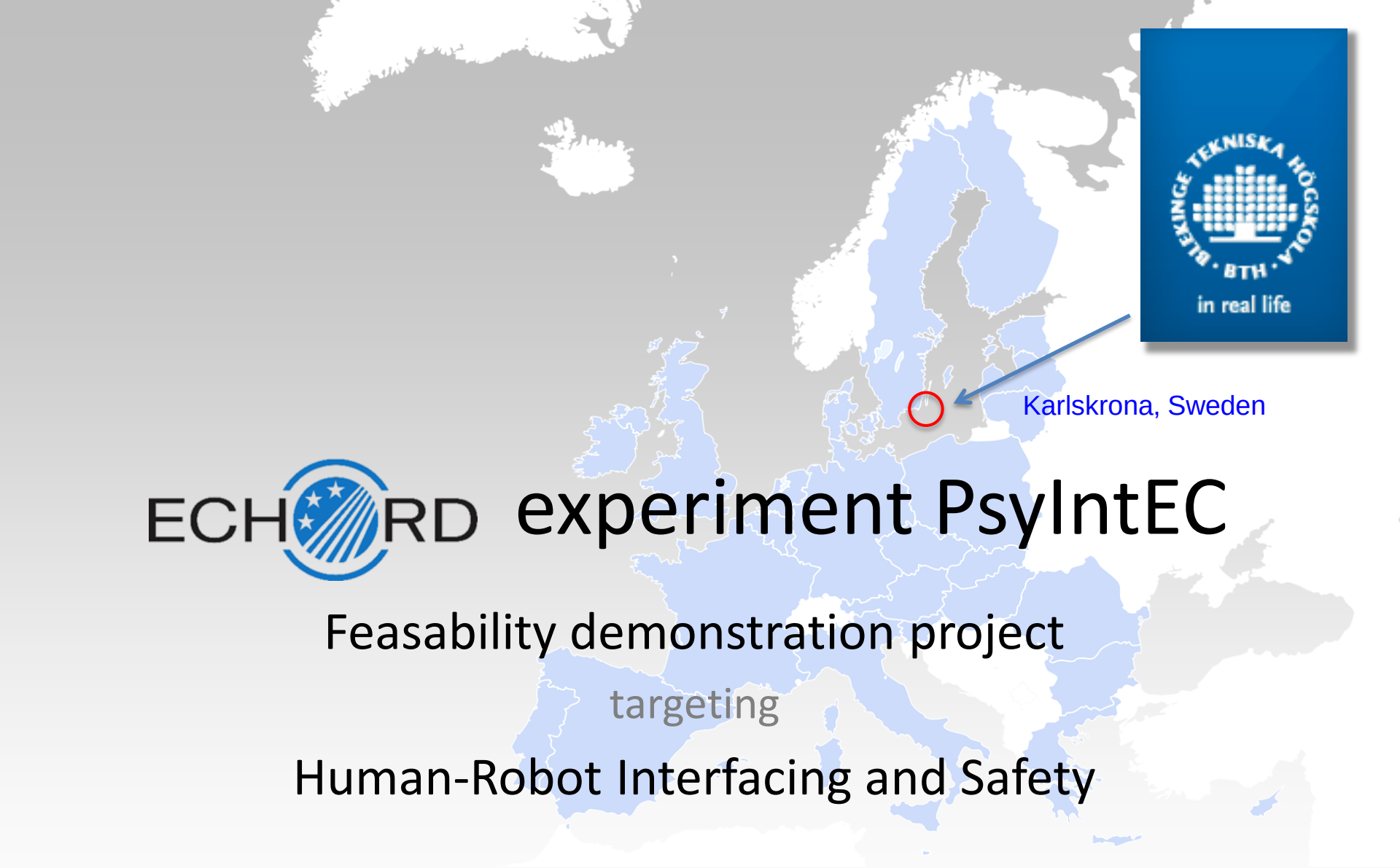


ECHORD experiment PsyIntEC

Feasability demonstration project

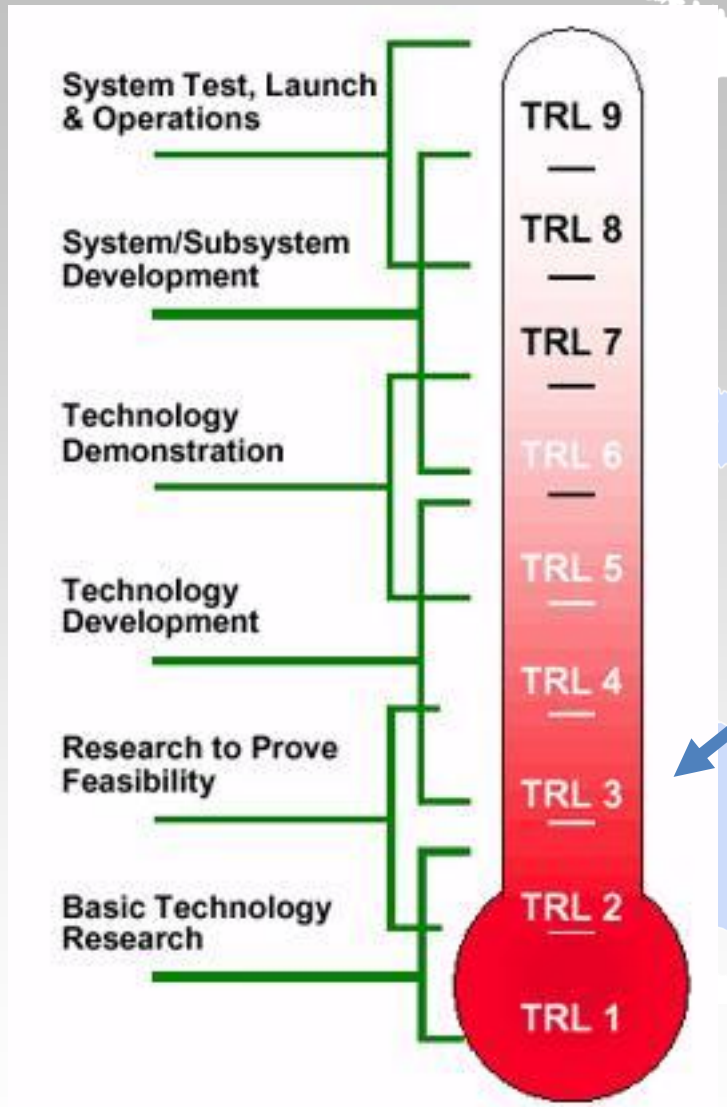
targeting

Human-Robot Interfacing and Safety

Dr. Johan Hagelbäck

Project idea

- Joint human-robot work cell.
- A human co-worker collaboratively solves a reference task with a robot.
- Measure affective states in the human co-worker,
- … and compare to doing the same task alone or collaboratively with another human.
- … and use that knowledge to adapt robot behavior, biofeedback (ongoing).



- Feasability Demonstration.
- Development of a workcell for measuring affective states in HRI.
- Experiments to build a human affect model in HRI.
- Development and demonstration of biofeedback (ongoing).

