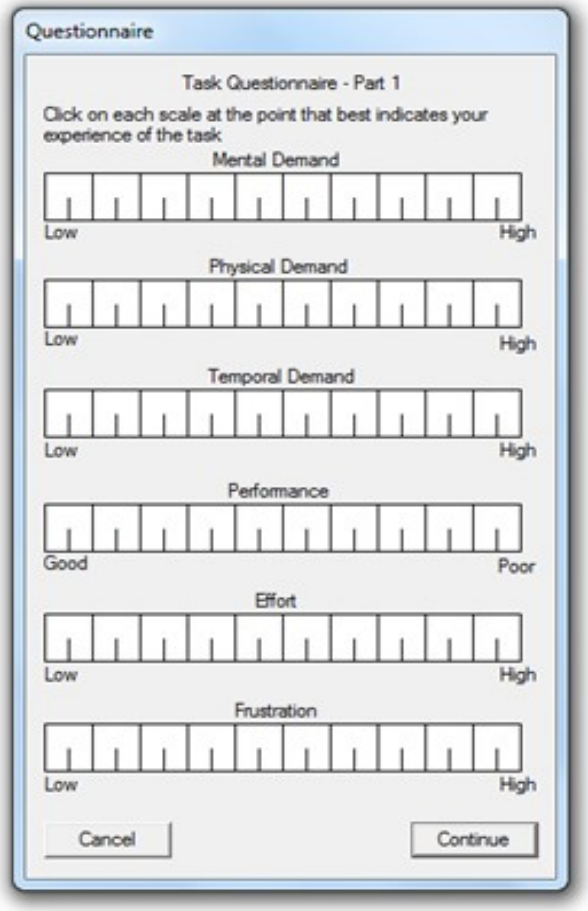
(2) Physiological sensors, used mostly by medicine

Questionnaires

- Are an inexpensive approach to collect vast amounts of information
- Do not represent a very significant effort for the researcher
- Easy to compile data
- Can be administered either by the researcher or by anyone else, possibly remotely

Subjective Measures

- Self-Report
- Questionares
- Fatigue Index



Fatigue Severity Scale

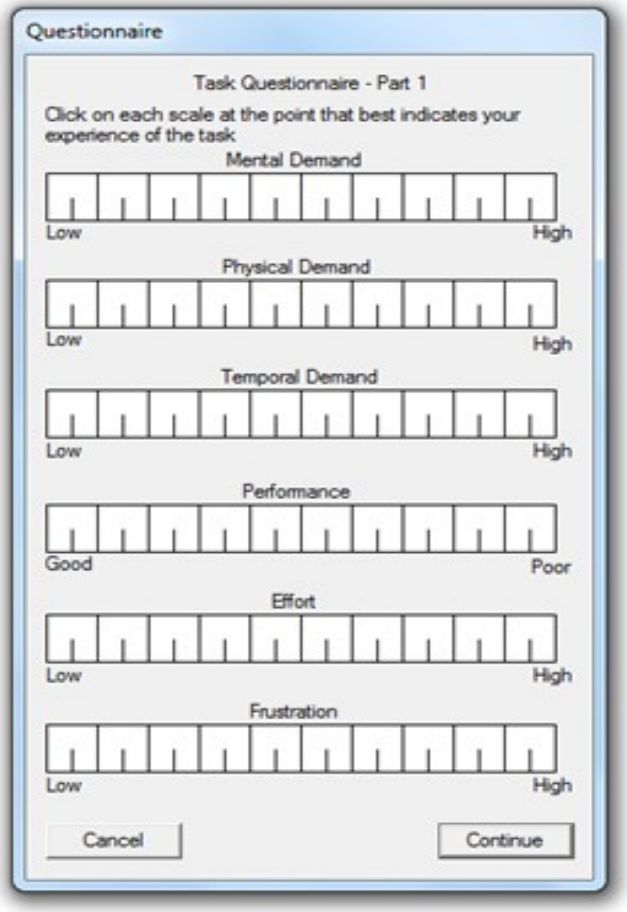
Fatigue Severity Scale (FSS)

During the past week, I have found that	Disagree ⟷ Agree						
1. My motivation is lower when I am fatigued.	1	2	3	4	5	6	7
2. Exercise brings on my fatigue.	1	2	3	4	5	6	7
3. I am easily fatigued.	1	2	3	4	5	6	7
4. Fatigue interferes with my physical functioning.	1	2	3	4	5	6	7
5. Fatigue causes frequent problems for me.	1	2	3	4	5	6	7
6. My fatigue prevents sustained physical functioning.	1	2	3	4	5	6	7
7. Fatigue interferes with carrying out certain duties and responsibilities.	1	2	3	4	5	6	7
8. Fatigue is among my 3 most disabling symptoms.	1	2	3	4	5	6	7
9. Fatigue interferes with my work, family, or social life.	1	2	3	4	5	6	7
						Total Score	
FSS mean score = total score for 9 items divided by 9.						Mean Score	

FSS mean score >4 indicates severe fatigue.

Krupp LB, et al. *Arch Neurol*. 1989;46:1121-1123.

NASA - TLX

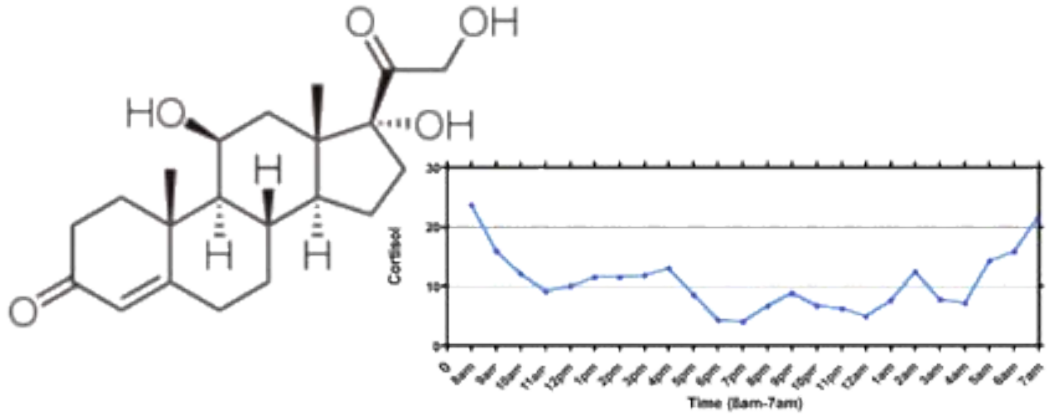

Questionnaire
Task Questionnaire - Part 1
Click on each scale at the point that best indicates your experience of the task
Mental Demand
Low
High
Physical Demand
Low
High
Temporal Demand
Low
High
Performance
Good
Poor
Effort
Low
High
Frustration
Low
High
Cancel
Continue

Physiological Sensors

- Are very precise in assessing the state of an individual (e.g. stress, fatigue, emotions)
- Can be used as a basis for medical treatments
- Biofeedback units combine feedback from multiple bodily functions such as brain waves, muscular response or skin conductivity
- Are nowadays relatively small and price is dropping, although sometimes still expensive

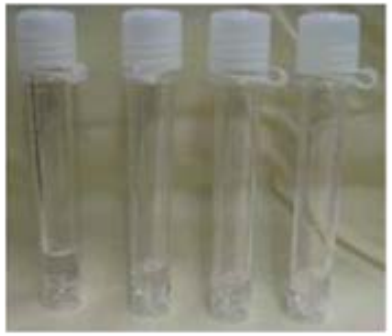
Stress Estimation

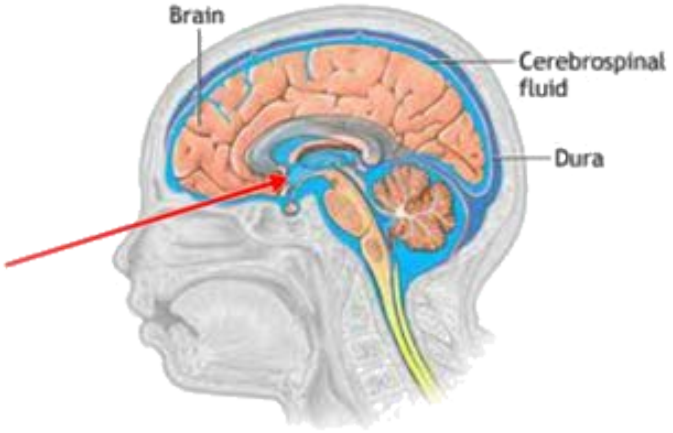
Cortisol levels



Stress Estimation

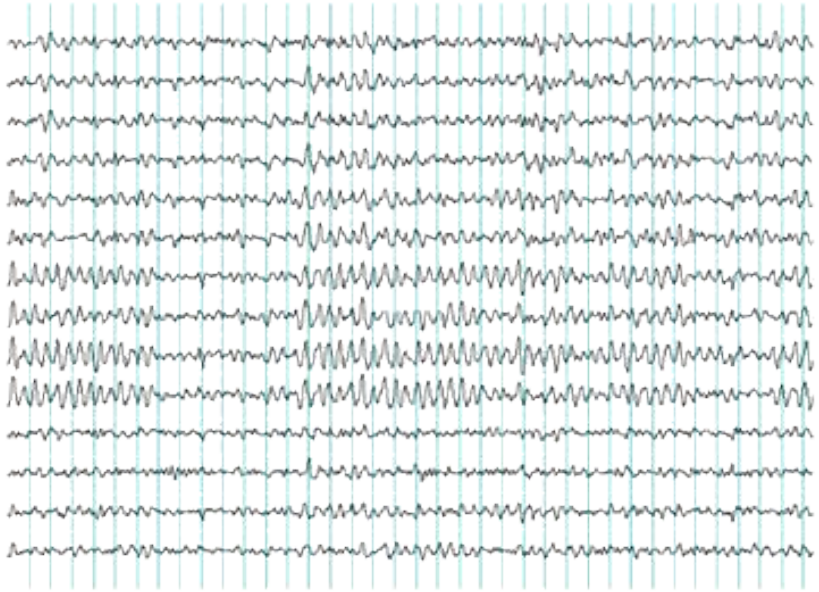
Corticotropin-releasing hormone



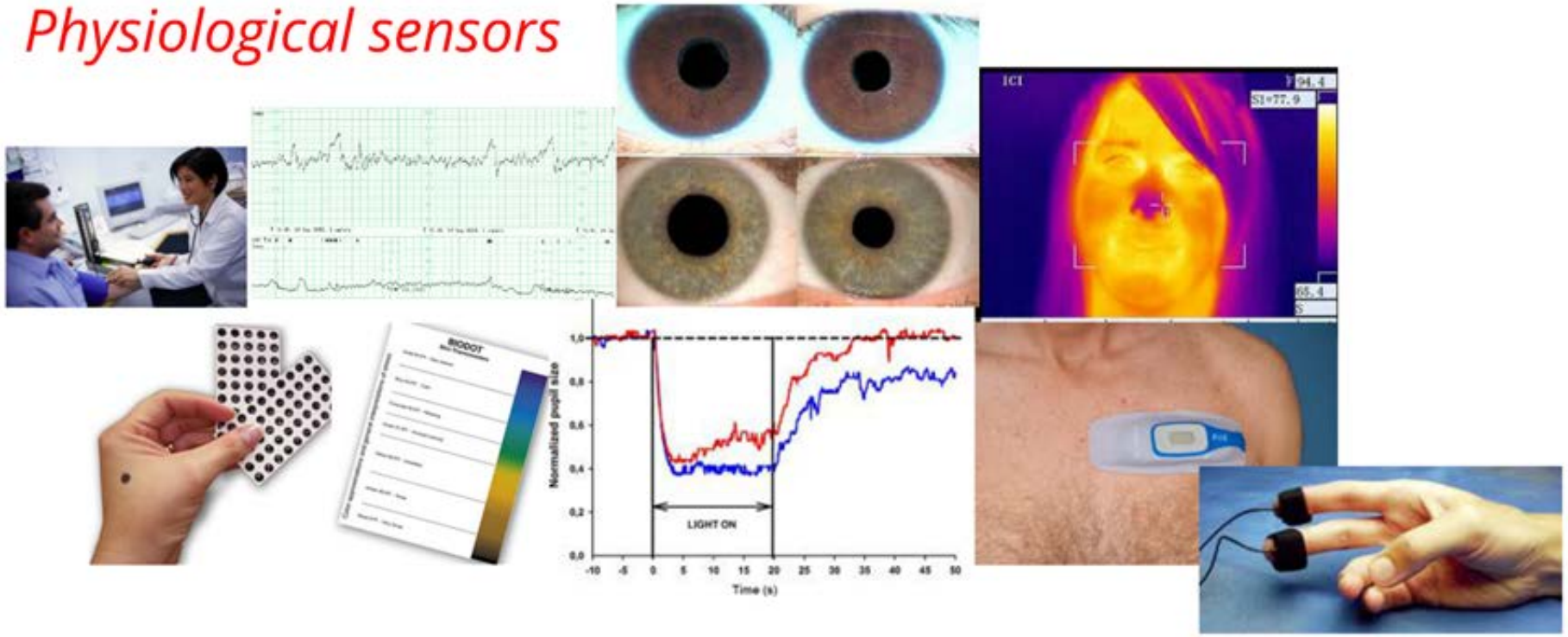


Stress Estimation

Electroencephalogram



Stress Estimation



Stress Estimation

State Trait Anxiety Inventory

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	1	2	3	4
	Not at all	**A little**	**Somewhat**	**Very Much So**
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I feel tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel uncomfortable	1	2	3	4
11. I feel self confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I feel jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

Fatigue Detection

- There are three different ways to detect and monitor mental fatigue:
  - Physiological Measurements
  - Human Performance
  - Subjective Measures

Physiological Measurements

A way of measuring mental fatigue is to measure the physiological responses it causes on the body

Brain related measures	Eye related measures	Heart related measures
Functional magnetic	Electrooculography	Electrocardiography
Resonance imaging	Blink interval	Heart rate variability
Electroencephalography	Blink rate	Heart rate
Event related potentials	Blink closure duration	Blood volume
	Pupil Size	

SmartCap

EyeCheck

Fatigue Detection System in Distance Education

Disadvantages

Questionnaires

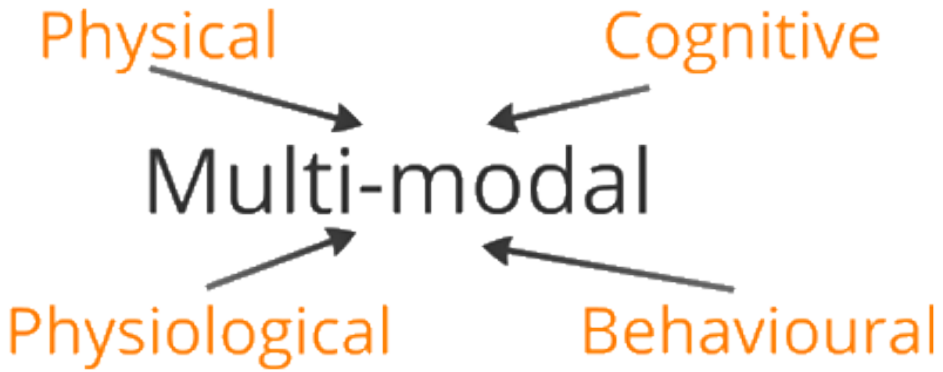
- Slow, no real-time
- People can lie or hide certain aspects

Physiological Sensors

- Can be expensive
- Intrusive
- Have wires or require batteries
- Have very specific placement needs

A new view on the problem

Our approach



Train models

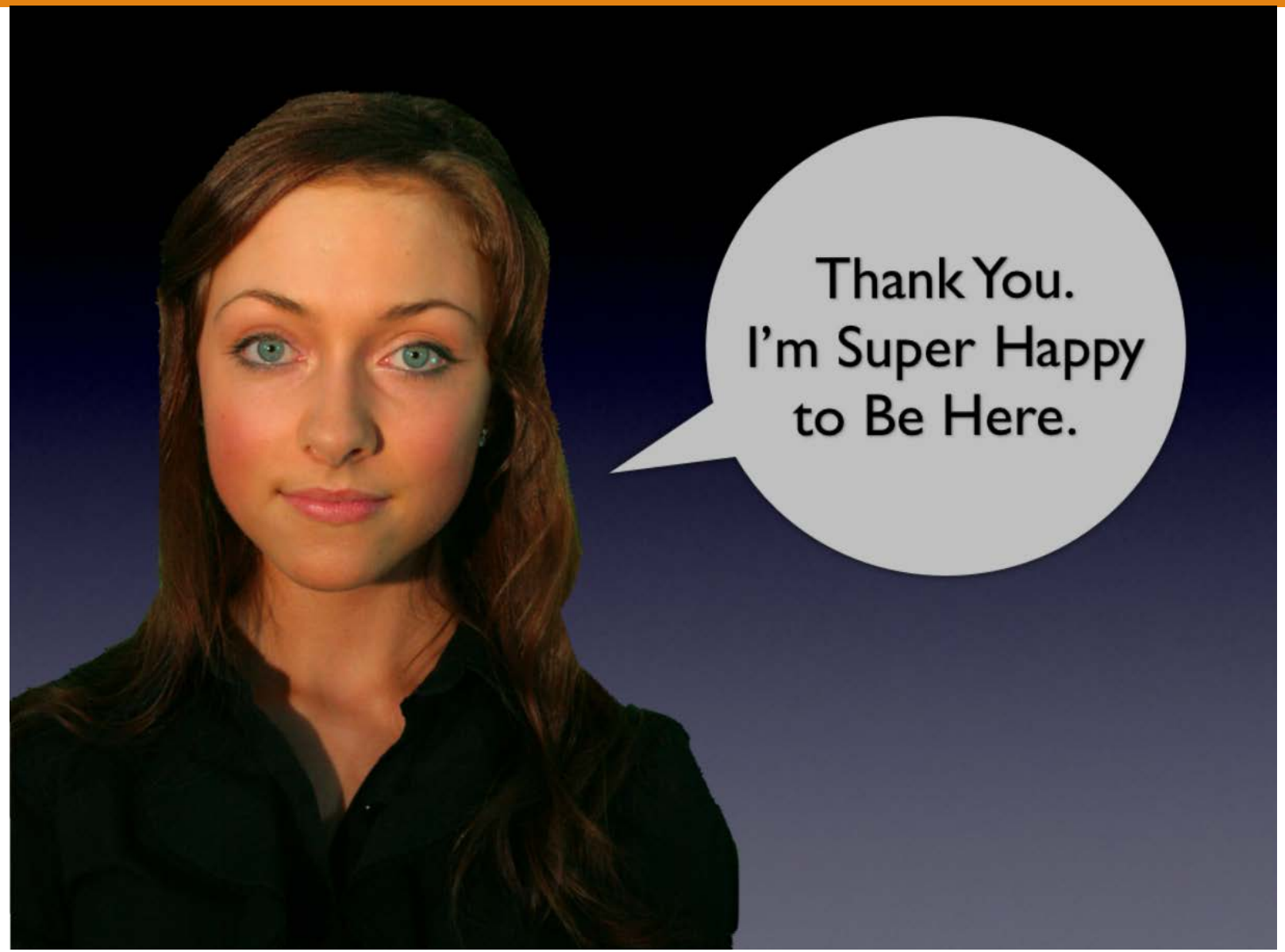
Personalized

Use in real time

Motivation

- Take advantage of our interaction
- Promise of exciting new applications
- Improve poor interaction mechanisms