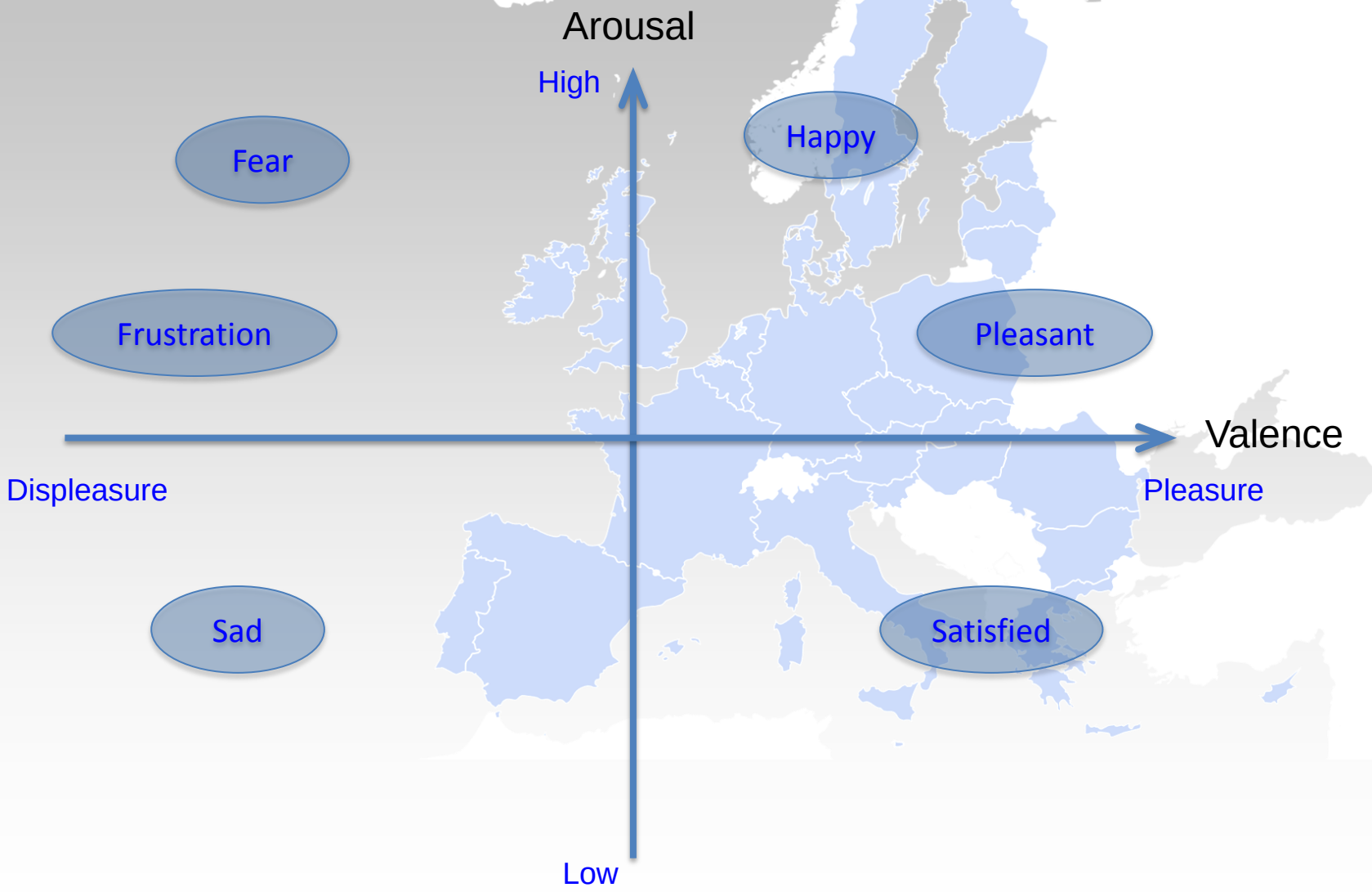
Collaborative task

- Towers of Hanoi
- Single-player game, two-player game by using turn-taking.
- Relatively easy to understand for (most) participants, but requires some thought to complete.