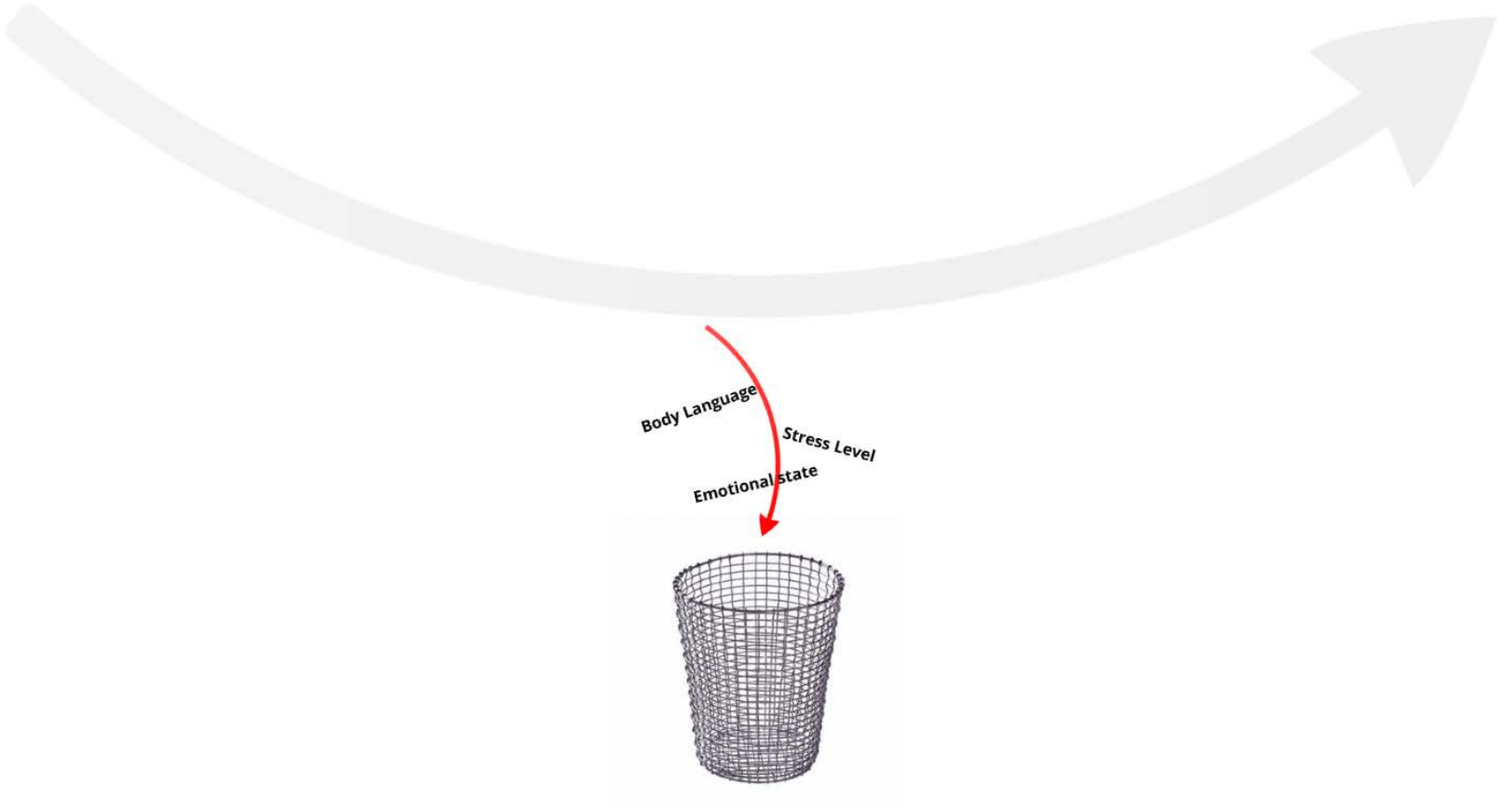
Motivation



Motivation

Field of application

Motivation

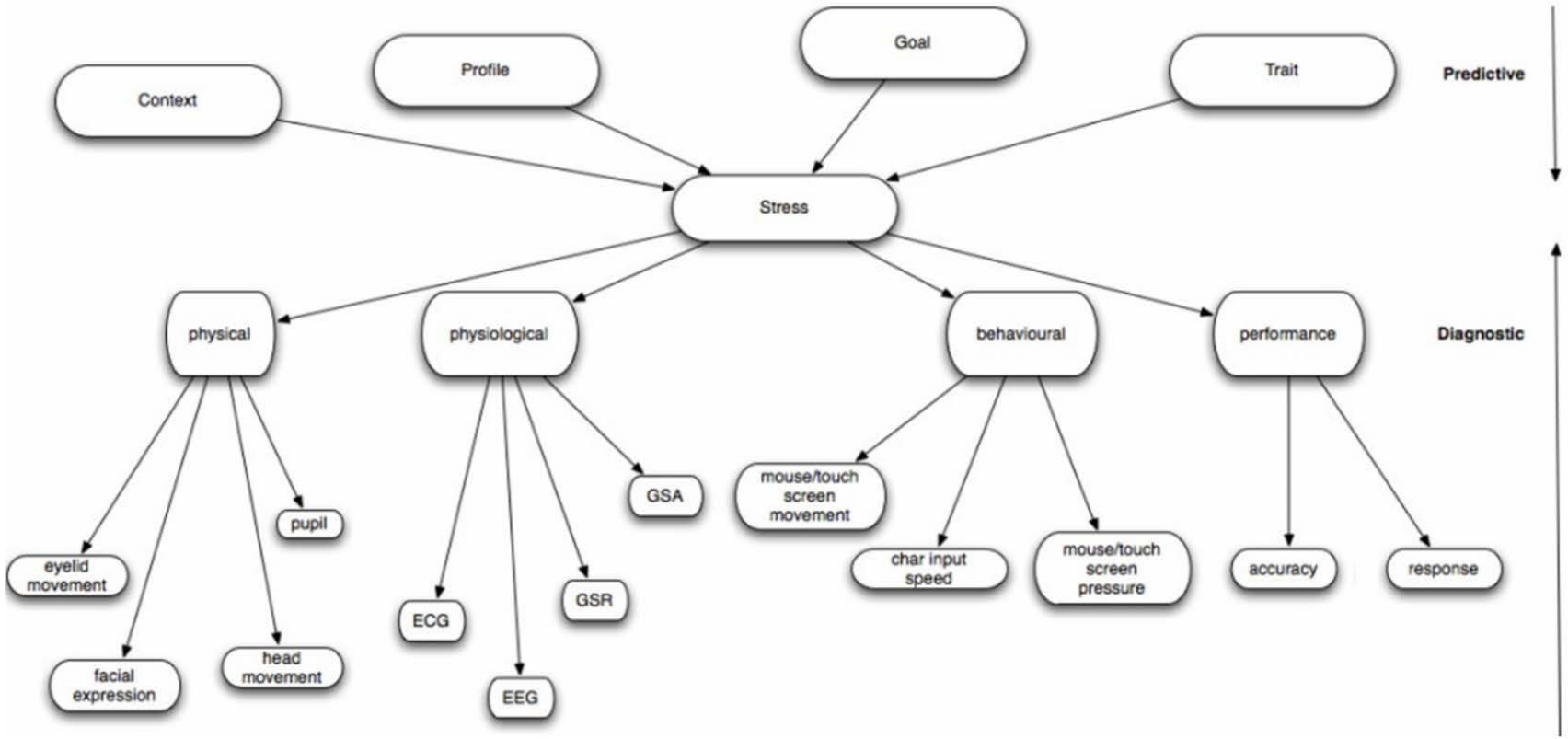


Behavioural Analysis

Our approach

- Our challenge
  - Estimate Stress and Fatigue in a non-invasive way
- How we do it
  - Analyzing the behavior of the users when interacting with technological devices

Multi-modal model



amount of movement

touch intensity
average, maximum, minimum

keydown time

acceleration

acceleration

errors per key pressed

click duration

velocity

touch duration

time between clicks

time between keys pressed

total excess of distance traveled between each two clicks

precision

double click speed

number of double clicks

score

distance while clicking

signed sum of angles between each two clicks

touch pattern

distance between clicks

sum of distances from pointer to line between clicks

average excess of distance traveled between each two clicks

absolute sum of angles between each two clicks

average of distances from pointer to line between clicks

Behaviorism

- All things that organisms do—including acting, thinking, and feeling—can and should be regarded as behaviors
- Psychological disorders are best treated by altering behavior patterns or modifying the environment
- Behavior can be studied in a methodical and recognizable manner with no consideration of internal mental states

Fields of Application

- **AIDS prevention**
- **Conservation of natural resources**
- **Education**
- **Gerontology**
- **Health and exercise**
- **Industrial safety**
- **Littering**
- **Medical procedures**
- **Parenting**
- **Seatbelt use**
- **Severe mental disorders**
- **Sports**
- **Zoo management and care of animals**

...

Behavior

- Behavior is the activity of living organisms. Human behavior is the entire gamut of what people do including thinking and feeling
- Behavior can be determined by applying the Dead Man's test:
  - If a dead man can do it, it isn't behavior. And if a dead man can't do it, then it is behavior

Operant conditioning

- Is a voluntary form of learning in which an individual's behavior is modified by its consequences
- It may change in form, frequency, or strength
- Is the result of reinforcement and punishment

"studying hard for a particular class will result in good grades"

Respondent conditioning

- All organisms respond in predictable ways to certain stimuli
- These stimulus–response relations are called reflexes
- The smell of food (stimulus) elicits a dog's salivation

Stimulus

A stimulus is an "energy change" that affects an organism through its receptor cells

A stimulus can be described:

- **Topographically** by its physical features
- **Temporally** by when they occur in respect to the behavior
- **Functionally** by their effect on behavior

Environment

- The environment is the entire constellation of stimuli in which an organism exists
- This includes events both inside and outside of an organism

Reinforcement

- Reinforcement is the most important principle of behavior
- It is the process by which behavior is strengthened, if a behavior is followed closely in time by a stimulus and this results in an increase in the future frequency of that behavior
- May be positive or negative

Punishment

- Punishment is a process by which a consequence immediately follows a behavior which decreases the future frequency of that behavior
- Like reinforcement, a stimulus can be added (positive punishment) or removed (negative punishment)
- Punishment can often result in unwanted side effects, and has therefore been used only after reinforcement-only procedures have failed to work

Extinction

- The procedure of withholding/discontinuing reinforcement of a previously reinforced behavior, resulting in the decrease of that behavior
- The behavior is then set to be extinguished
- Extinction procedures are often preferred over punishment procedures that are frequently deemed unethical

Experimental control

- At least one participant
- At least one behavior (dependent variable)
- At least one setting
- A system for measuring the behavior and ongoing visual analysis of data
- At least one treatment or intervention condition
- Manipulations of the independent variable so that its effects on the dependent variable may be quantitatively or qualitatively analyzed
- An intervention that will benefit the participant in some way

Experimental Control

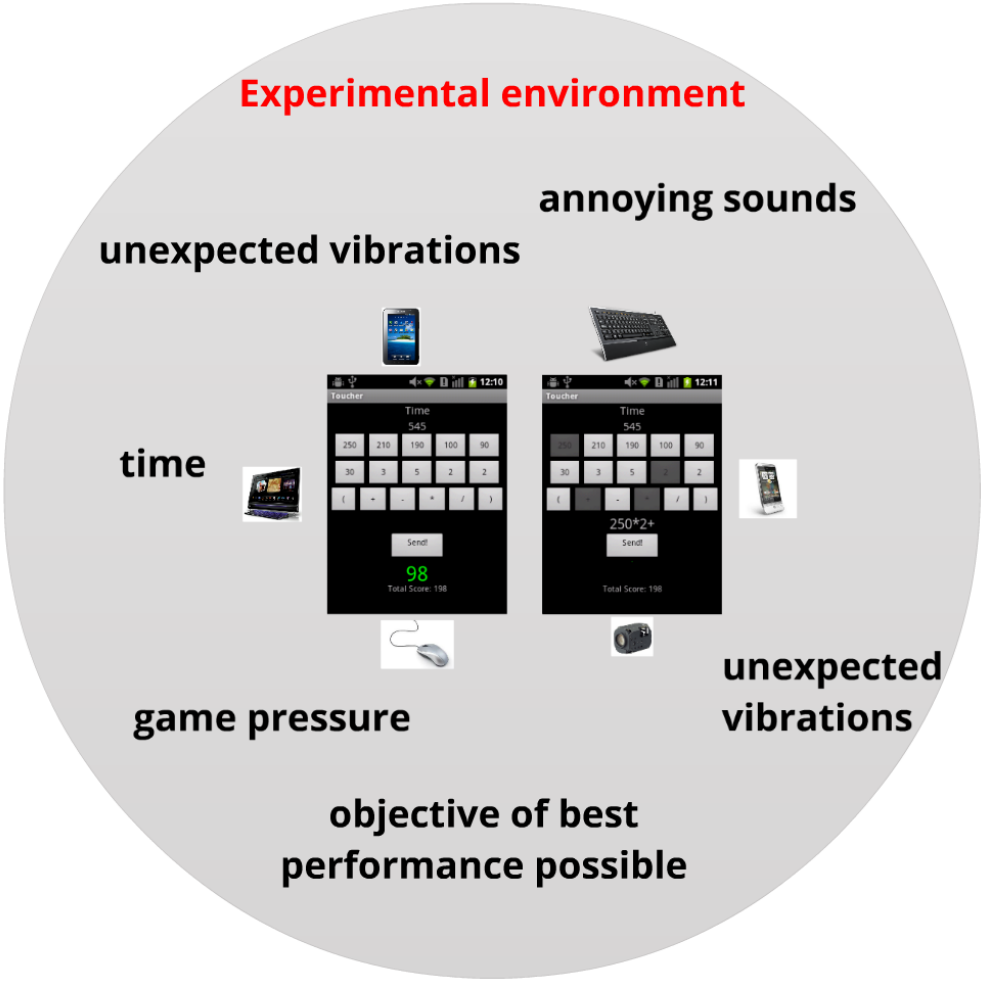
At least one participant

Experimental Control

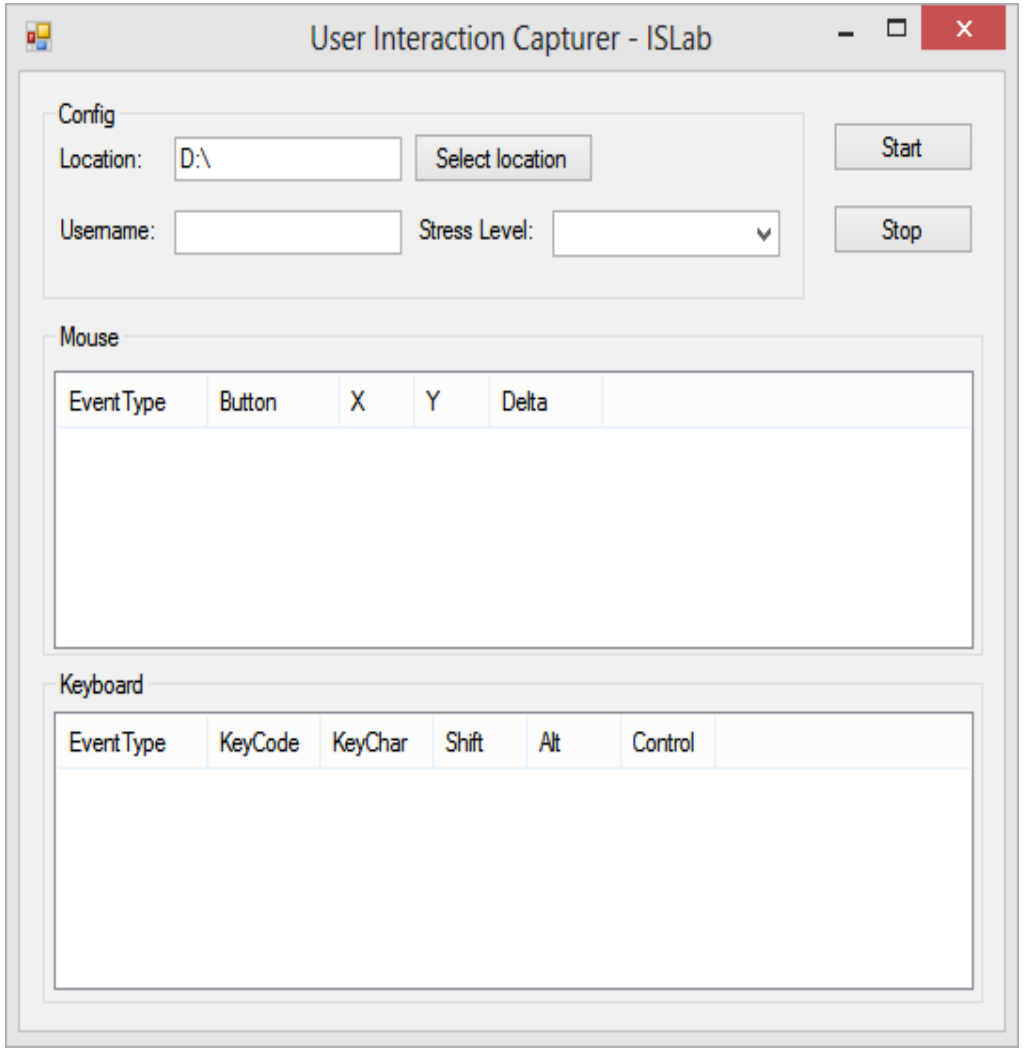
At least one behavior (dependent variable)

Experimental Control

At least one setting



Experimental Control



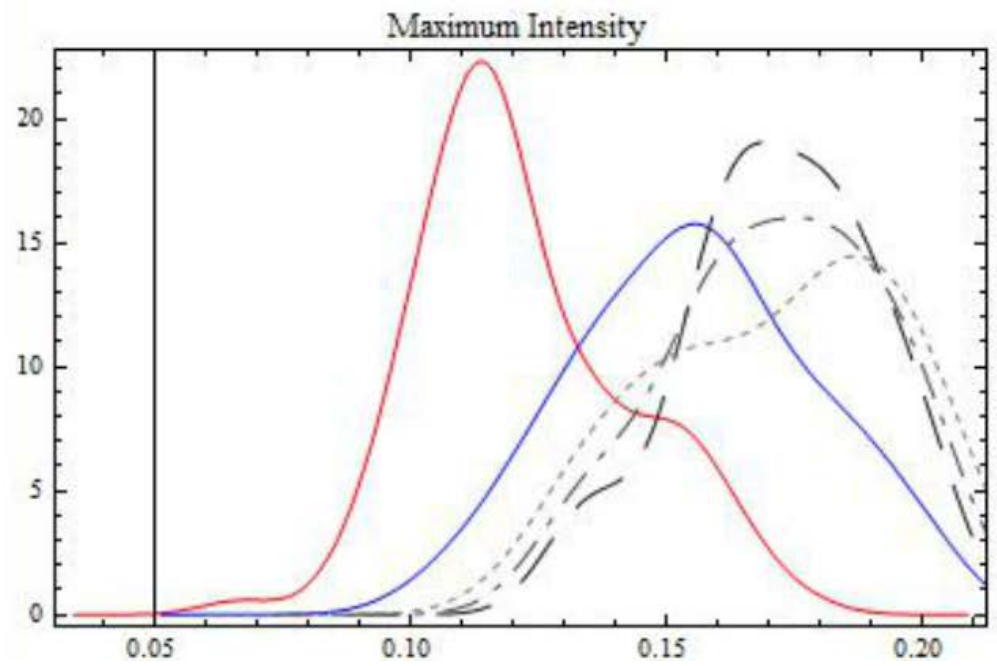
Experimental Control

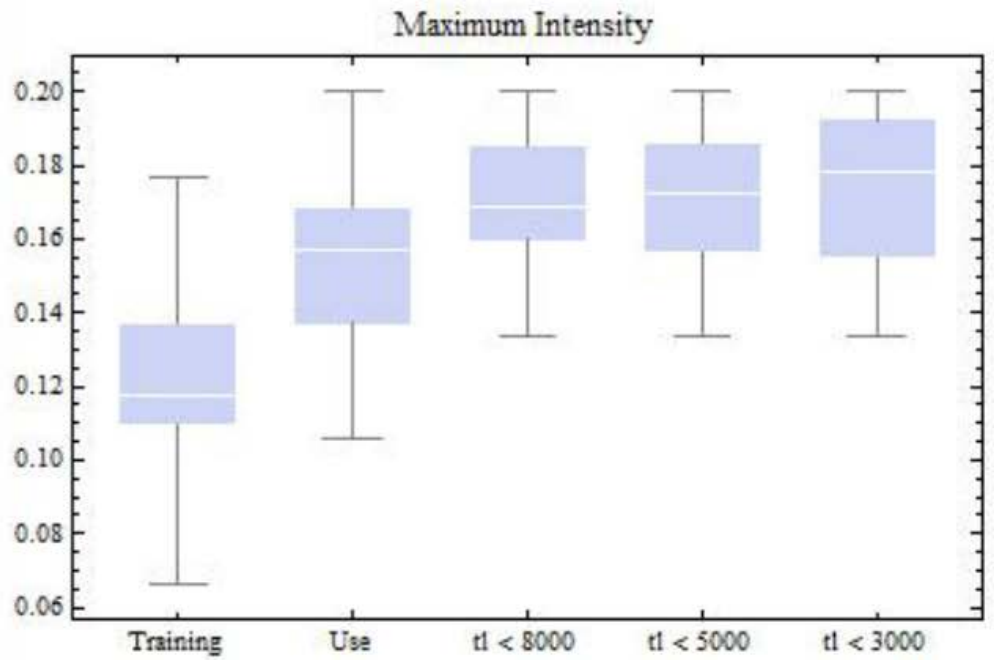
A system for measuring the behavior and ongoing visual analysis of data

Results

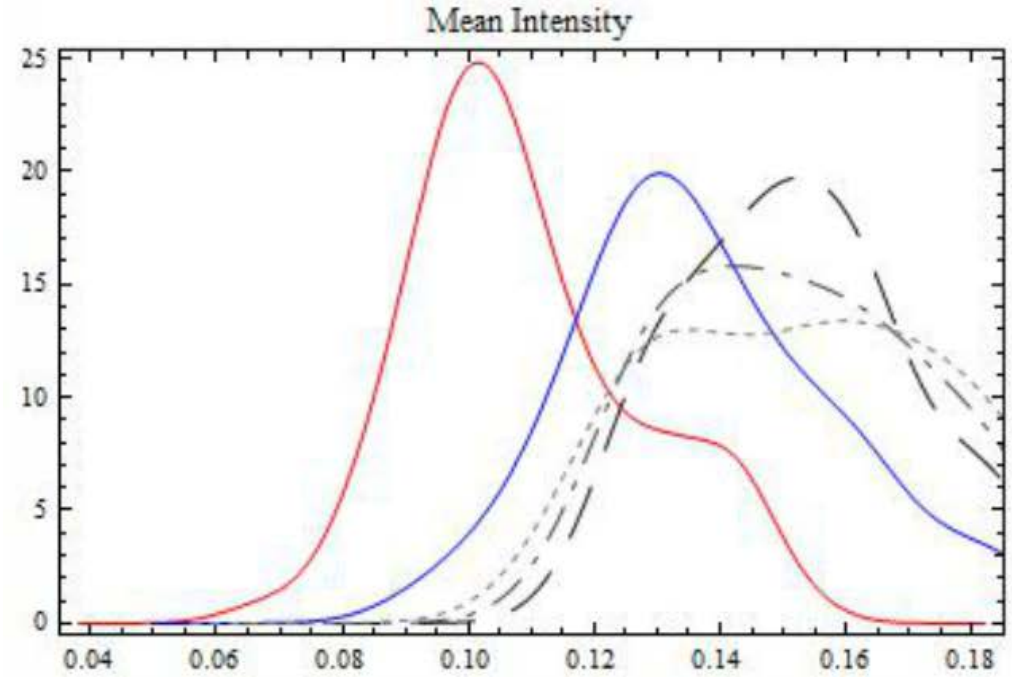
STRESS AND FATIGUE

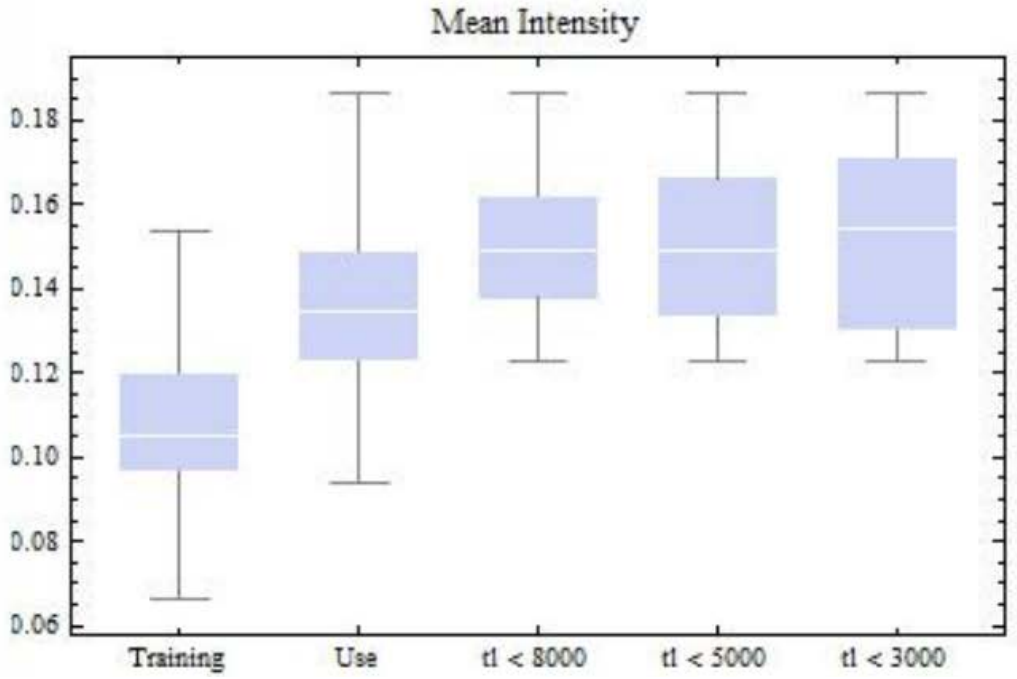
Results Stress





Results Stress





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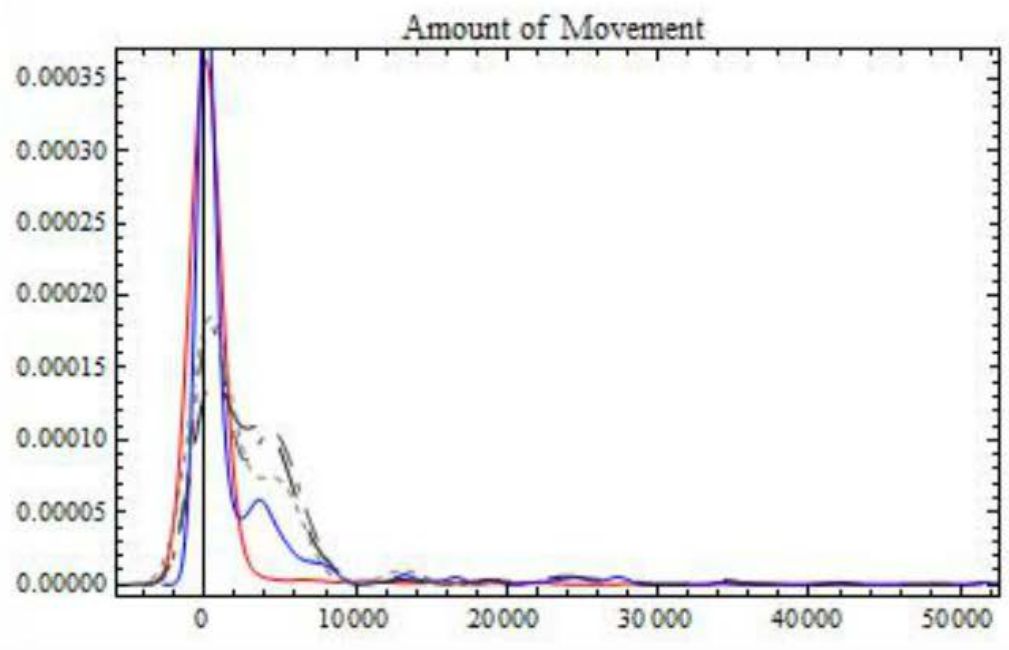
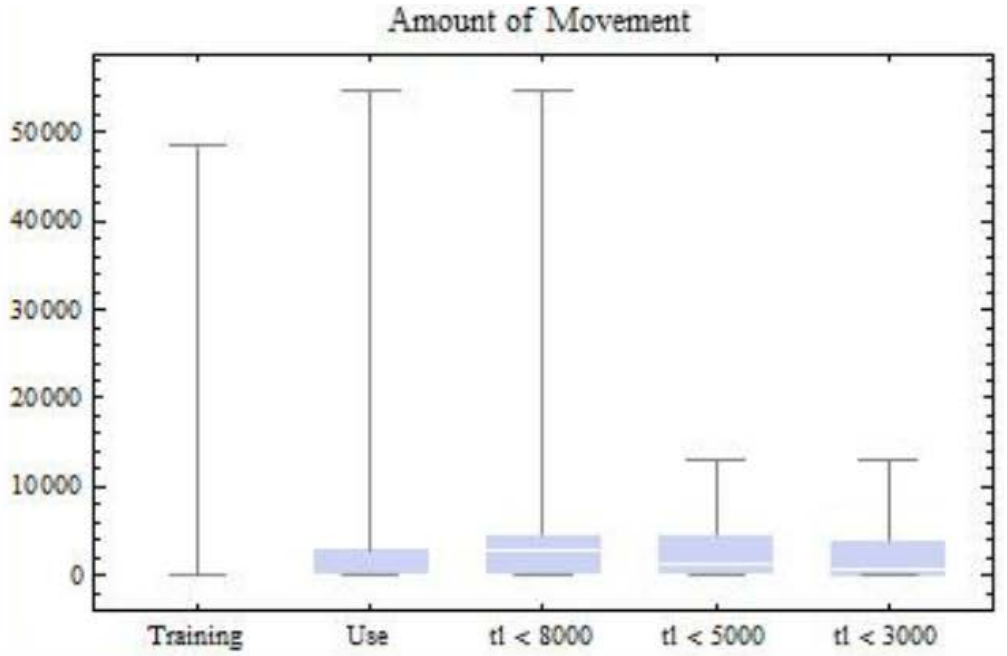
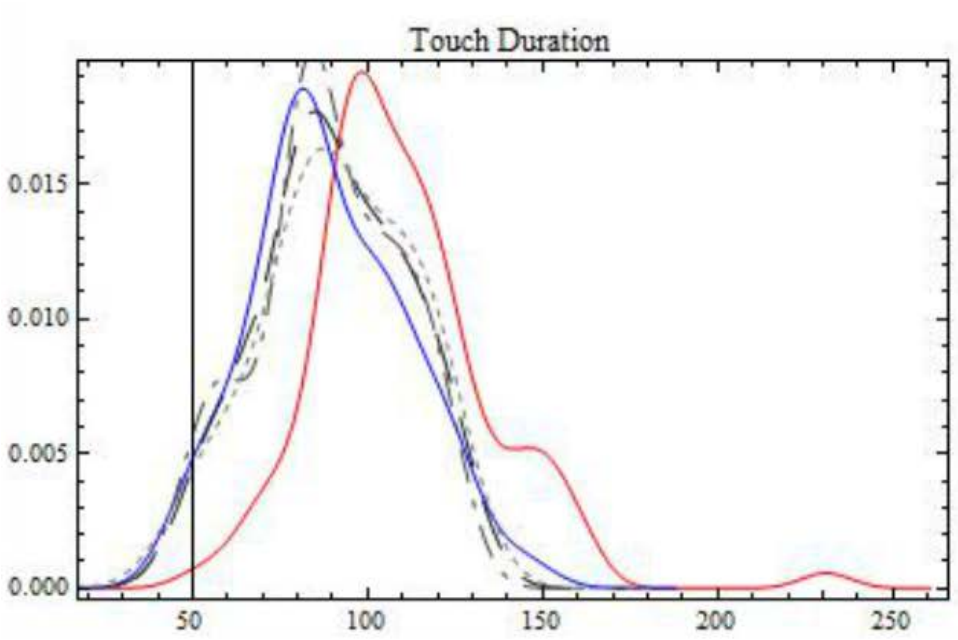
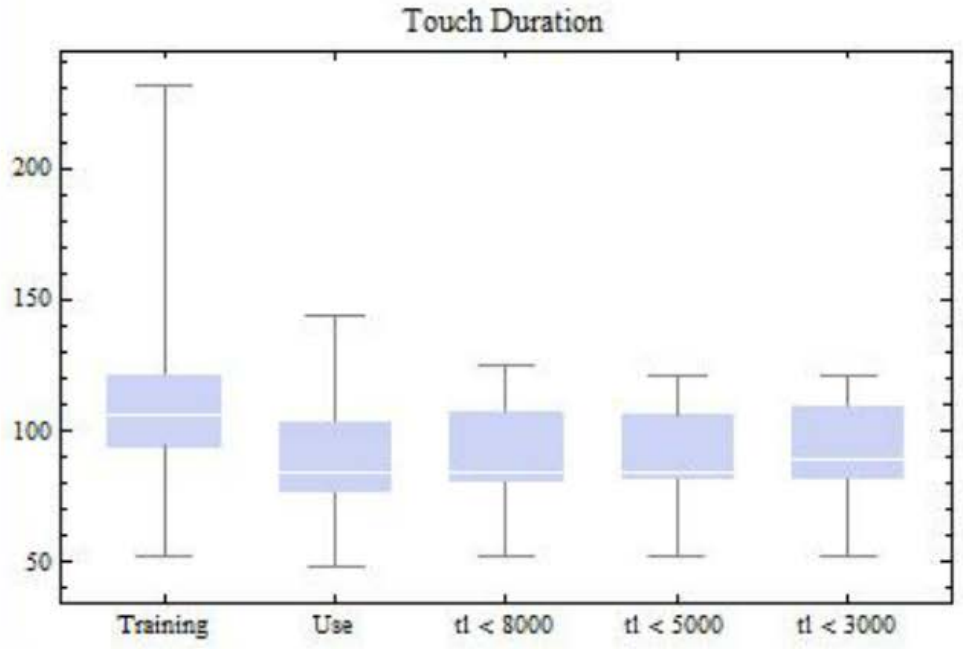




Results Stress





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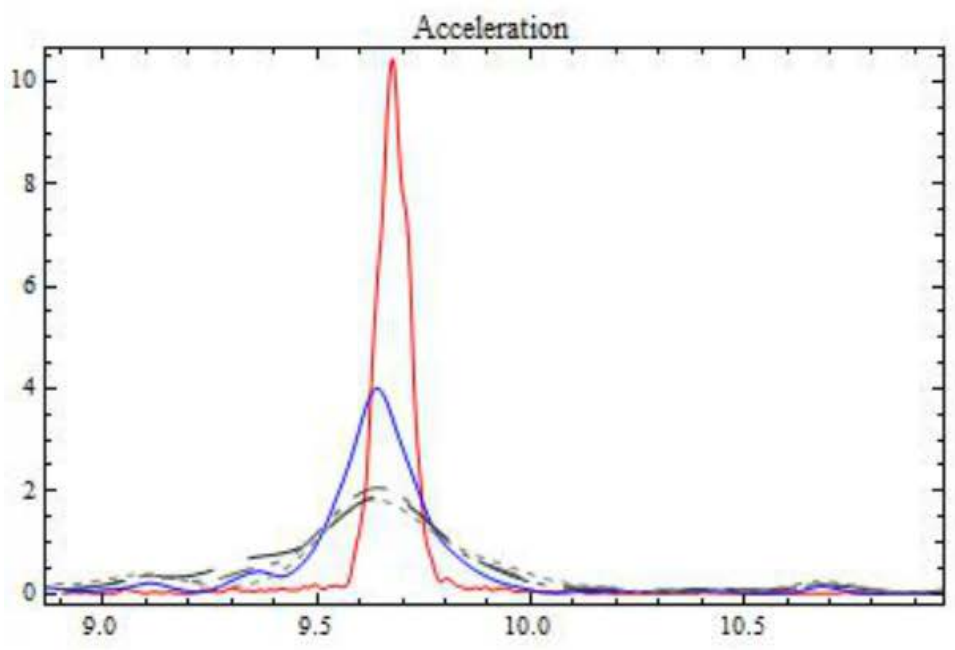