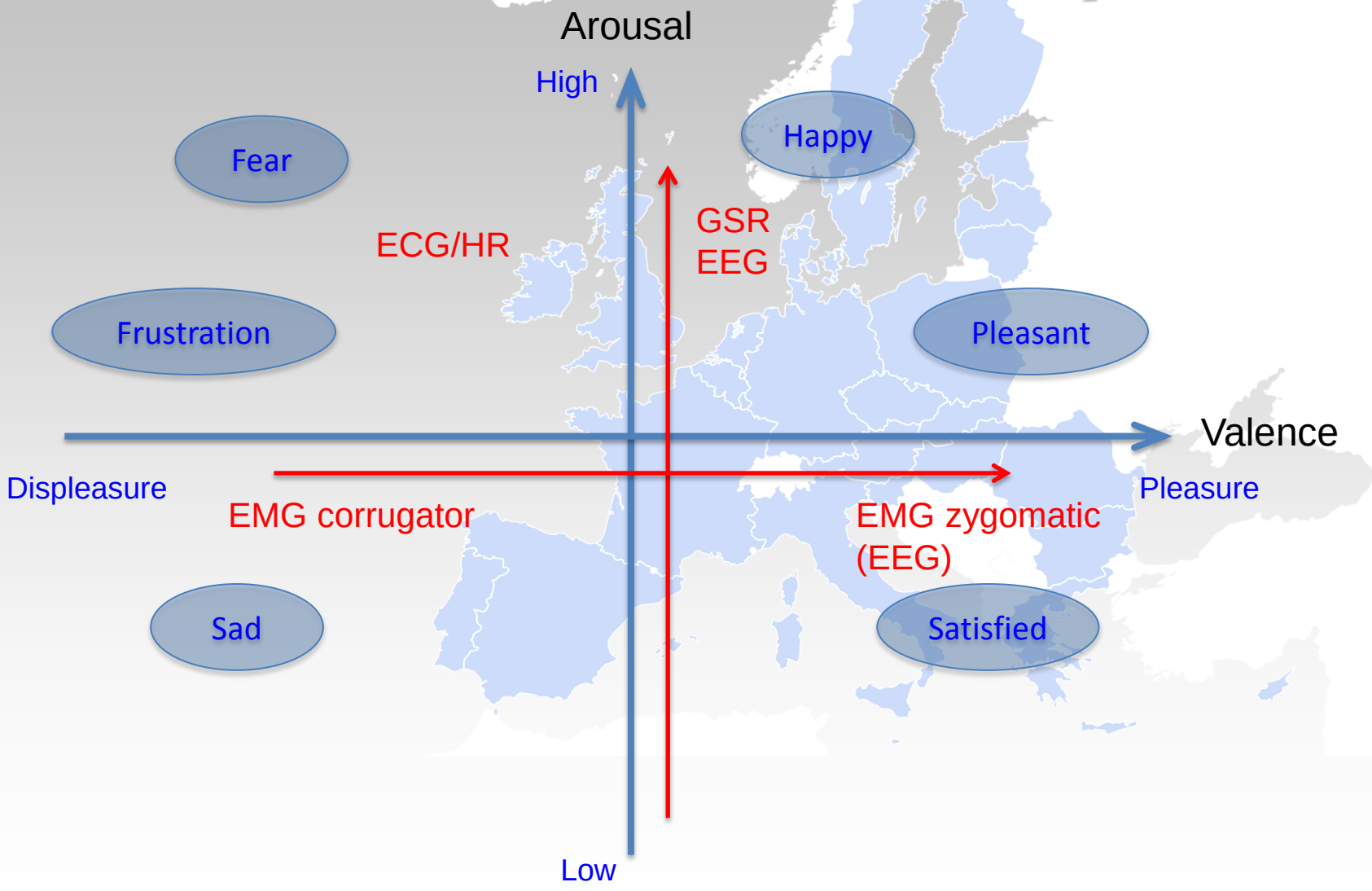
Psychophysiology sensors

Sensor	Measure
EEG 8 electrodes in frontal lobe	Electrical activity in the brain.
ECG	Heart rate.
EMG corrugator	Facial muscle activity at the eyebrow.
EMG zygomatic	Facial muscle activity at the corners of the mouth.
GSR	Skin conductance in the palm.