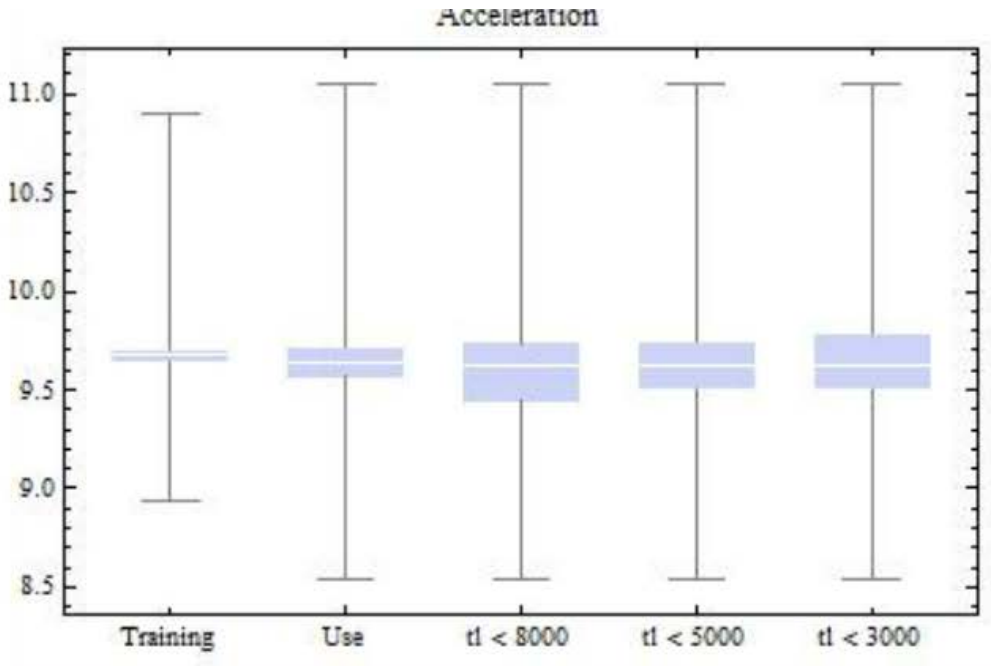

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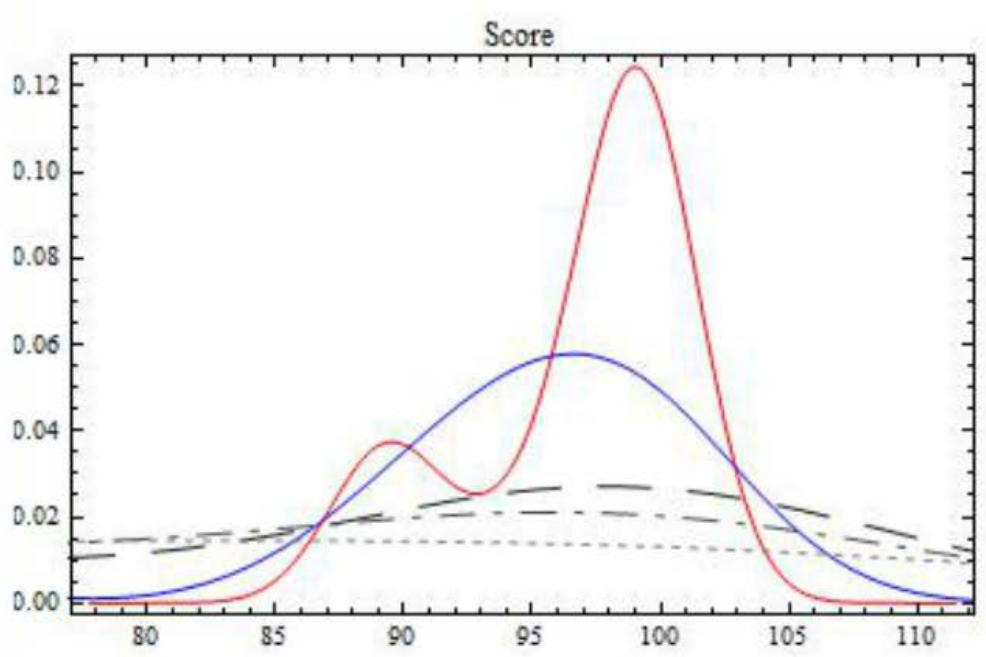
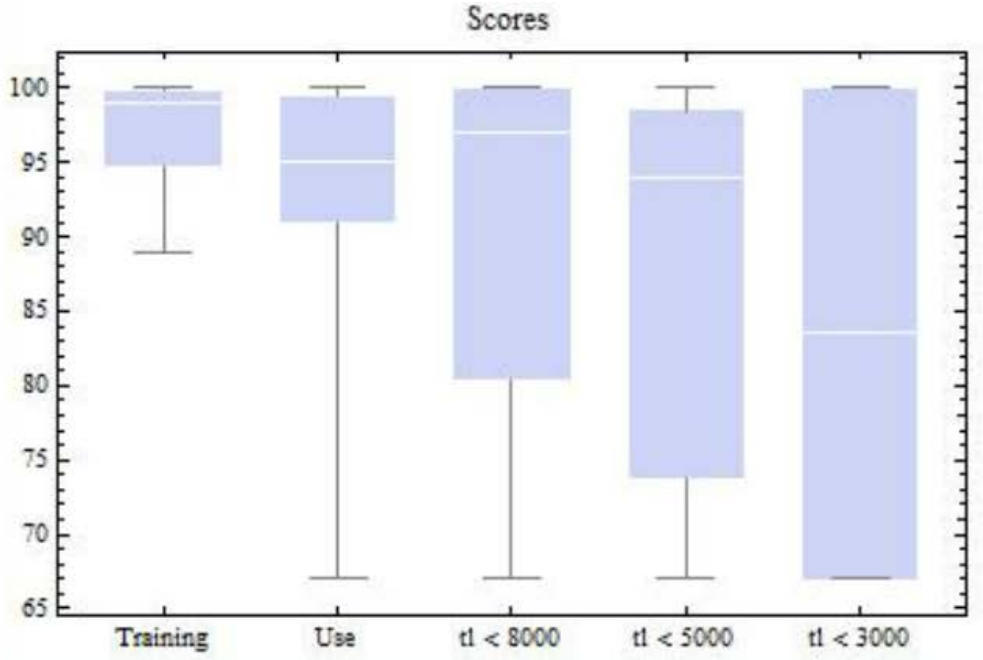
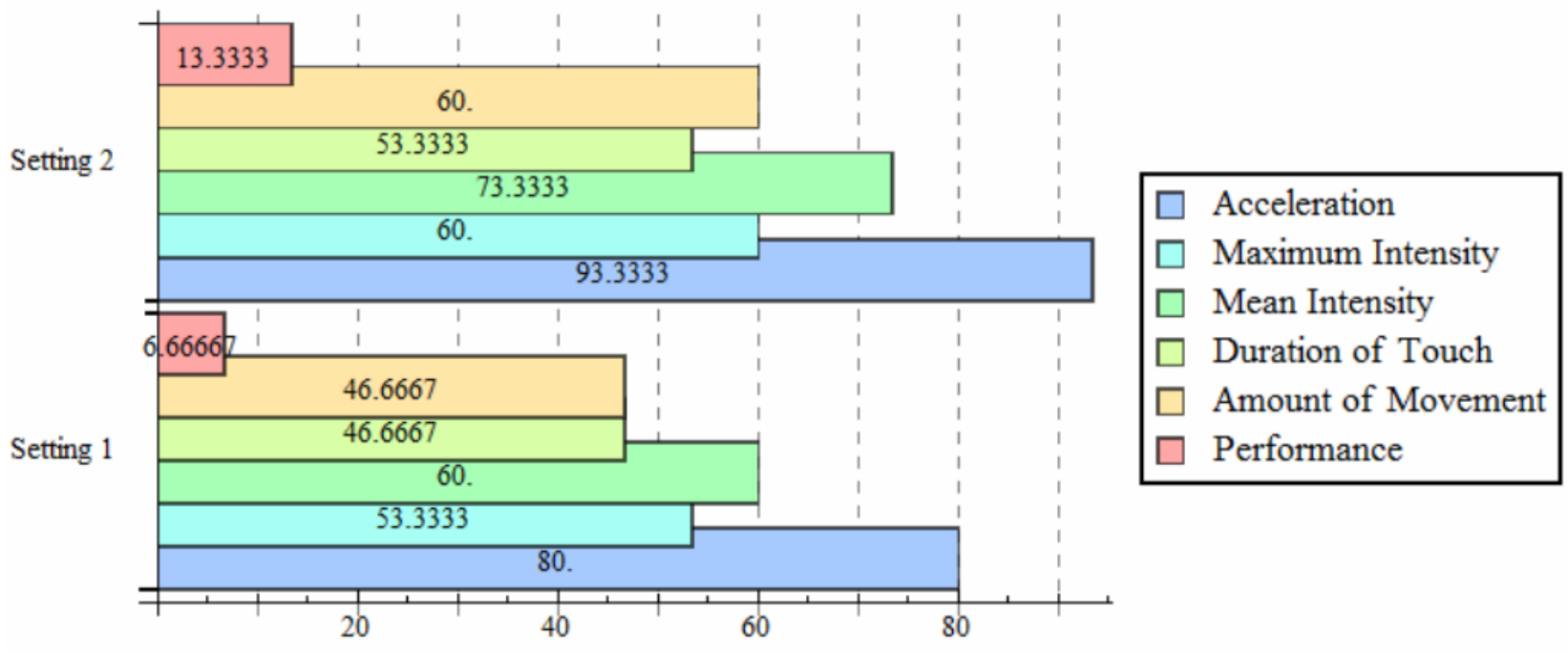




Results Stress

Summary of dave			
Data	Reject H_0	P Value	Timeleft results
Acceleration	True	4.30258×10^{-13}	True True True
Maximum Intensity	True	1.94289×10^{-11}	True True True
Mean Intensity	True	6.5901×10^{-11}	True True True
Duration of Touch	True	9.54313×10^{-6}	True True True
Amount of Movement	True	0.0157983	False False False
Scores	False	0.398694	False False False

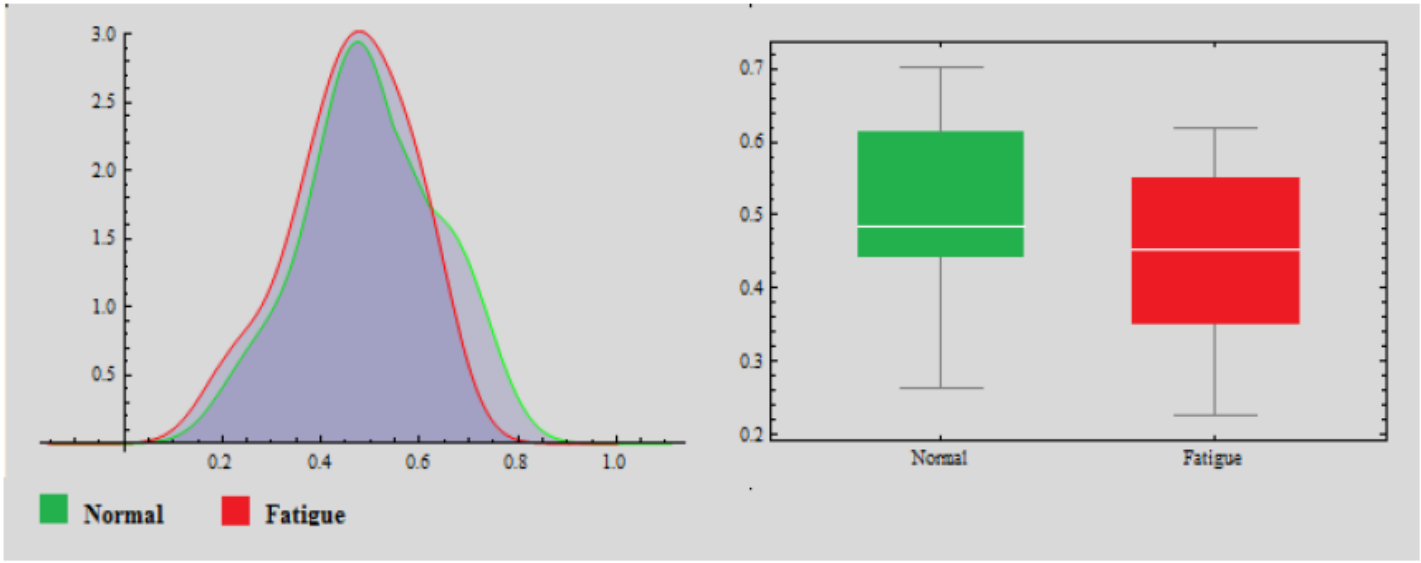
Results Stress



Results Fatigue

Mouse Acceleration

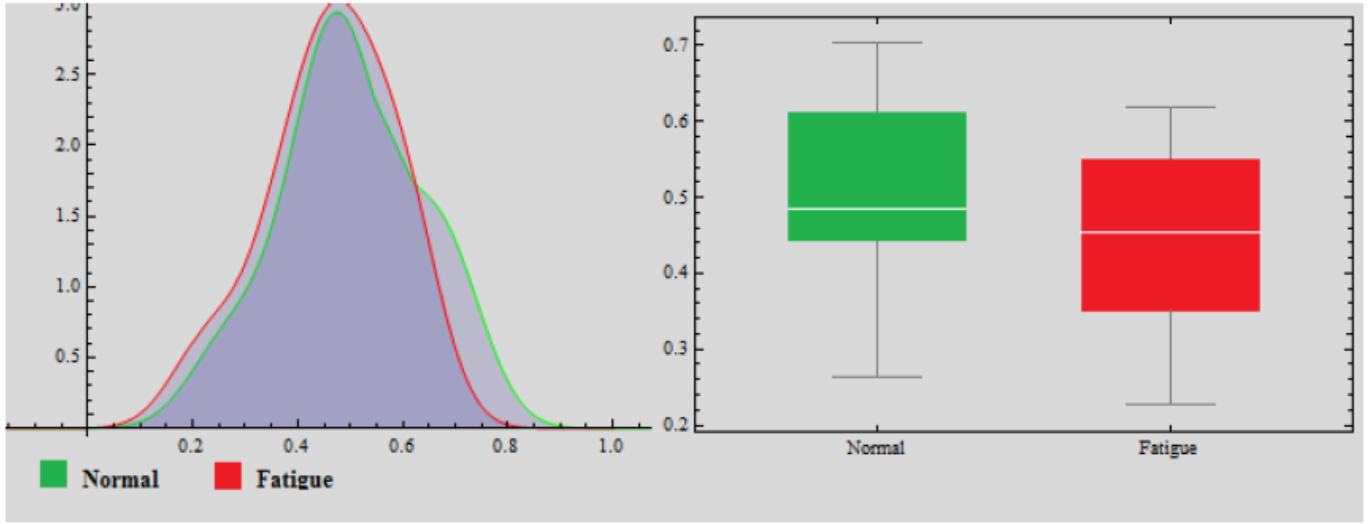
State	*Average*	*Standard D.*	*Median*	*Max*	*Min*
Normal	0.423	0.103	0.409	0.617	0.242
Fatigue	0.394	0.092	0.405	0.546	0.208



Results Fatigue

Mouse Velocity

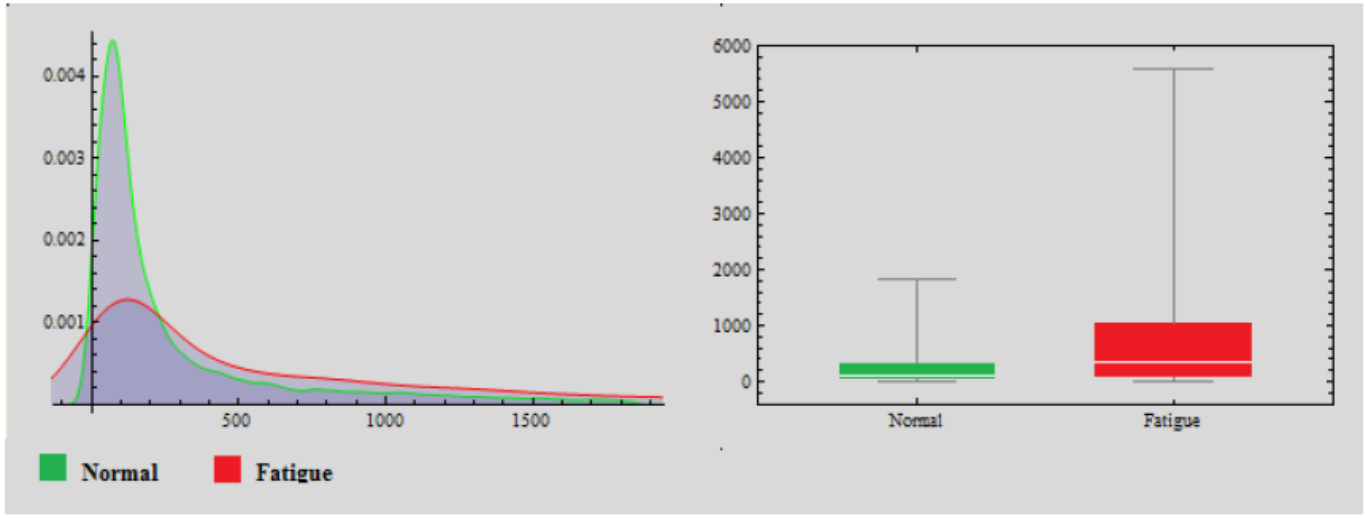
State	*Average*	*Standard D.*	*Median*	*Max*	*Min*
Normal	0.500	0.132	0.484	0.702	0.262
Fatigue	0.462	0.119	0.469	0.618	0.226



Results Fatigue

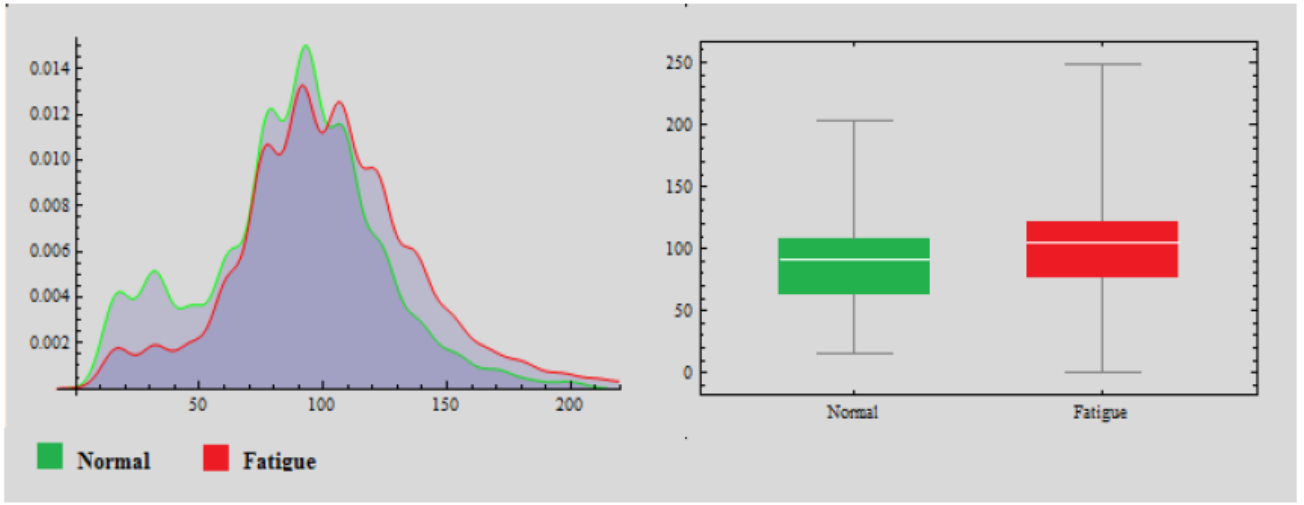
Time Between Keys

State	*Average*	*Standard D.*	*Median*	*Max*	*Min*
Normal	79.826	7.752	80.500	88.240	63.480
Fatigue	85.530	5.870	87.290	92.050	72.700



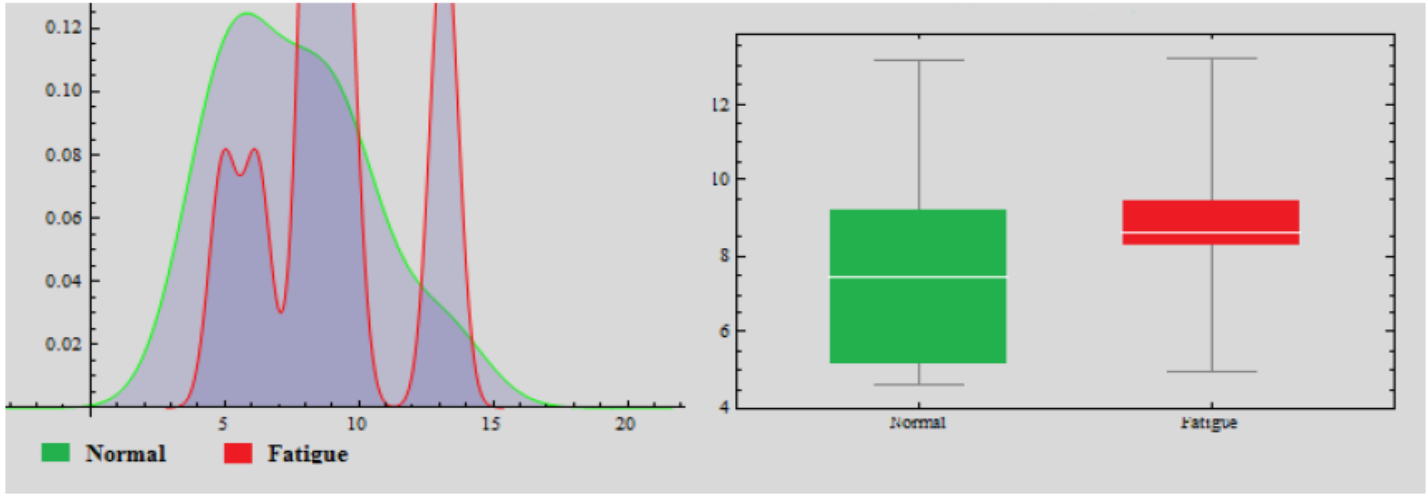
Key Down Time

State	*Average*	*Standard D.*	*Median*	*Max*	*Min*
Normal	469.193	399.321	299.726	1316.930	78.059
Fatigue	956.367	632.898	943.678	2156.400	87.892

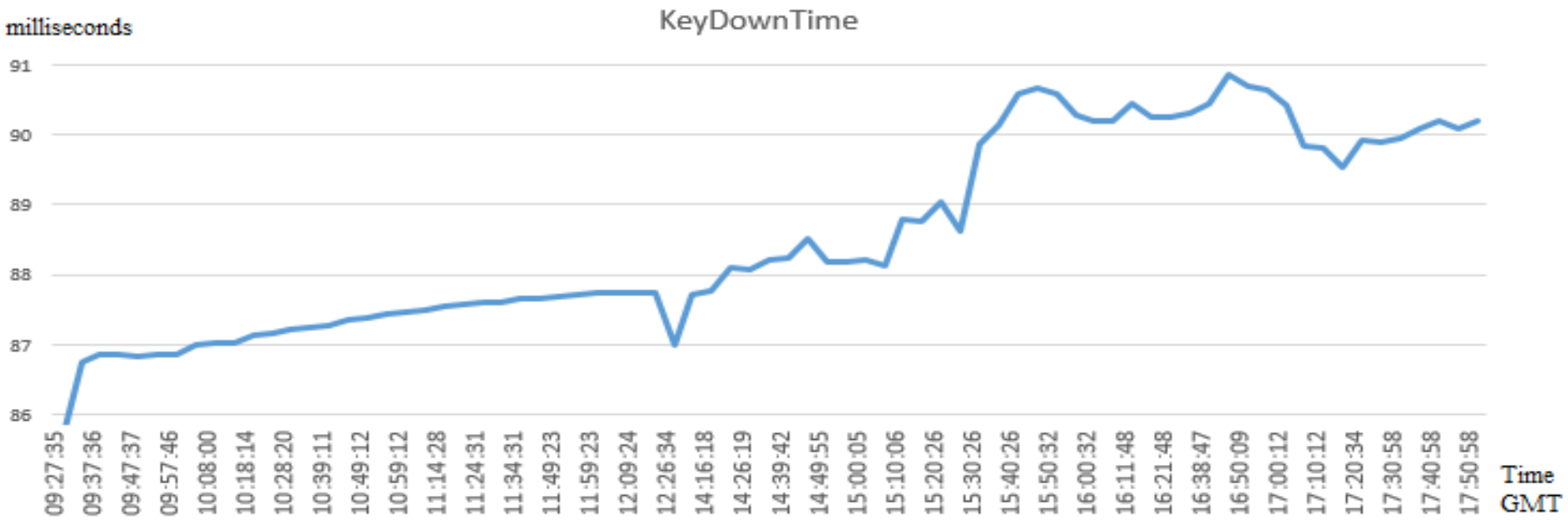


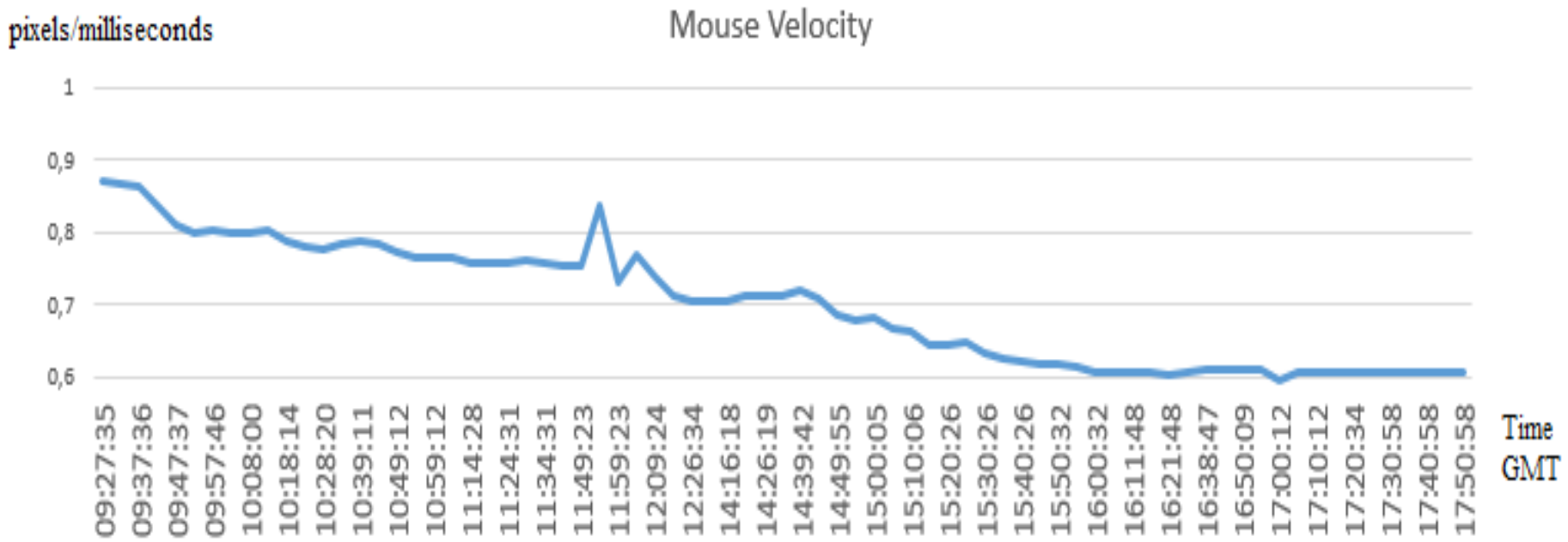
Errors per key

State	*Average*	*Standard D.*	*Median*	*Max*	*Min*
Normal	7.643	2.768	7.444	13.137	4.625
Fatigue	9.010	2.600	8.597	13.217	4.942