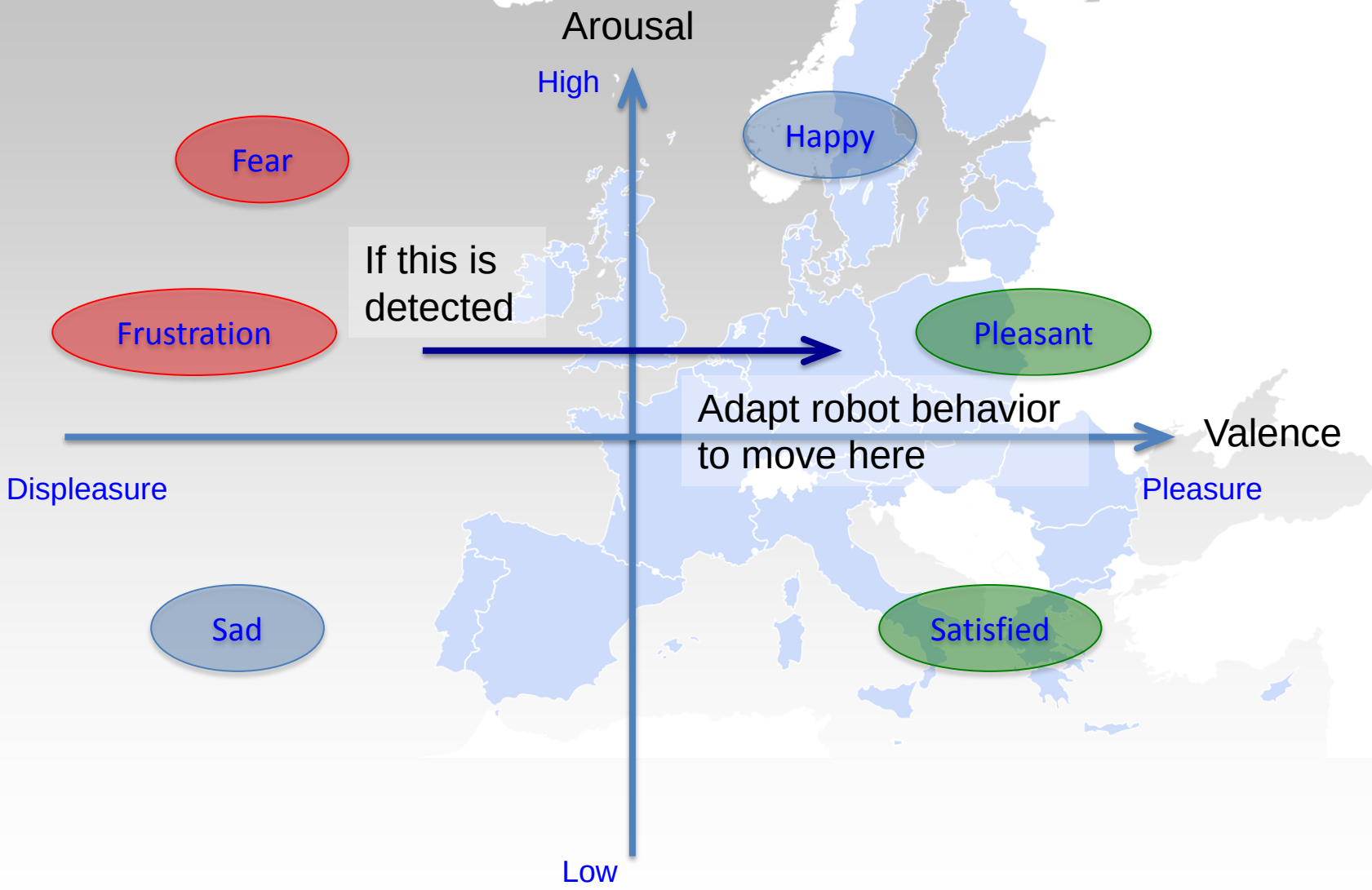
Affective states



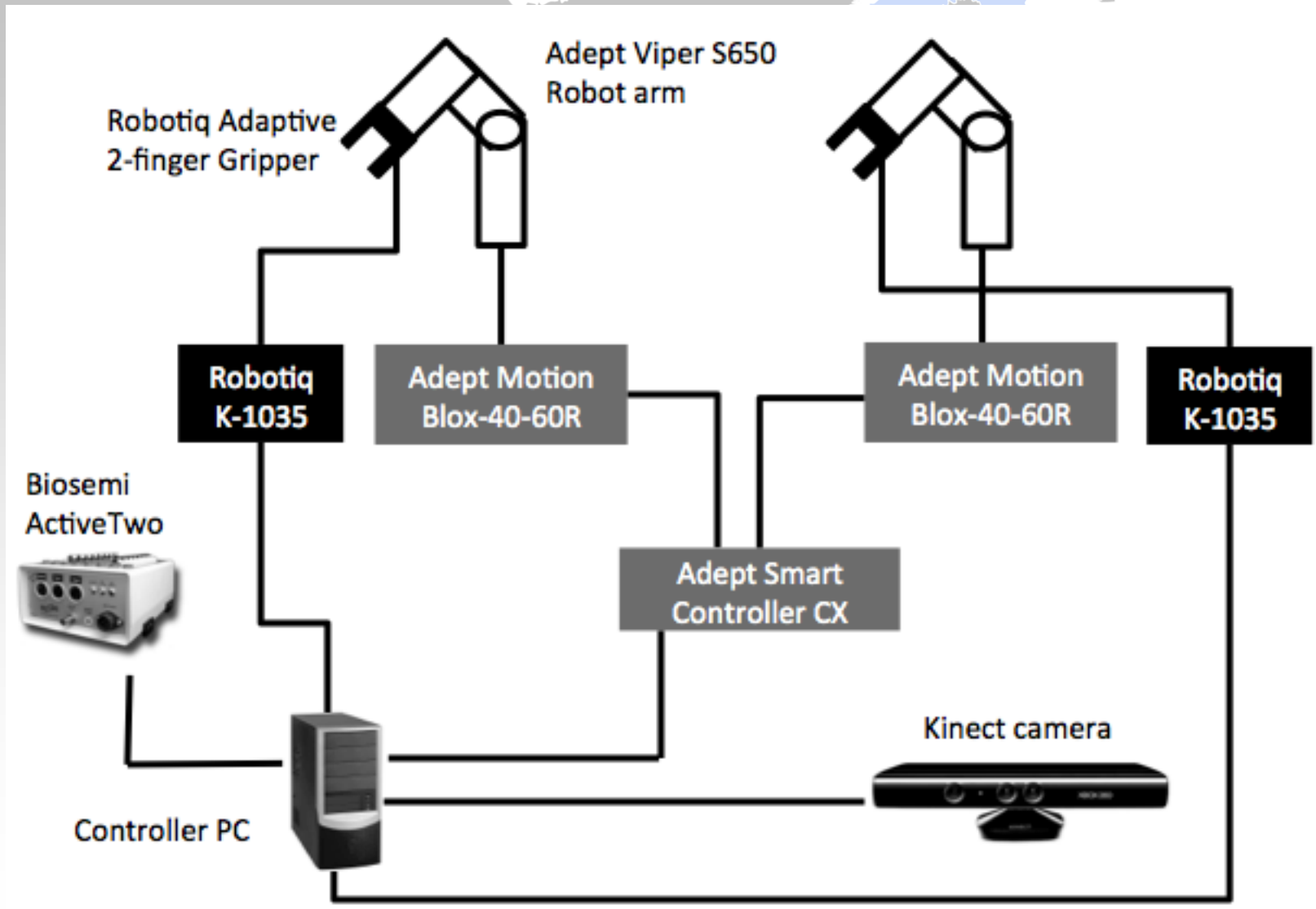
Affective states



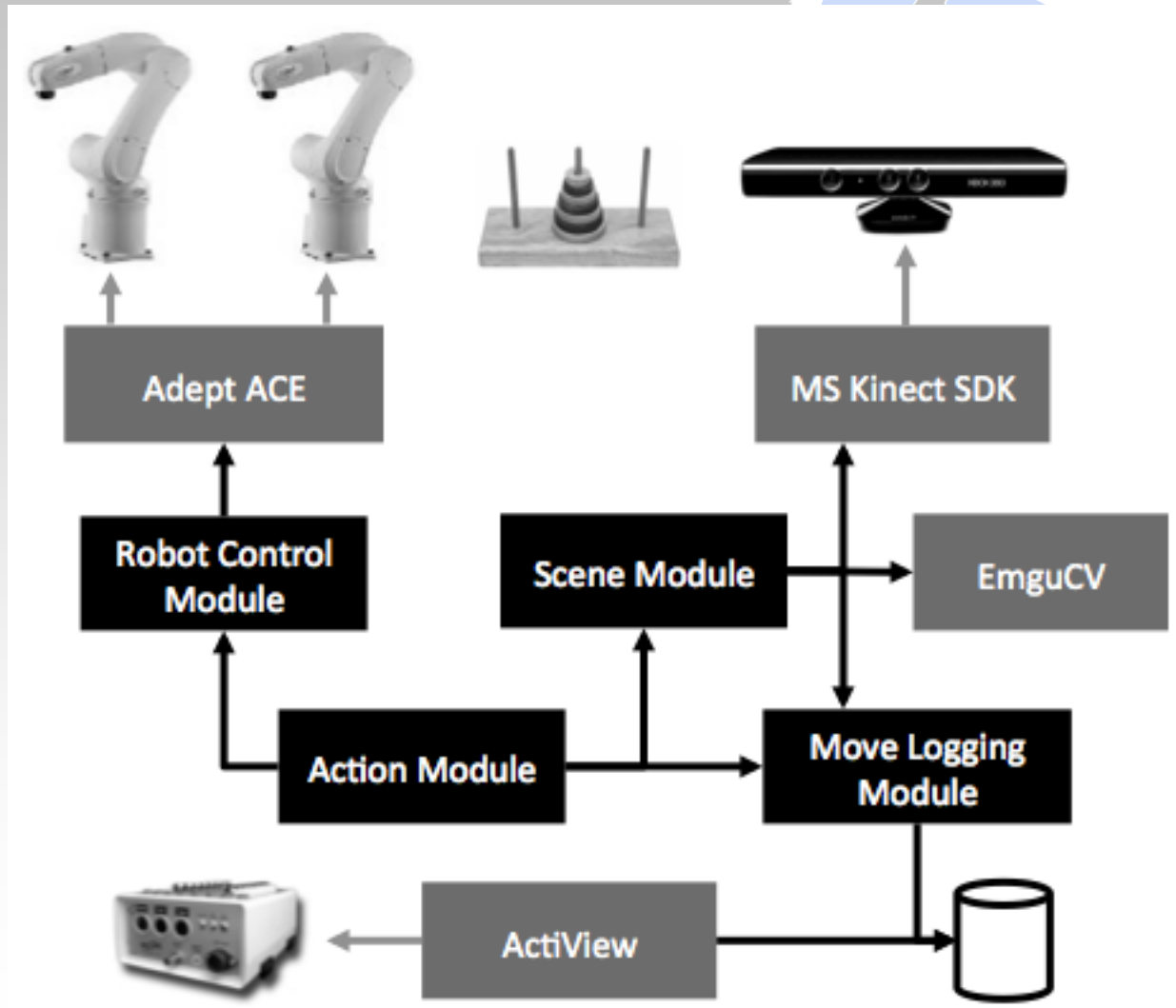
Adaptive robot behavior



Hardware setup

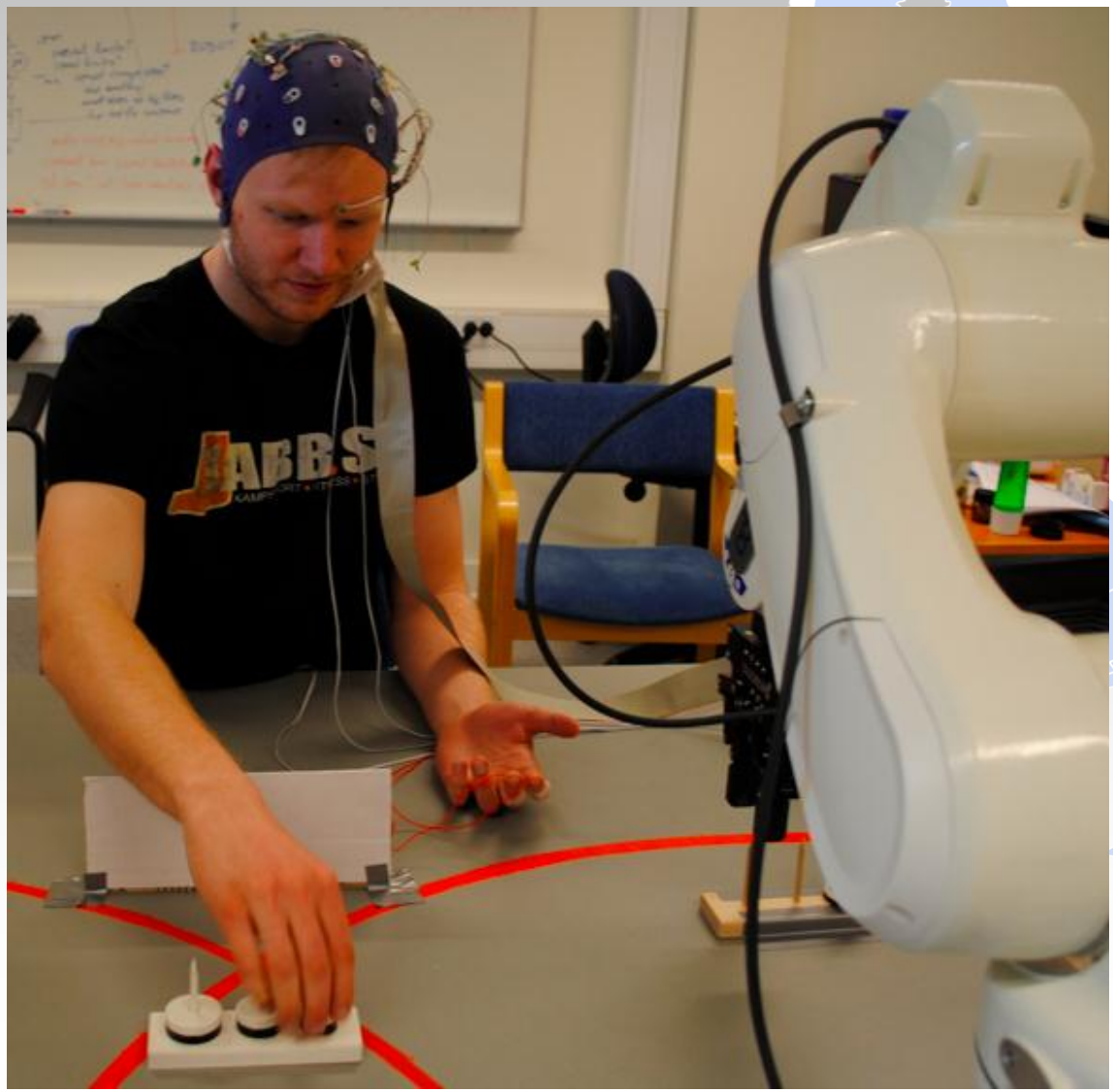


Software setup



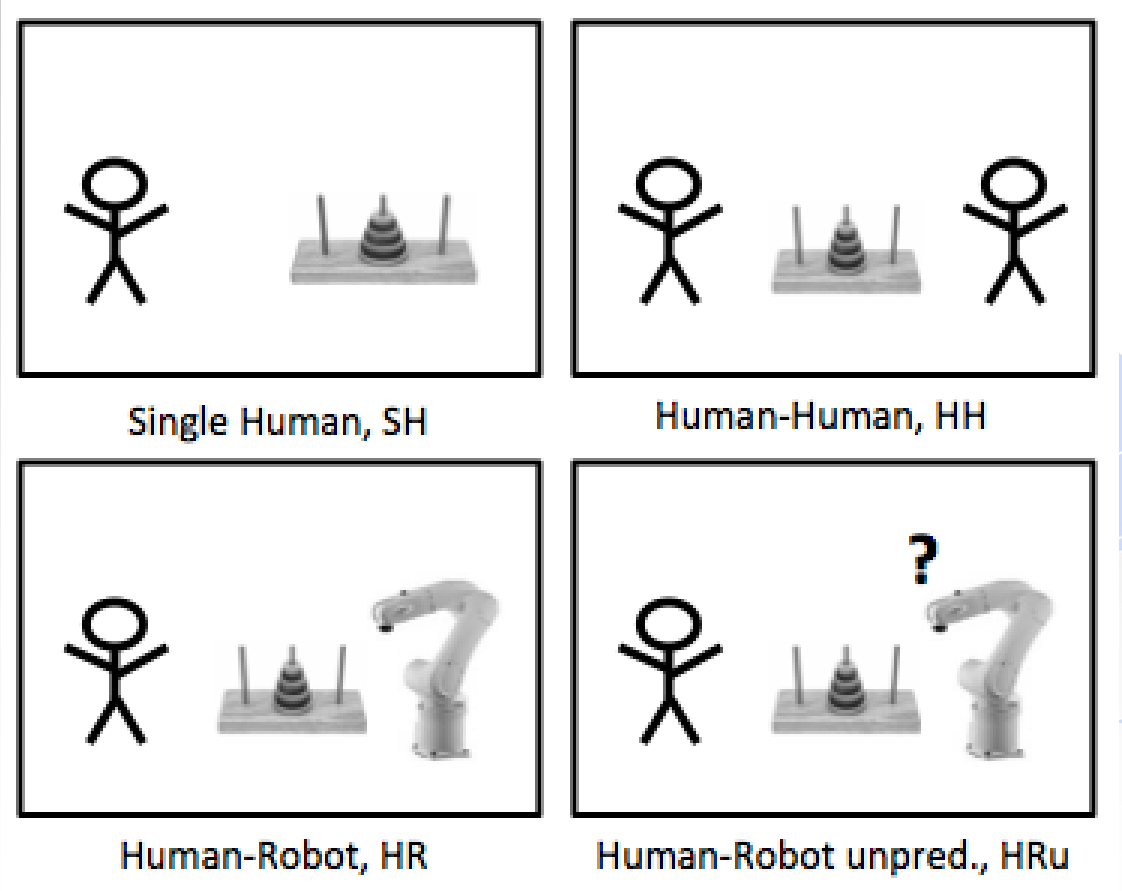
Work scene

Work scene



Experiment

- Four experiment conditions:

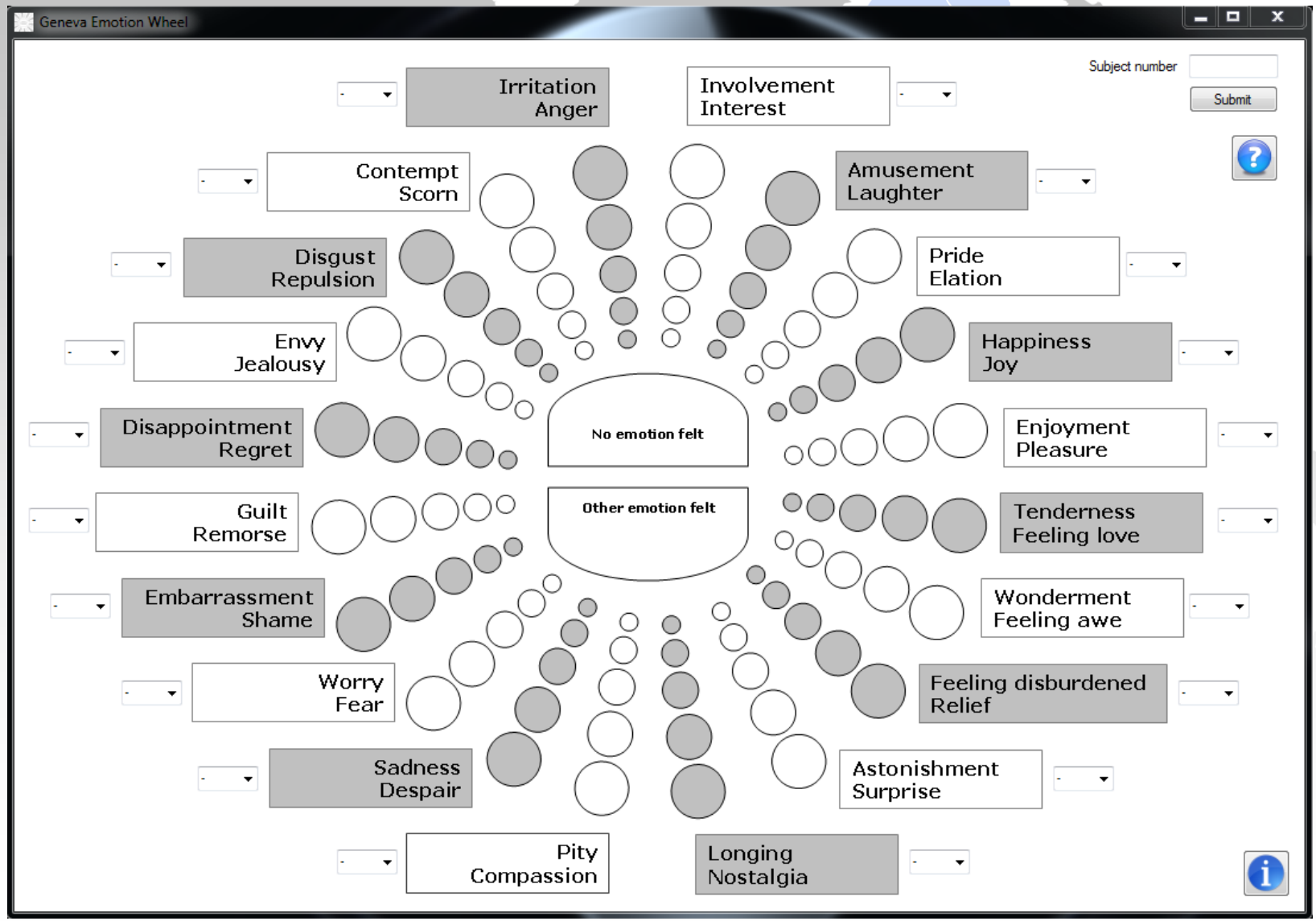


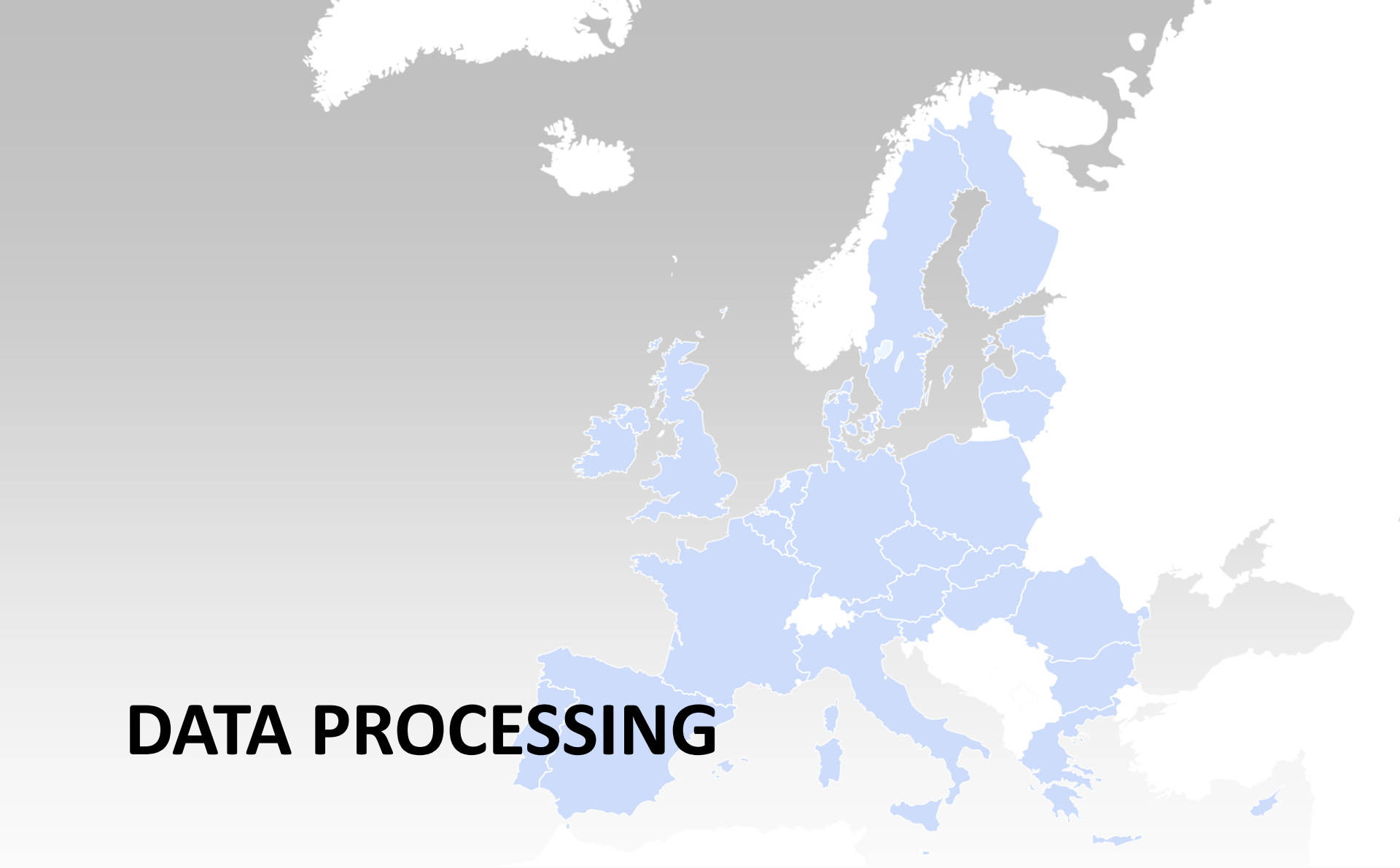
Experiment

- Three games per condition (in total 12 games)
- Psychophysiological data from sensors
- Geneva Emotion Wheel (GEW)
    - Subjective feelings
- Video

- 70 participants
- 90 mins each

GEW


Geneva Emotion Wheel
Subject number
Submit
Irritation
Anger
Involvement
Interest
Contempt
Scorn
Amusement
Laughter
Disgust
Repulsion
Pride
Elation
Envy
Jealousy
Happiness
Joy
Disappointment
Regret
No emotion felt
Enjoyment
Pleasure
Guilt
Remorse
Other emotion felt
Tenderness
Feeling love
Embarrassment
Shame
Wonderment
Feeling awe
Worry
Fear
Feeling disburdened
Relief
Sadness
Despair
Astonishment
Surprise
Pity
Compassion
Longing
Nostalgia



DATA PROCESSING

Removal of recording errors

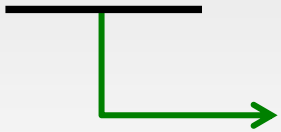
- Data points out-of-bounds of value range for a sensor were removed.