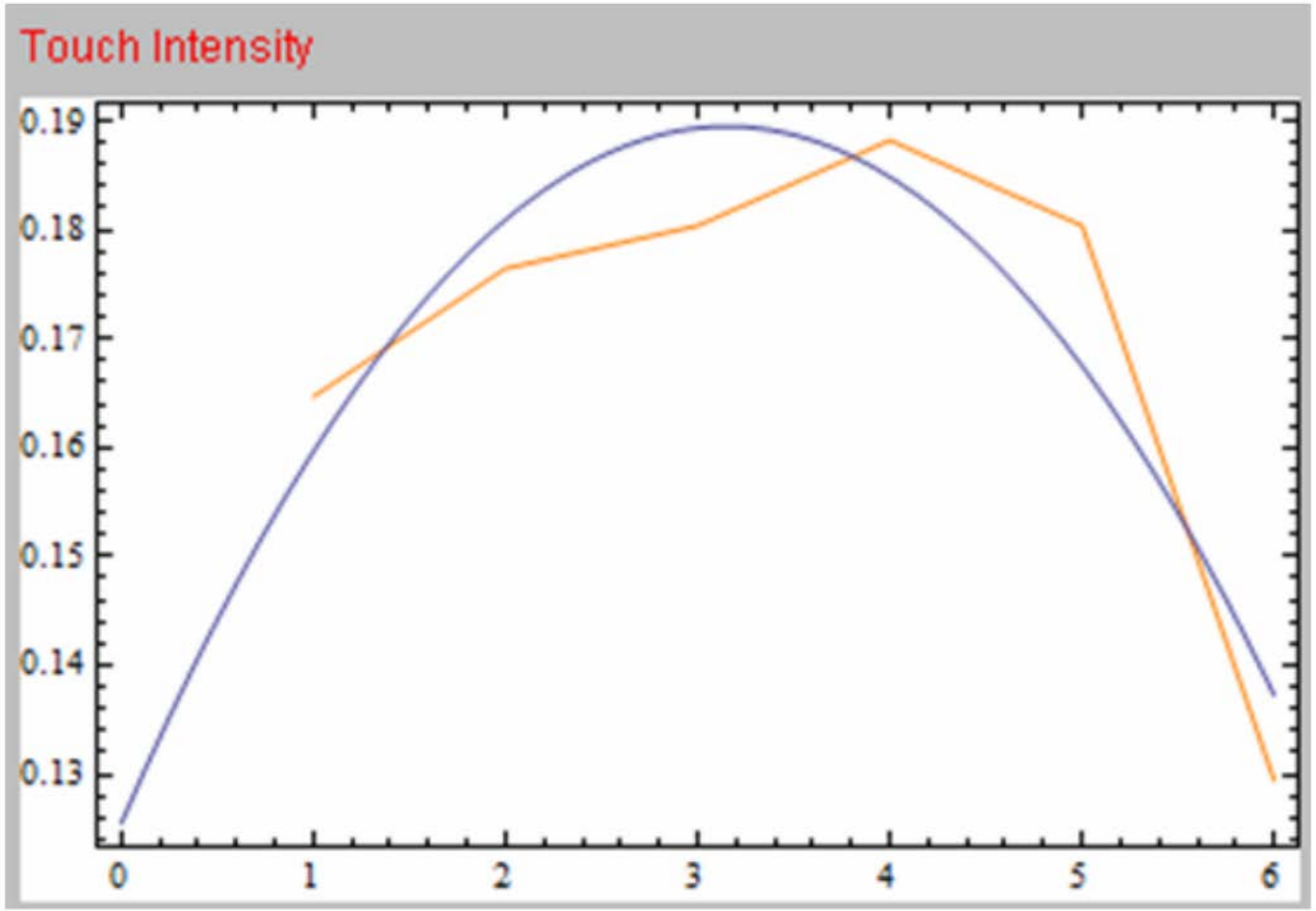


Daily Evolution



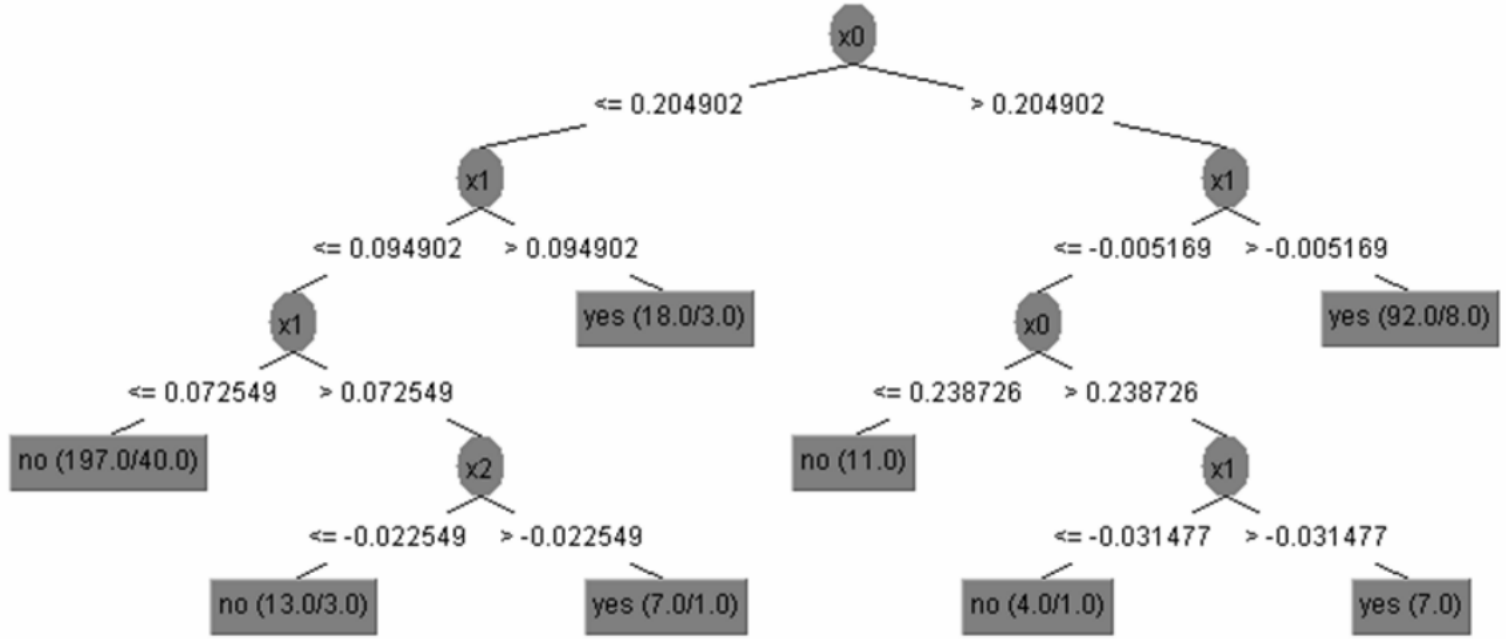

pixels/milliseconds
Mouse Velocity
1
0,9
0,8
0,7
0,6
09:27:35
09:37:36
09:47:37
09:57:46
10:08:00
10:18:14
10:28:20
10:39:11
10:49:12
10:59:12
11:14:28
11:24:31
11:34:31
11:49:23
11:59:23
12:09:24
12:26:34
14:16:18
14:26:19
14:39:42
14:49:55
15:00:05
15:10:06
15:20:26
15:30:26
15:40:26
15:50:32
16:00:32
16:11:48
16:21:48
16:38:47
16:50:09
17:00:12
17:10:12
17:20:34
17:30:58
17:40:58
17:50:58
Time
GMT

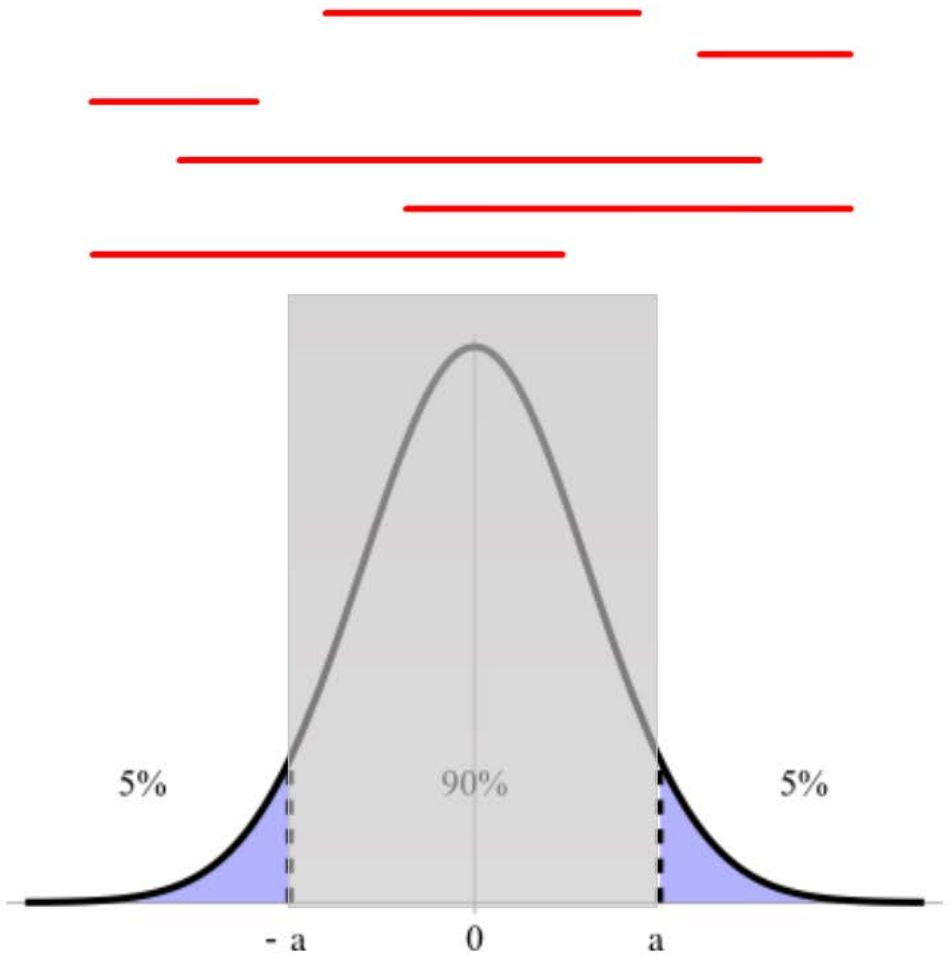
Results



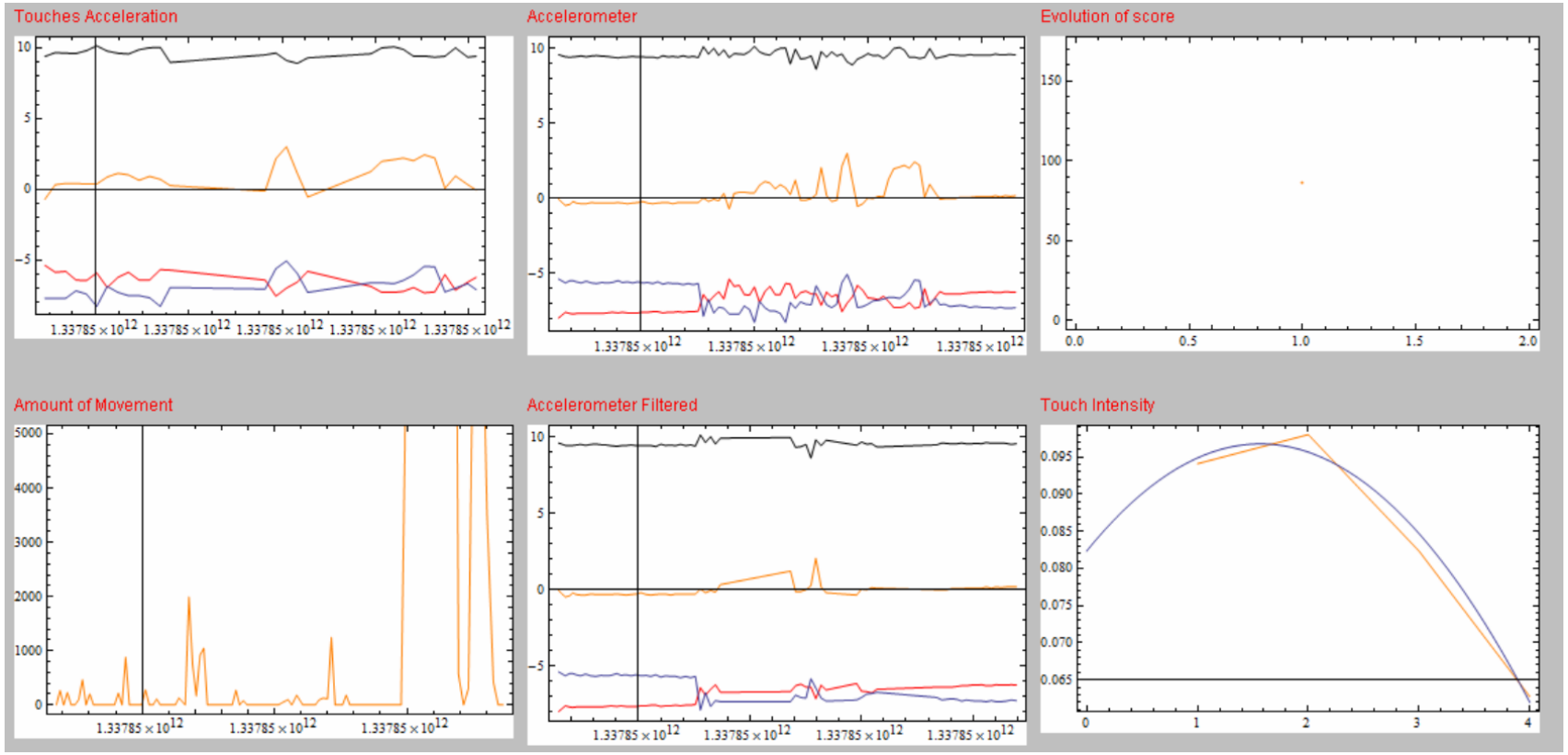
Results

$$ax^2 + bx + c = 0$$

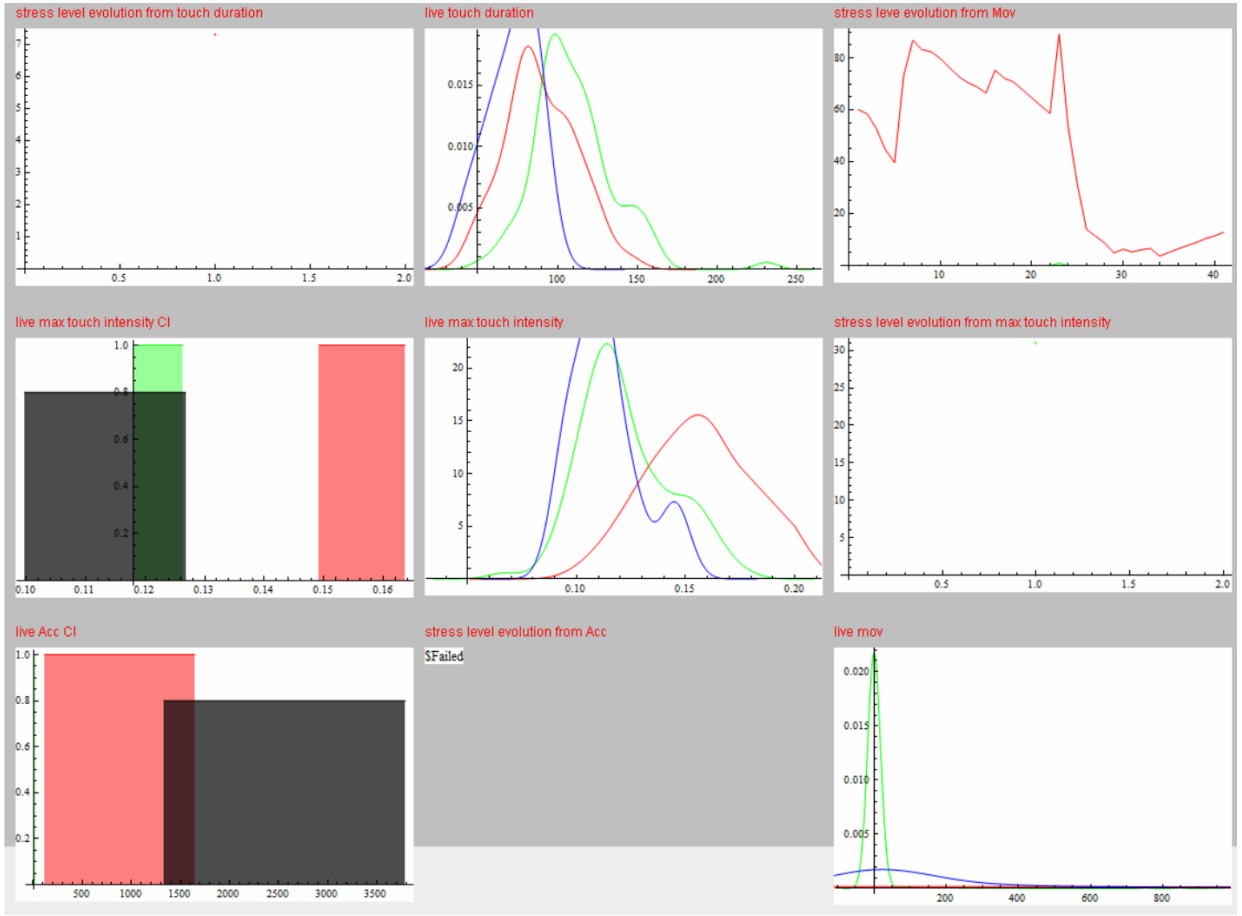



5%
90%
5%
- a
0
a

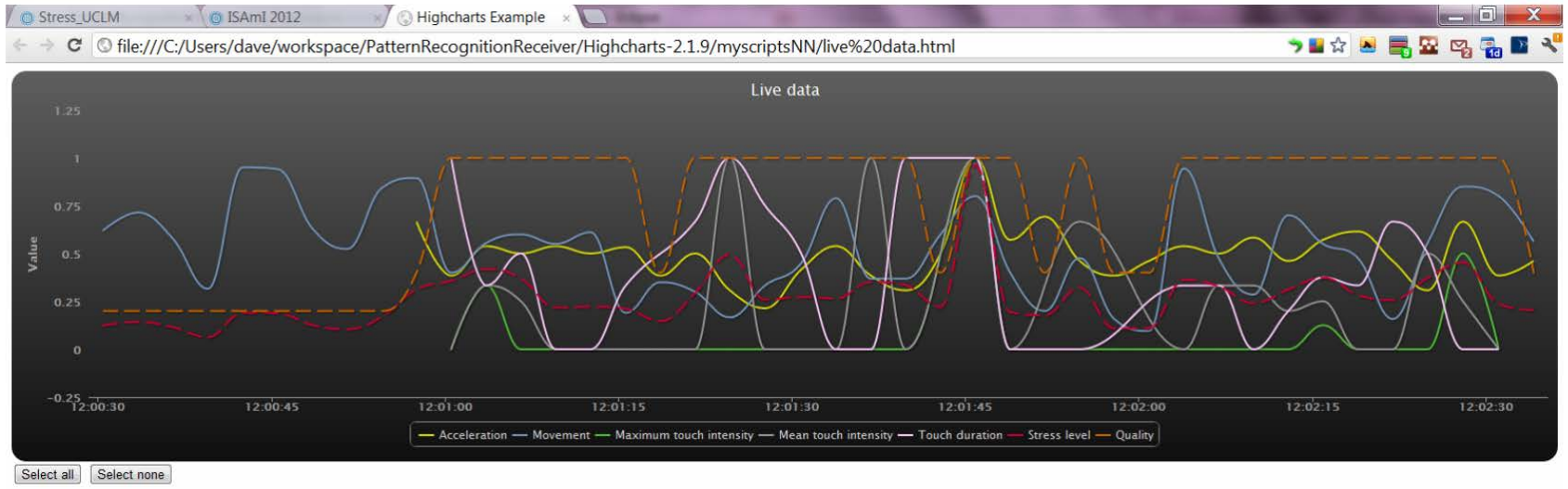
Results


Touches Acceleration
Accelerometer
Evolution of score
Amount of Movement
Accelerometer Filtered
Touch Intensity