Sensor	Amount of data removed
EEG	17.7%
ECG	21.4%
EMG corrugator	5%
EMG zygomatic	13.2%
GSR	6.1%

Cut data into segments

Baseline Removal

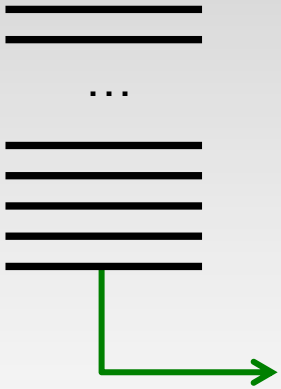
BL = mean value of baseline segment



- Mean - BL
- Min - BL
- Max - BL
- Standard deviation

Average over all participants

- Game 1 Condition 1 Participant n_1 is averaged with Game 1 Condition 1 Participant n_2
- Different order for participants



- Mean: mean [$(\text{mean-BL})_1$, $(\text{mean-BL})_2$, … , $(\text{mean-BL})_{70}$]
- Min: Global minimum $(\text{data-BL})_n$
- Max: Global maximum $(\text{data-BL})_n$
- Standard deviation: mean [std_1, std_2, …, std_{70}]

Data Values

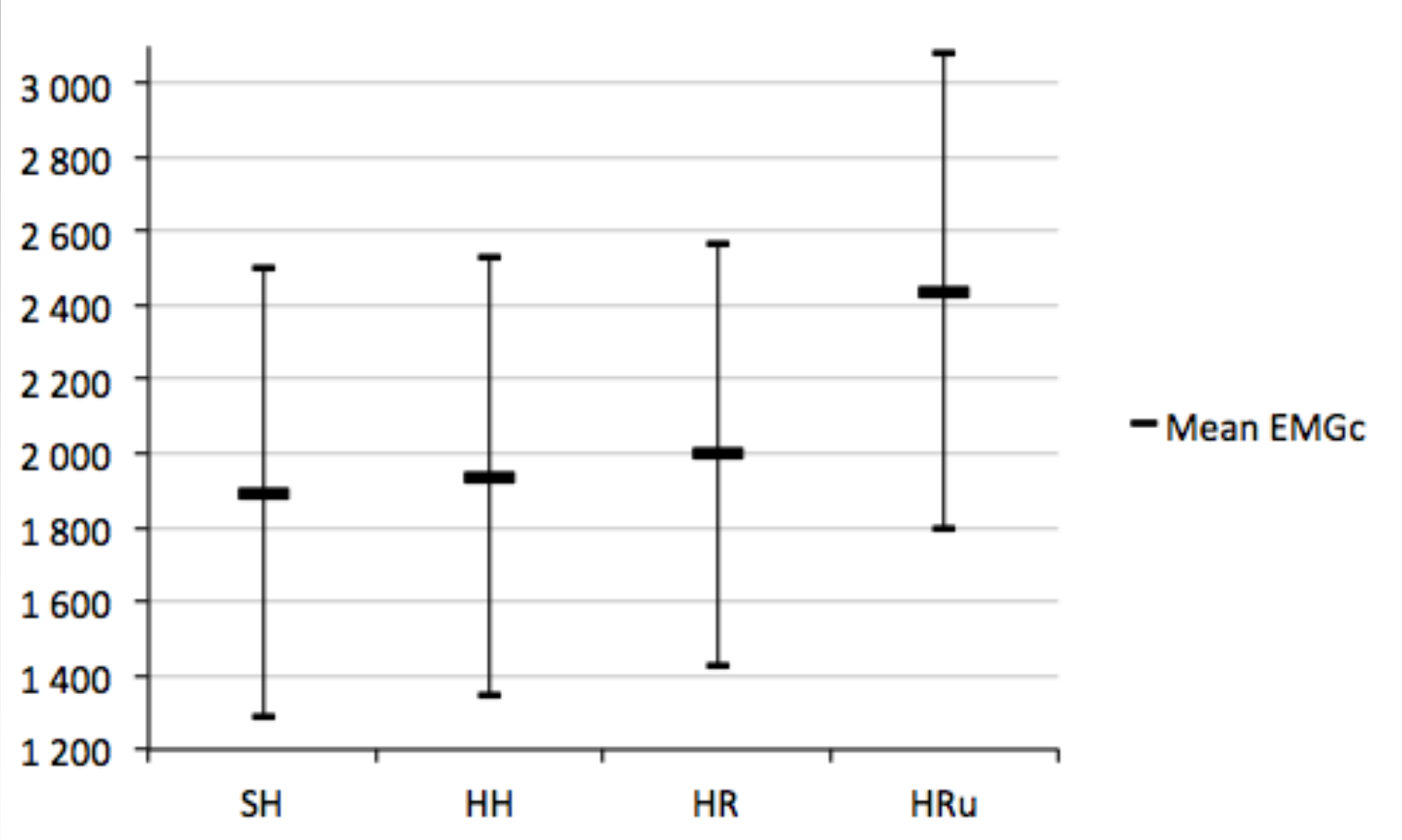
	SH				HH			
Sensor	Avg	StdDev	Min	Max	Avg	StdDev	Min	Max
EMGC	1894	4311	-9055	11060	1938	4277	-9251	11947
EMGZ	1583	3540	-5308	9665	1105	3111	-6421	8502
GSR	846.8	811.8	-985.5	3447.1	1130	774.3	-525.2	3227.6
Heart rate	2.816	5.911	-11.46	21.74	2.300	5.384	-12.44	15.26
EEG	919	2431	-3937	6600	1166	2523	-3948	7687
	HR				HRu			
	Avg	StdDev	Min	Max	Avg	StdDev	Min	Max
EMGC	1997	4051	-6443	11740	2439	4623	-7989	11966
EMGZ	1092	3555	-6931	9759	1498	3898	-6818	9853
GSR	767.7	896.6	-1281.2	3302.6	688.1	874.3	-1433.5	2791.4
Heart rate	1.427	5.783	-12.97	19.86	0.4977	4.638	-11.08	13.10
EEG	1146	2586	-3287	7425	1212	2576	-3899	7790

Comparison between Conditions

1. Compare mean values between the different conditions:
    - Single Human, SH
    - Human-human, HH
    - Human-Robot, HR
    - Human-Robot unpredictable, HRu
2. See if there are any noticeable differences in activation with, our without robots.