Results


stress level evolution from touch duration
live touch duration
stress leve evolution from Mov
live max touch intensity CI
live max touch intensity
stress level evolution from max touch intensity
live Acc CI
stress level evolution from Acc
$Failed
live mov

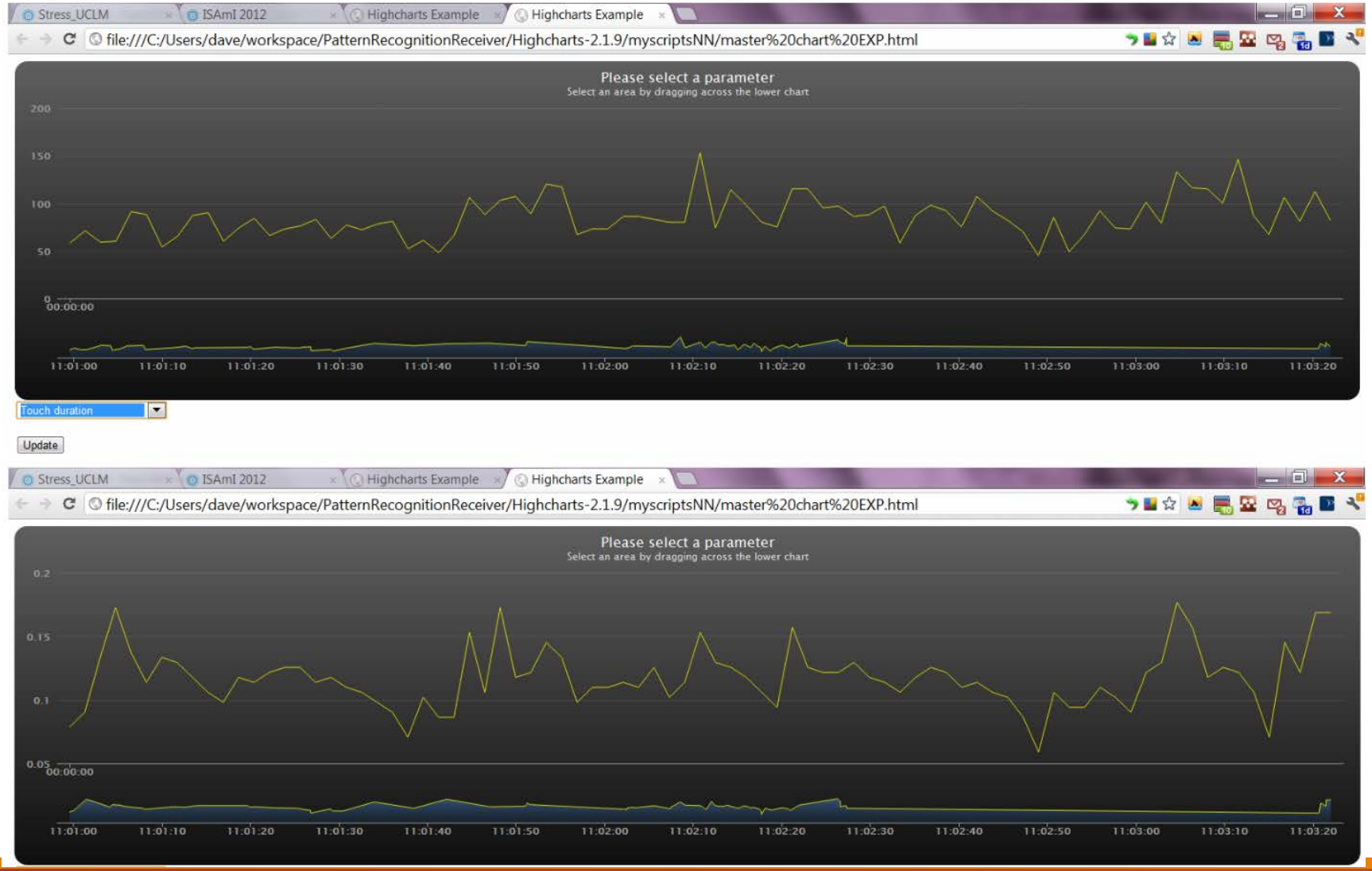
Experimental Control



Results

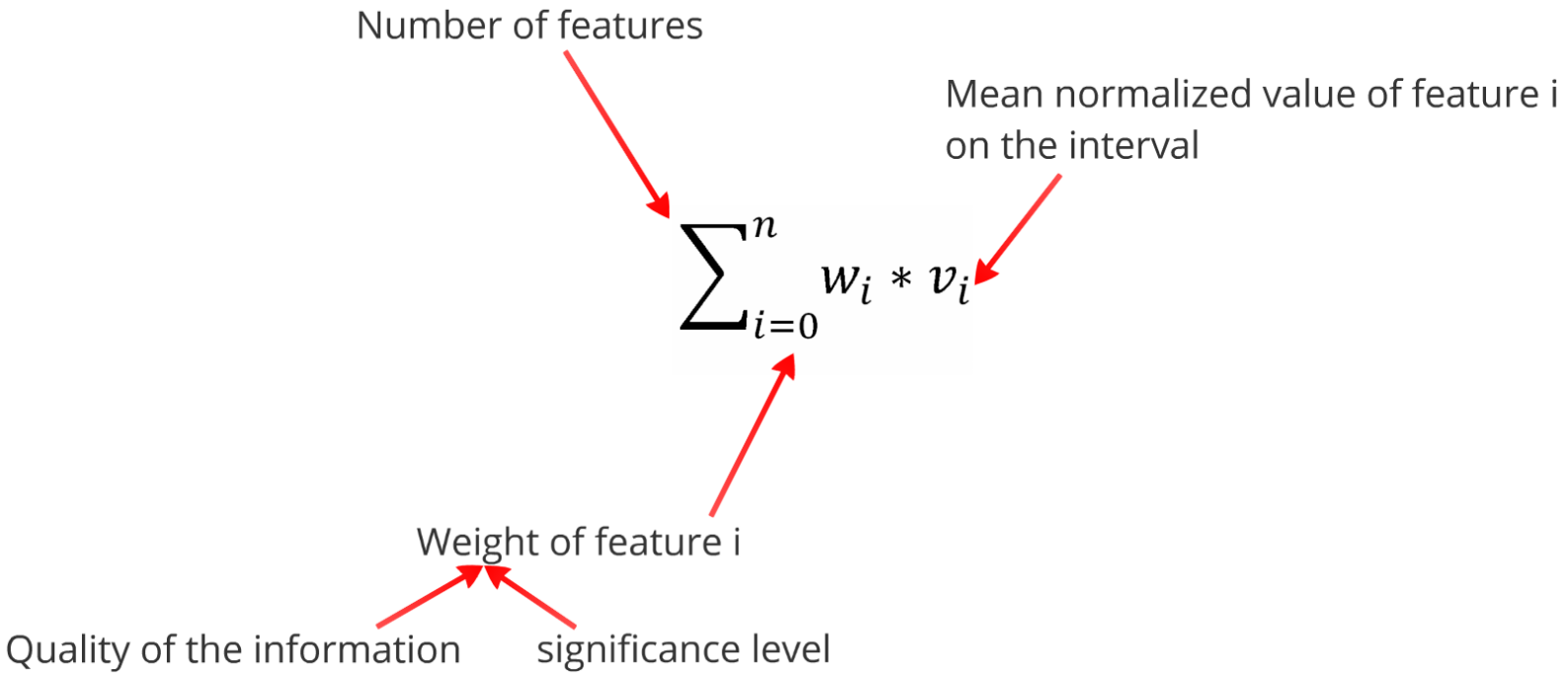

Stress_UCLM
ISAmI 2012
Highcharts Example
Highcharts Example
file:///C:/Users/dave/workspace/PatternRecognitionReceiver/Highcharts-2.1.9/myscriptsNN/master%20chart%20EXP.html
Please select a parameter
Select an area by dragging across the lower chart
150k
100k
50k
0k
-50k
00:00:00
00:00:01
11:00:30
11:00:45
11:01:00
11:01:15
11:01:30
11:01:45
11:02:00
11:02:15
11:02:30
11:02:45
11:03:00
11:03:15
11:03:30
11:03:45
11:04:00
11:04:15
11:04:30
Amount of Movement
Update
Stress_UCLM
ISAmI 2012
Highcharts Example
Highcharts Example
file:///C:/Users/dave/workspace/PatternRecognitionReceiver/Highcharts-2.1.9/myscriptsNN/master%20chart%20EXP.html
Please select a parameter
Select an area by dragging across the lower chart
20
15
10
5
0
11:01:00
11:01:10
11:01:20
11:01:30
11:01:40
11:01:50
11:02:00
11:02:10
11:02:20
11:02:30
11:02:40
11:02:50
11:03:00
11:03:10
11:03:20
11:03:30
11:03:40

Results


Stress_UCLM
ISAmI 2012
Highcharts Example
Highcharts Example
file:///C:/Users/dave/workspace/PatternRecognitionReceiver/Highcharts-2.1.9/myscriptsNN/master%20chart%20EXP.html
Please select a parameter
Select an area by dragging across the lower chart
200
150
100
50
0
00:00:00
11:01:00
11:01:10
11:01:20
11:01:30
11:01:40
11:01:50
11:02:00
11:02:10
11:02:20
11:02:30
11:02:40
11:02:50
11:03:00
11:03:10
11:03:20
Touch duration
Update
Stress_UCLM
ISAmI 2012
Highcharts Example
Highcharts Example
file:///C:/Users/dave/workspace/PatternRecognitionReceiver/Highcharts-2.1.9/myscriptsNN/master%20chart%20EXP.html
Please select a parameter
Select an area by dragging across the lower chart
0.2
0.15
0.1
0.05
00:00:00
11:01:00
11:01:10
11:01:20
11:01:30
11:01:40
11:01:50
11:02:00
11:02:10
11:02:20
11:02:30
11:02:40
11:02:50
11:03:00
11:03:10
11:03:20

Results

Manipulations of the independent variable so that its effects on the dependent variable may be quantitatively or qualitatively analyzed



Experimental Control

At least one treatment or intervention condition

An intervention that will benefit the participant in some way

Depending on the domain of application…

Case-studies & fields of application

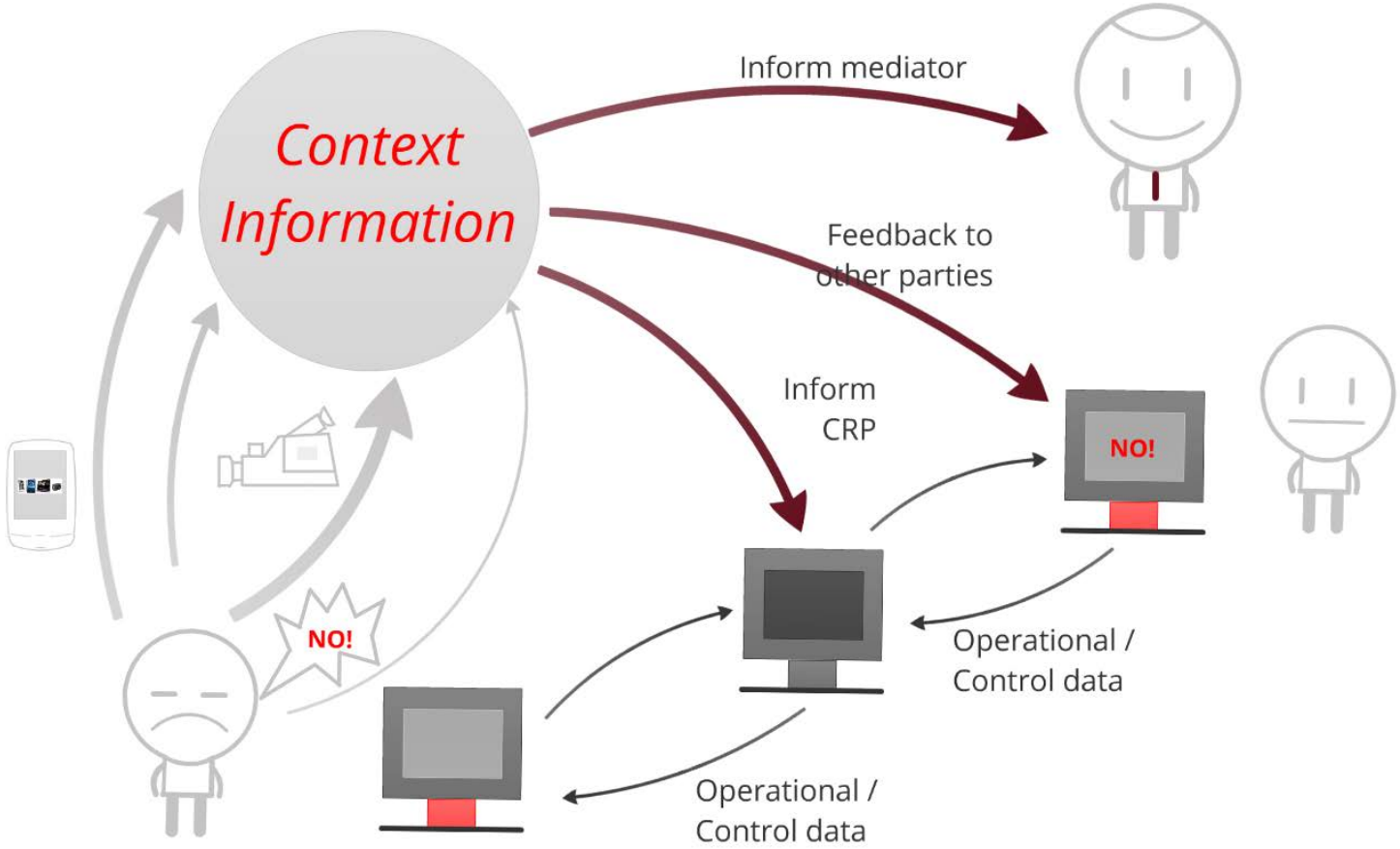
LEGAL FIELD

EDUCATION

FATIGUE MANAGEMENT

FIELDS OF APPLICATION

Online Dispute Resolution



E-learning

Fatigue Management

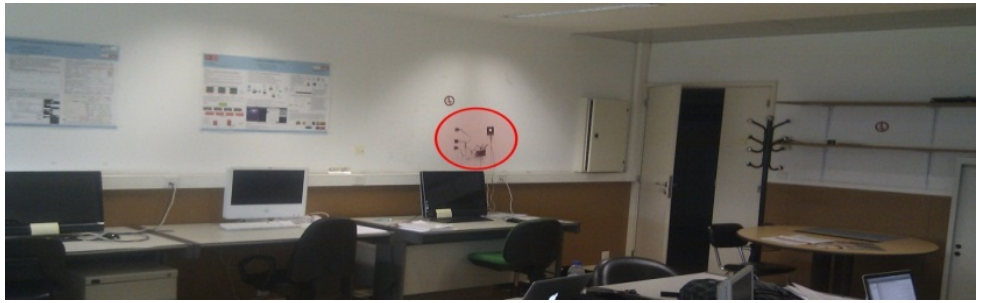


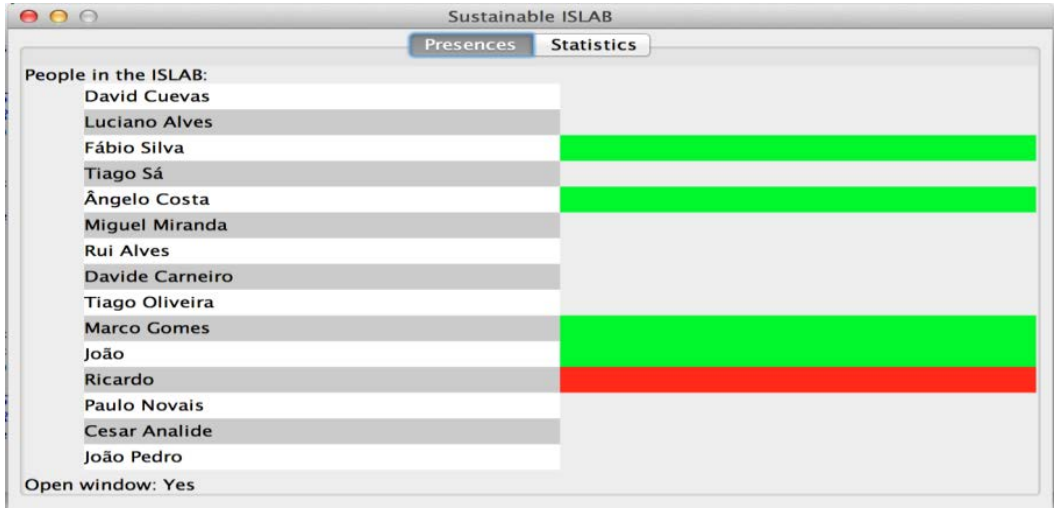

Fields of Application

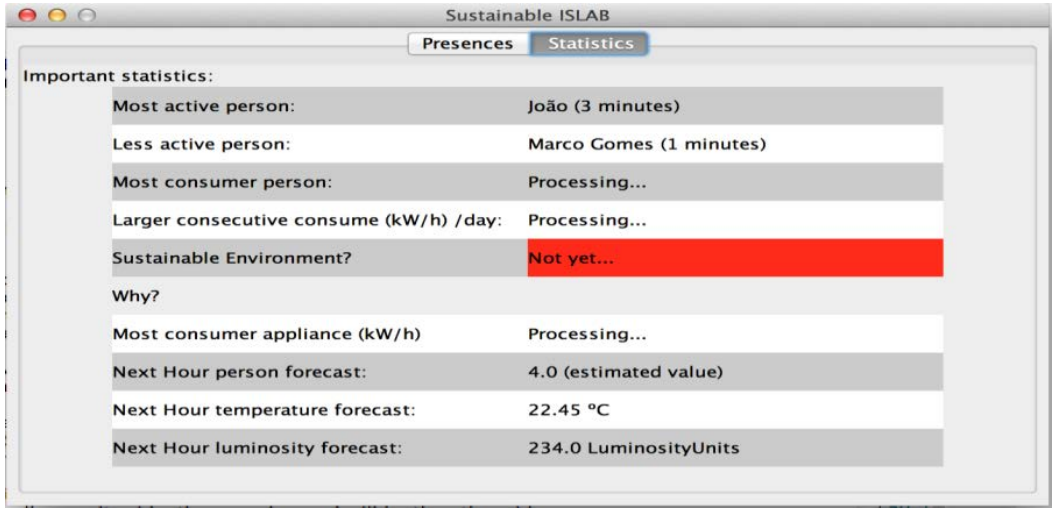
ISLab

Energetic Sustainability

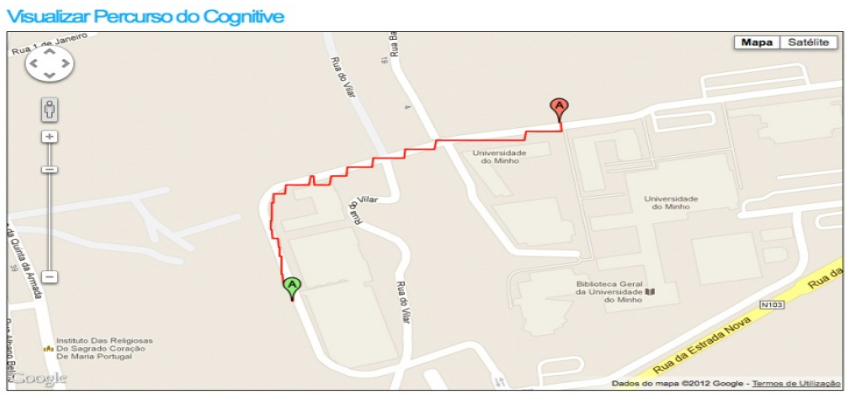
Intelligent systems for energetic sustainability







Orientation System



Augmented reality guiding system

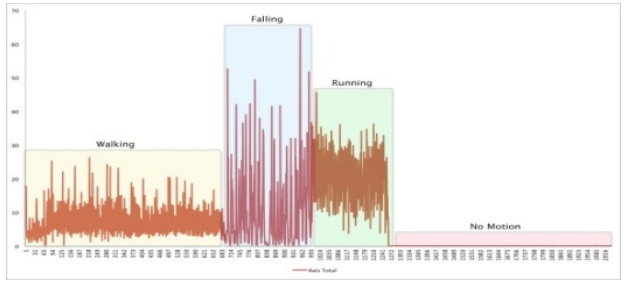
User and caregiver oriented

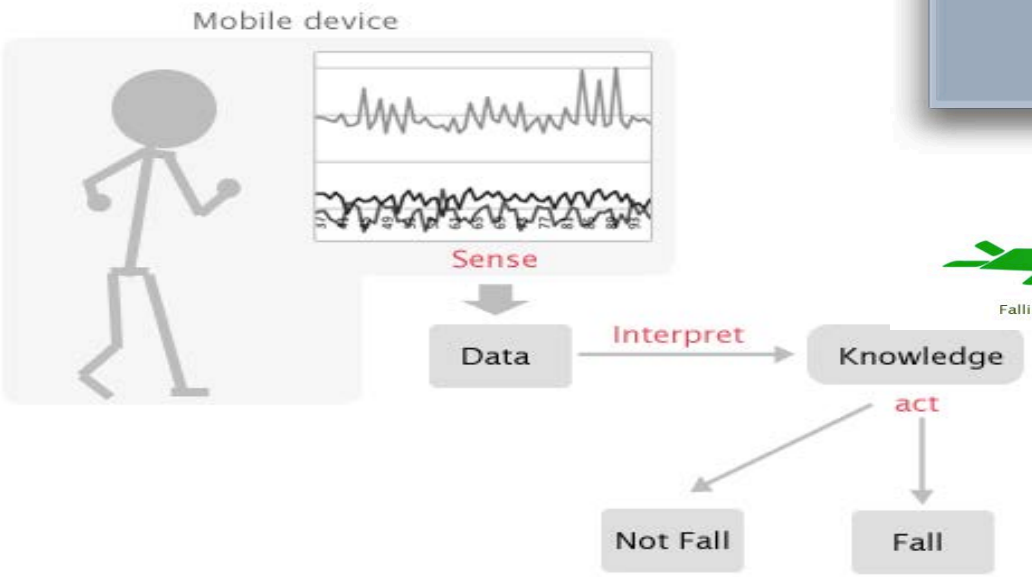
Multi-user tracking and profiling system

Location and path provider

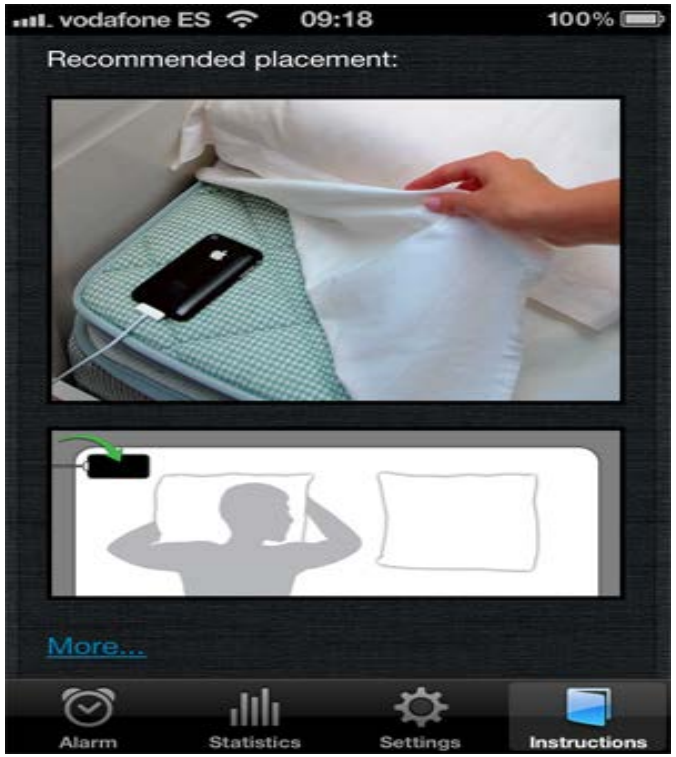
Analysis of Movement patterns

Mobile Intelligent Sensoring System





Sleep Monitoring

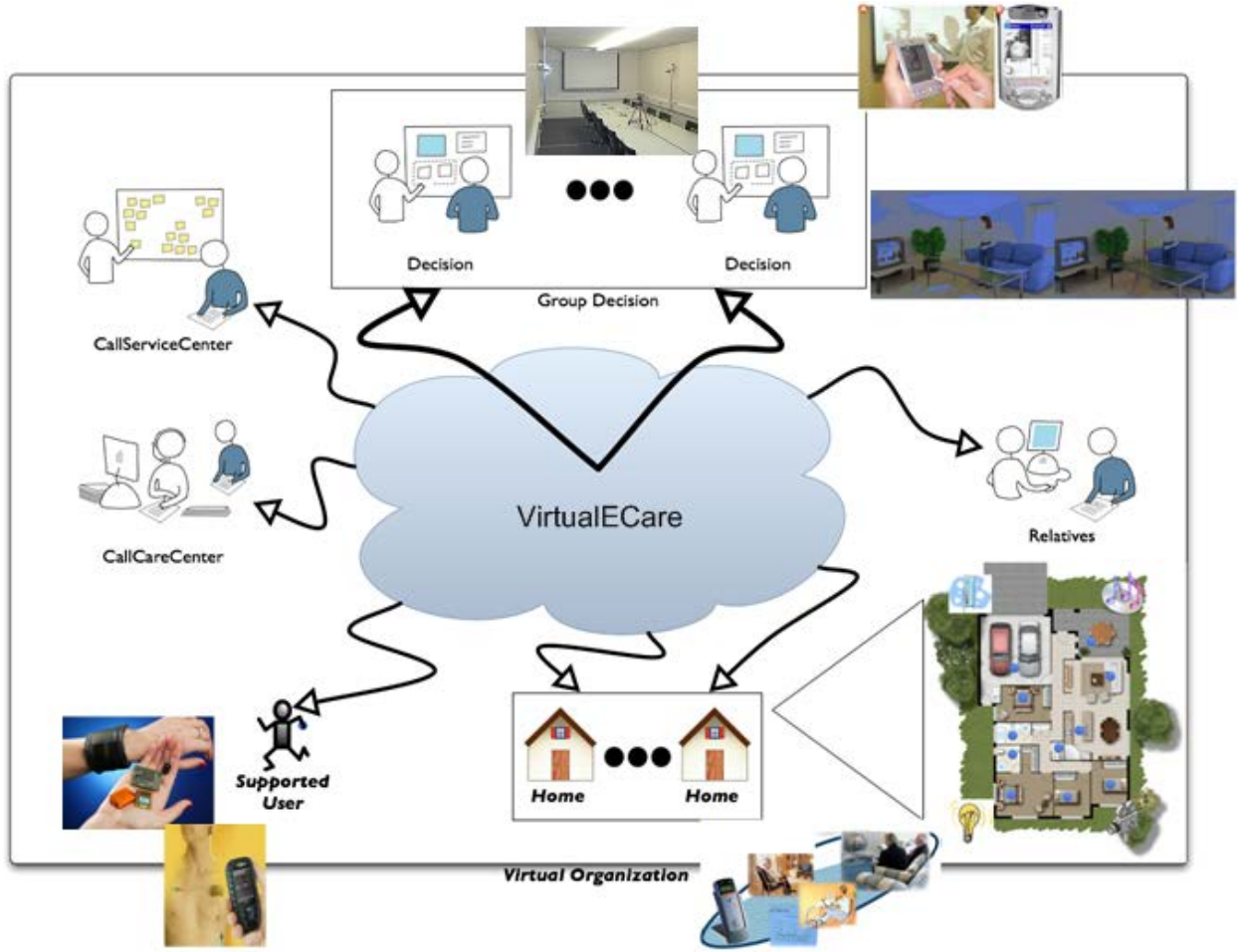


Ambient Assisted Living

VirtualECare Project

IGenda Project

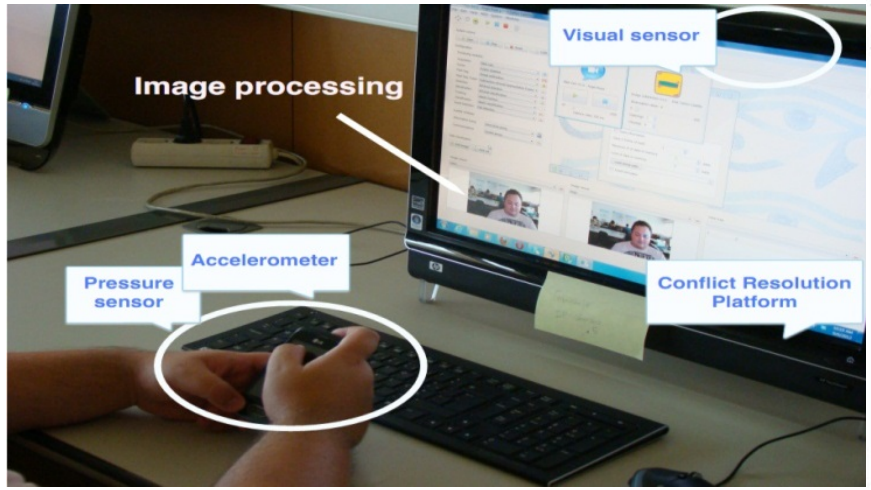
NordiGenda Project



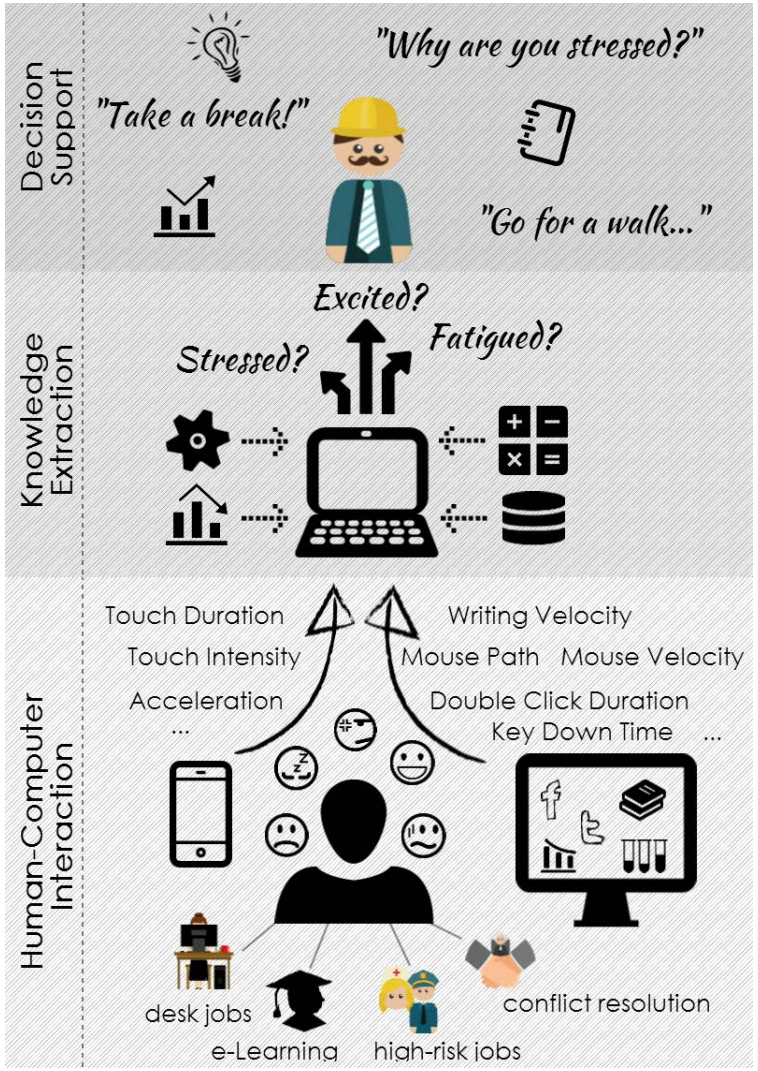
TIARAC Project

Conflict Handling Style

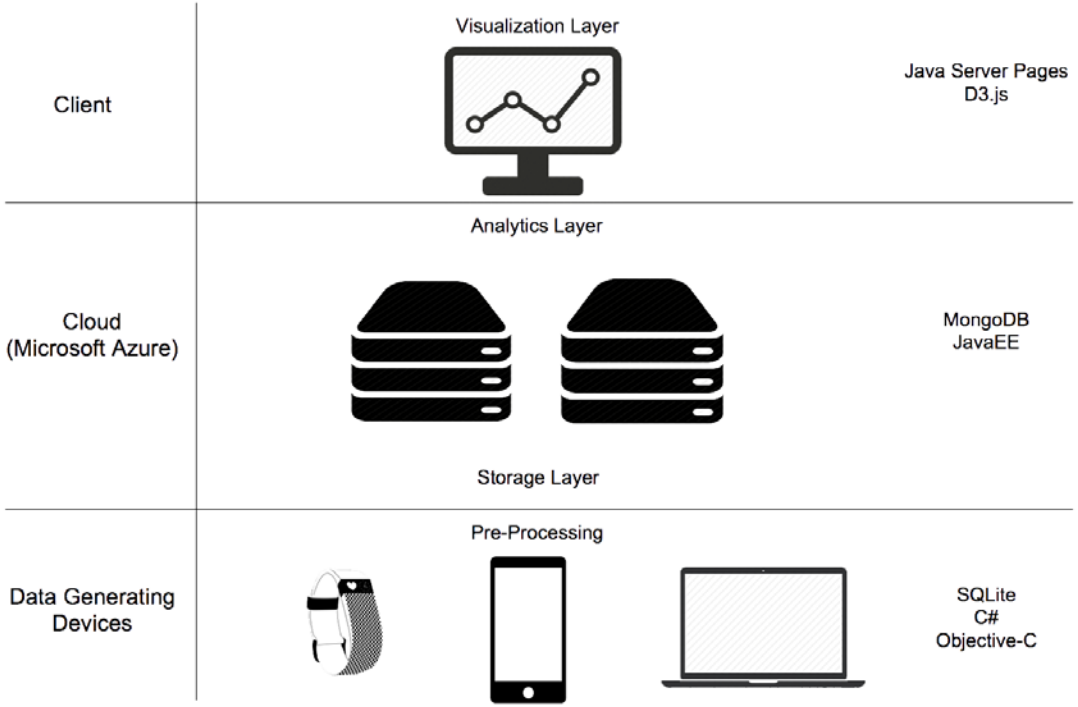
Behavioral and Context Analysis in an Online Dispute Resolution Environment



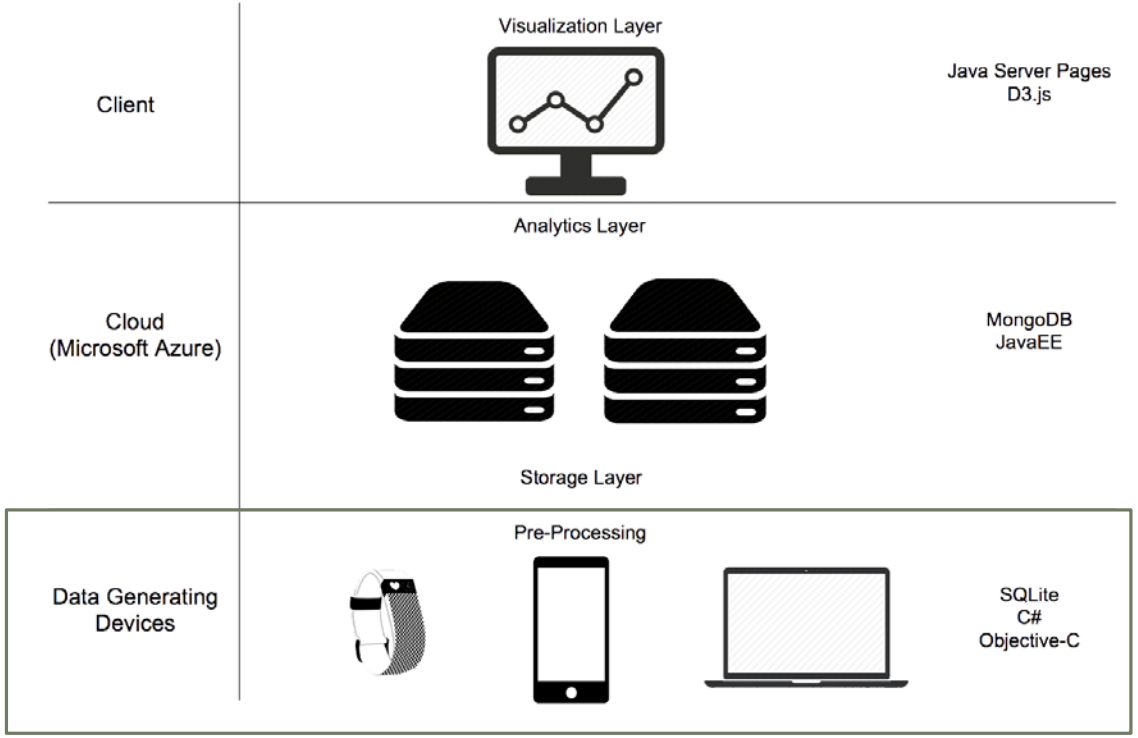
CAMCoF Project



Architecture



Data Generating

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MOV,635806021652898906,461,217
MOV,635806021652978914,461,216
MOV,635806021653058922,461,215
MOV,635806021653138930,461,214
MOV,635806021653218938,461,213
MOV,635806021653298946,461,211
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MOV,635806021654339050,461,209
MOV,635806021654819098,461,208
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MUL,635806021657139330,461,208
APP,635806021659875765, Microsoft Access - M2_TESTE02_Alunos (1)
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KU,635806021691702786,CFXOM82
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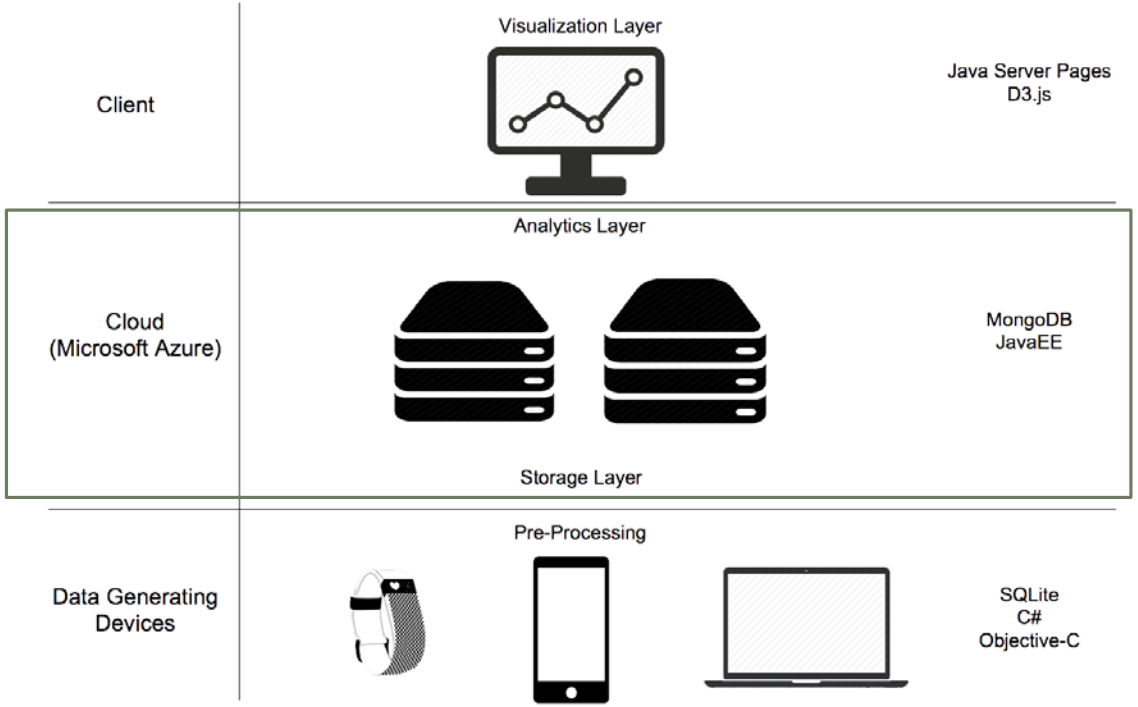
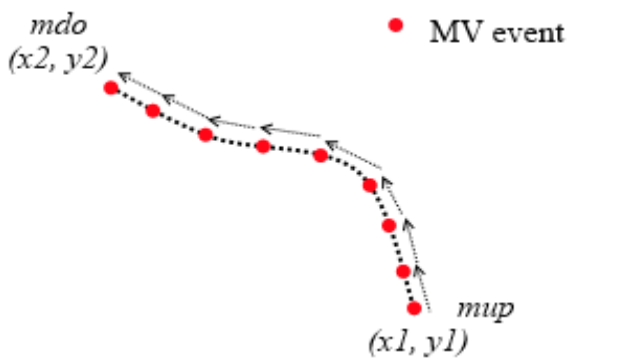
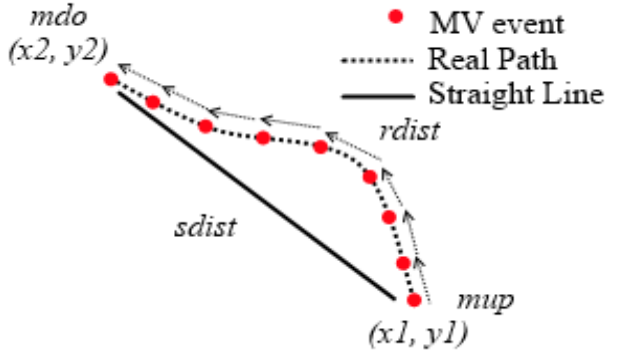
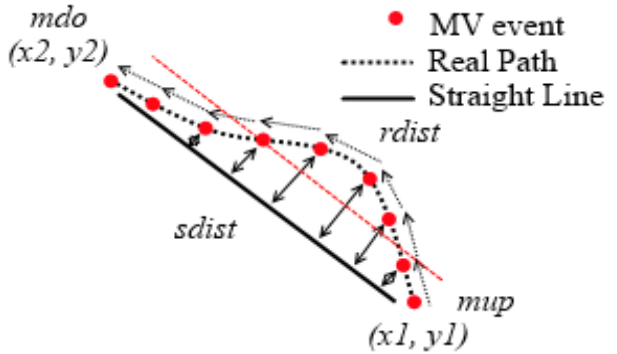
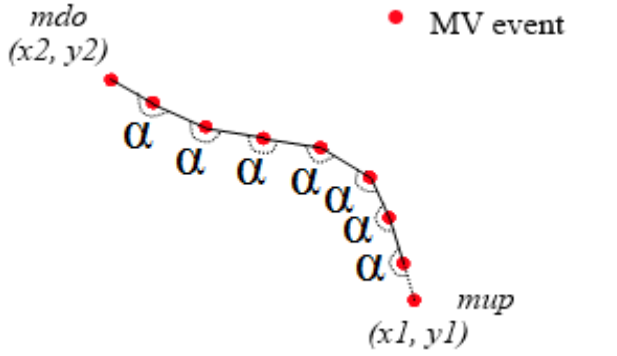
Processing


Visualization Layer
Client
Java Server Pages
D3.js
Analytics Layer
Cloud
(Microsoft Azure)
MongoDB
JavaEE
Storage Layer
Pre-Processing
Data Generating
Devices
SQLite
C#
Objective-C

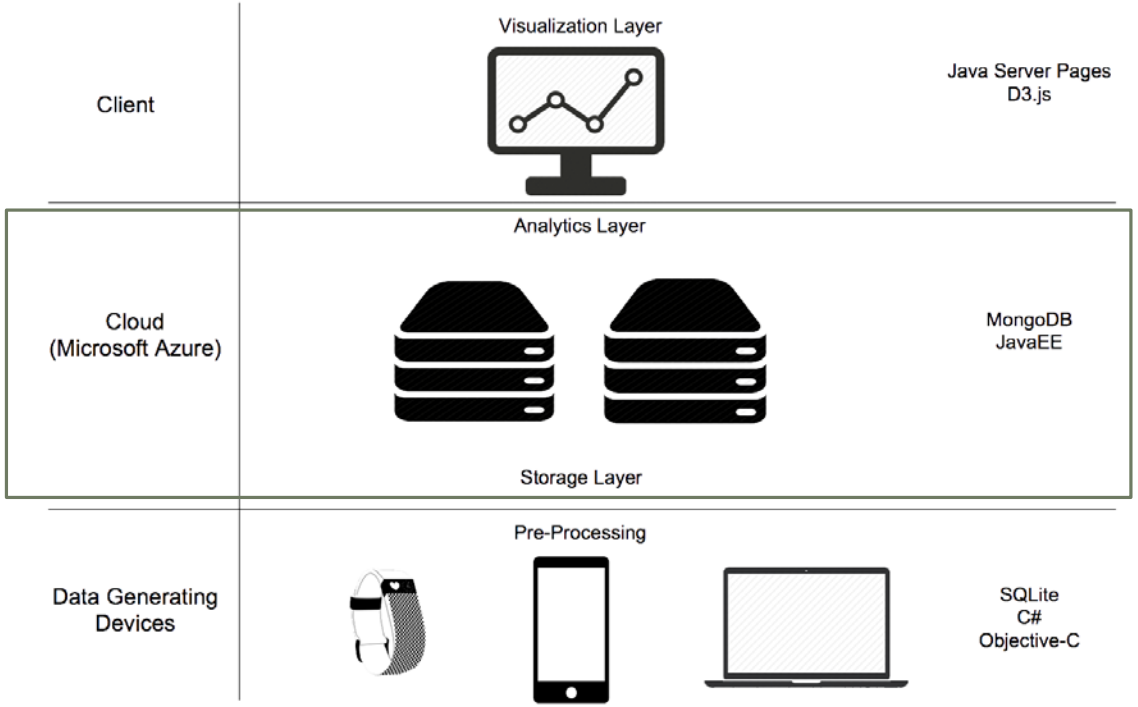

mdo
(x2, y2)
MV event
mup
(x1, y1)

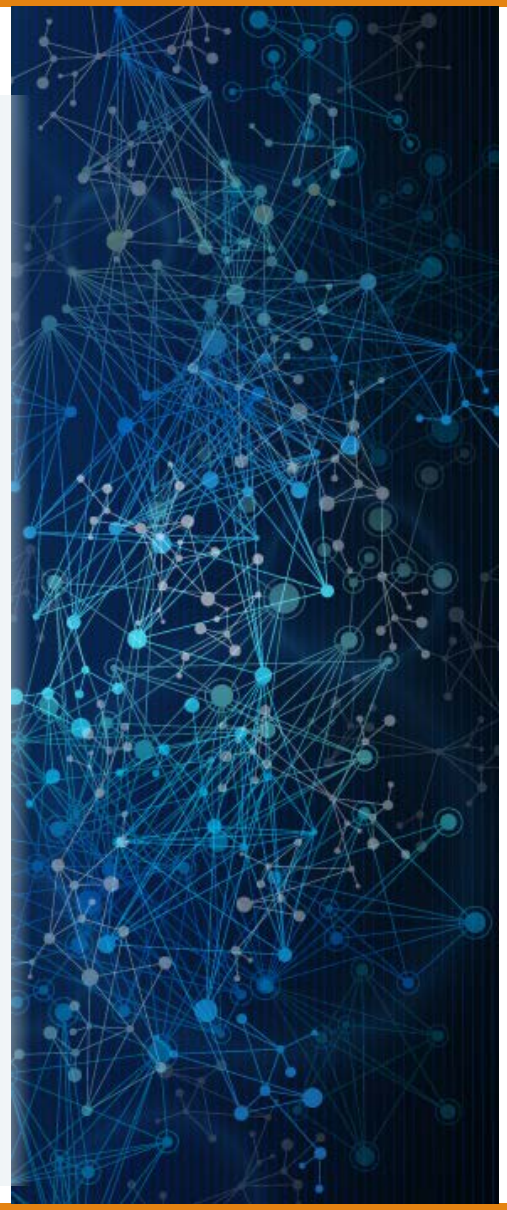

mdo
(x2, y2)
MV event
Real Path
Straight Line
rdist
sdist
mup
(x1, y1)


mdo
(x2, y2)
MV event
Real Path
Straight Line
rdist
sdist
mup
(x1, y1)

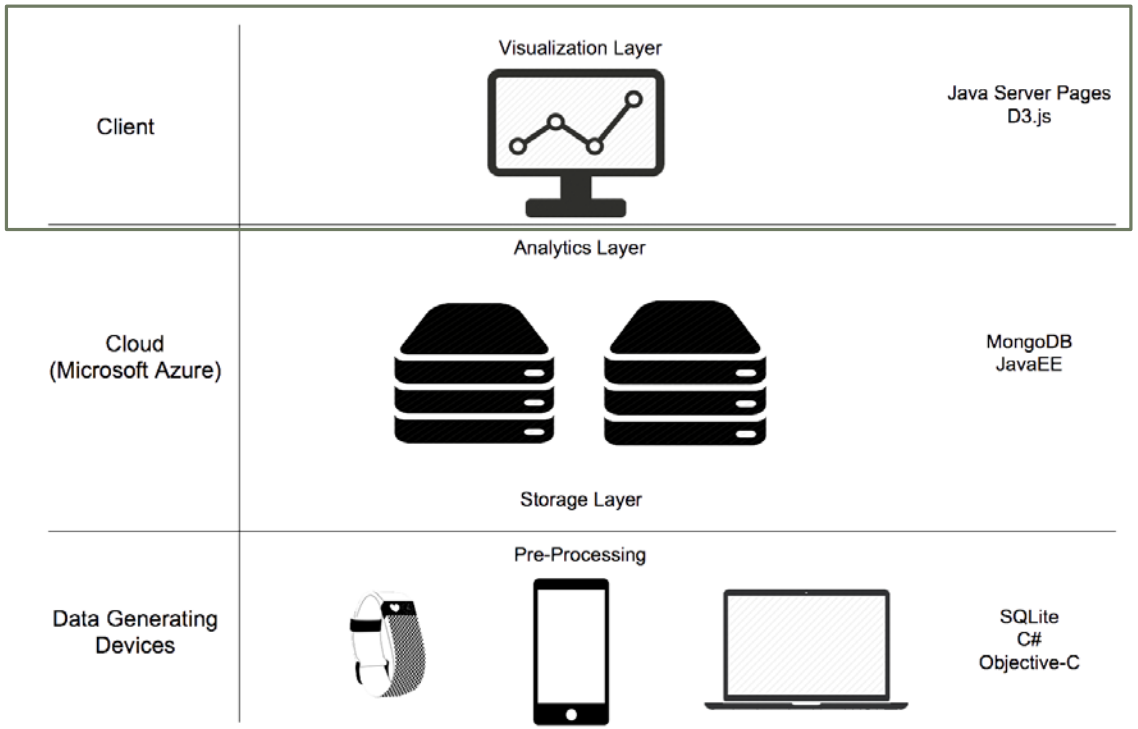

mdo
(x2, y2)
MV event
α
mup
(x1, y1)

Storage


Visualization Layer
Client
Java Server Pages
D3.js
Analytics Layer
Cloud
(Microsoft Azure)
MongoDB
JavaEE
Storage Layer
Pre-Processing
Data Generating
Devices
SQLite
C#
Objective-C



Visualization

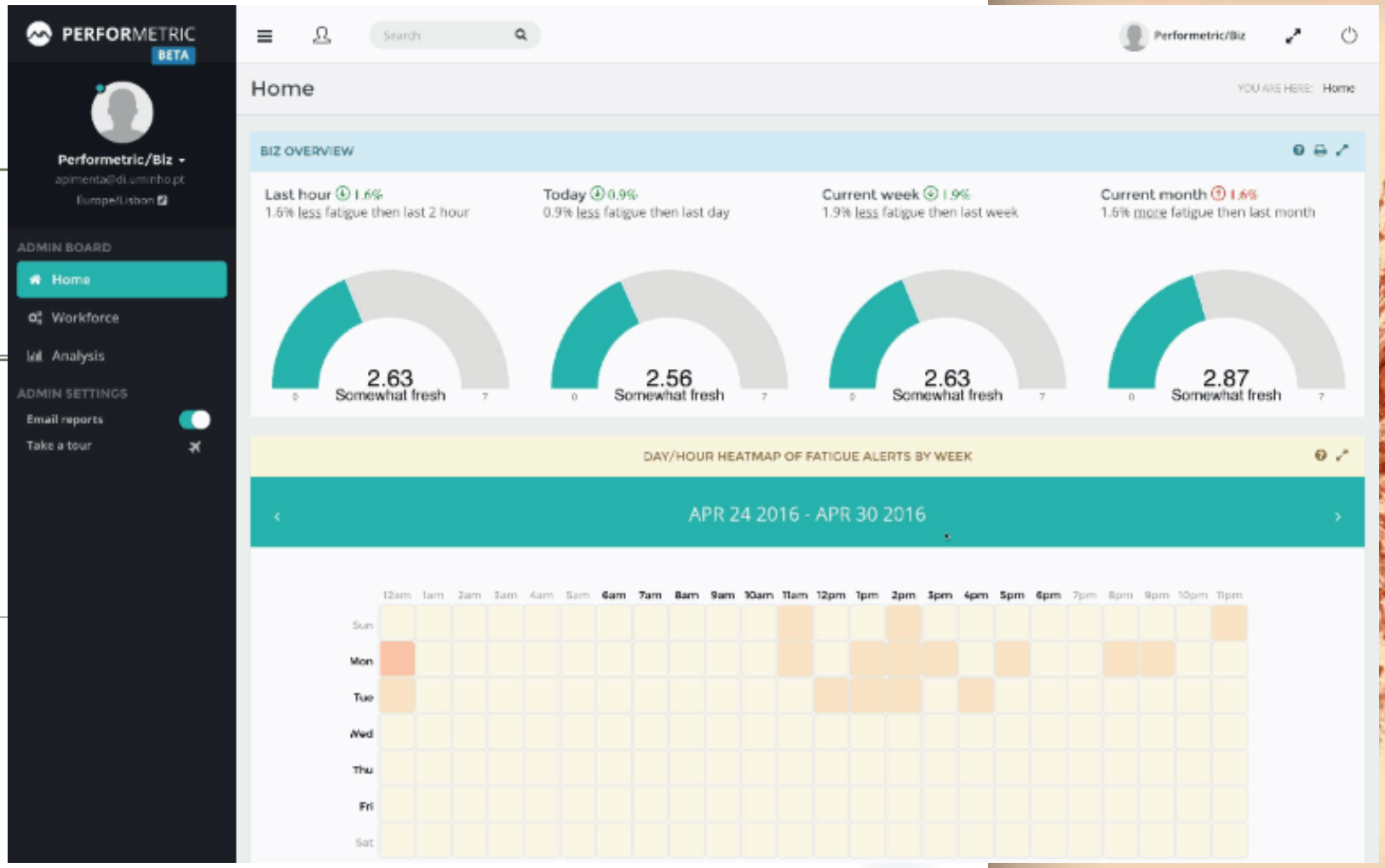


Big Data & HCI

Client

Cloud (Microsoft Azure)

Data Generating Devices



Recent Publications

A neural network to classify fatigue from human-computer interaction

Authors: André Pimenta — CCTC/Department of Informatics, University of Minho, Campus of Gualtar, 4710 - 057 Braga, Portugal
Davide Carneiro — CCTC/Department of Informatics, University of Minho, Campus of Gualtar, 4710 - 057 Braga, Portugal
José Neves — CCTC/Department of Informatics, University of Minho, Campus of Gualtar, 4710 - 057 Braga, Portugal
Paulo Novais — CCTC/Department of Informatics, University of Minho, Campus of Gualtar, 4710 - 057 Braga, Portugal

Published in:
· Journal
Neurocomputing archive
Volume 172 Issue C, January 2016
Pages 413-426
Elsevier Science Publishers B. V. Amsterdam, The Netherlands, The Netherlands
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2016 Article

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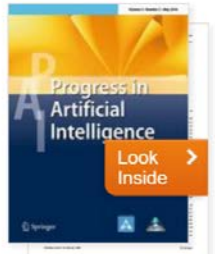
Regular Paper
Progress in Artificial Intelligence
pp 1-6

First online: 16 February 2016

The role of non-intrusive approaches in the development of people-aware systems

Paulo Novais , Davide Carneiro



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ELSEVIER

Future Generation Computer Systems

Available online 26 May 2016

In Press, Corrected Proof — Note to users

Quantifying the effects of external factors on individual performance

Davide Carneiro[a, b], Paulo Novais[b]

Show more

Chapter
Hybrid Artificial Intelligent Systems
Volume 9121 of the series Lecture Notes in Computer Science pp 345-356

Date: 29 May 2015

Using Mouse Dynamics to Assess Stress During Online Exams

Davide Carneiro , Paulo Novais, José Miguel Pêgo, Nuno Sousa, José Neves

Conclusions

- Just like Human-Human interaction, Human-computer Interaction is richer in information that what we can see at first sight
- This information can be used to develop more intelligent and sensitive interfaces
- This is in-line with one of the main objectives of Human-computer Interaction
  - To put the user in the middle

Conclusions

- The work carried out in the last years shows that:
  - Processes such as fatigue and stress have an effect on the interaction patterns
  - This effect can be measured in a non-invasive and continuous way
  - Such information can be used to improve Human-computer Interaction

"Siri and virtual assistants like her will soon change everything. I. Mean. Everything."
Mike Elgan, in Computerworld, Sep 21, 2015

"The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country."

Klaus Schwab, Founder and Executive Chairman, World Economic Forum

"Looking to the future, the next big step will be for the very concept of the 'device' to fade away. Over time, the computer itself — whatever its form factor — will be an intelligent assistant helping you through your day. We will move from mobile-first to an AI-first world"

Sundar Pichai, Google CEO April 28 2016

The Role of Non-Intrusive Approaches in the Development of People-Aware Systems

PAULO NOVAIS

Intelligent Systems Lab/ALGORITMI CENTER

Departamento de Informática

Universidade do Minho – Portugal – pjon@di.uminho.pt