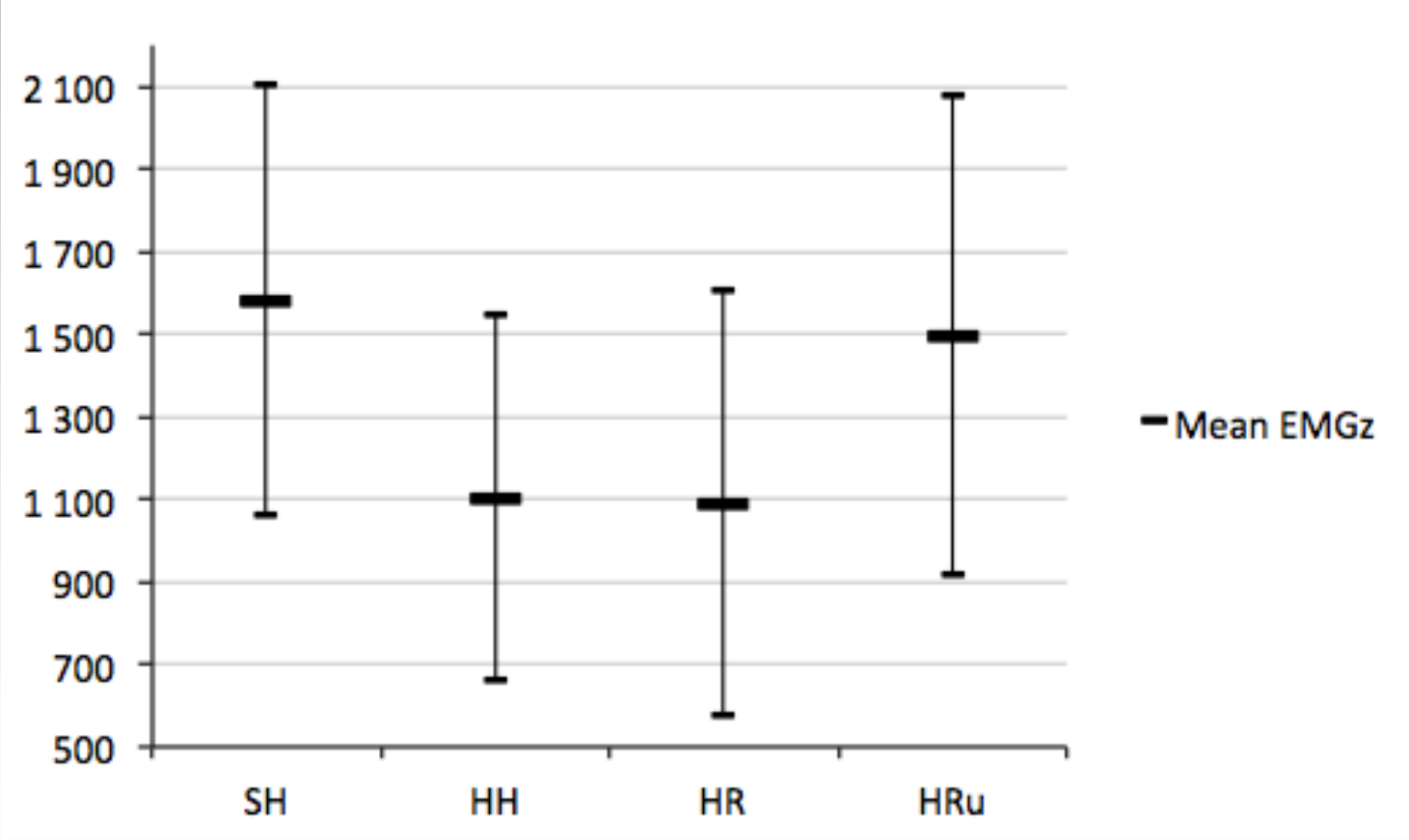
RESULTS

EMG corrugator



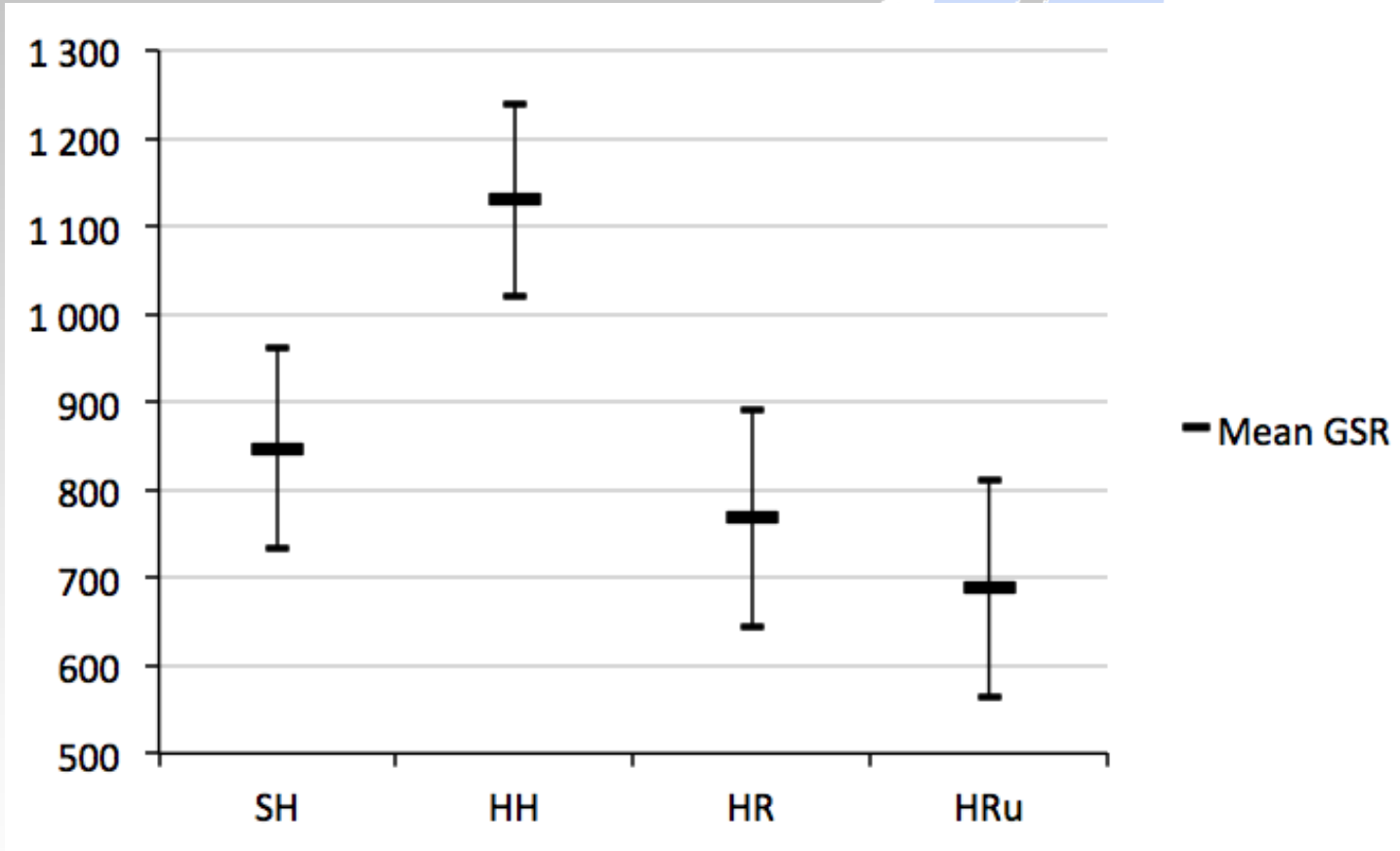
Good indicator of negative valence (displeasure)

EMG zygomatic



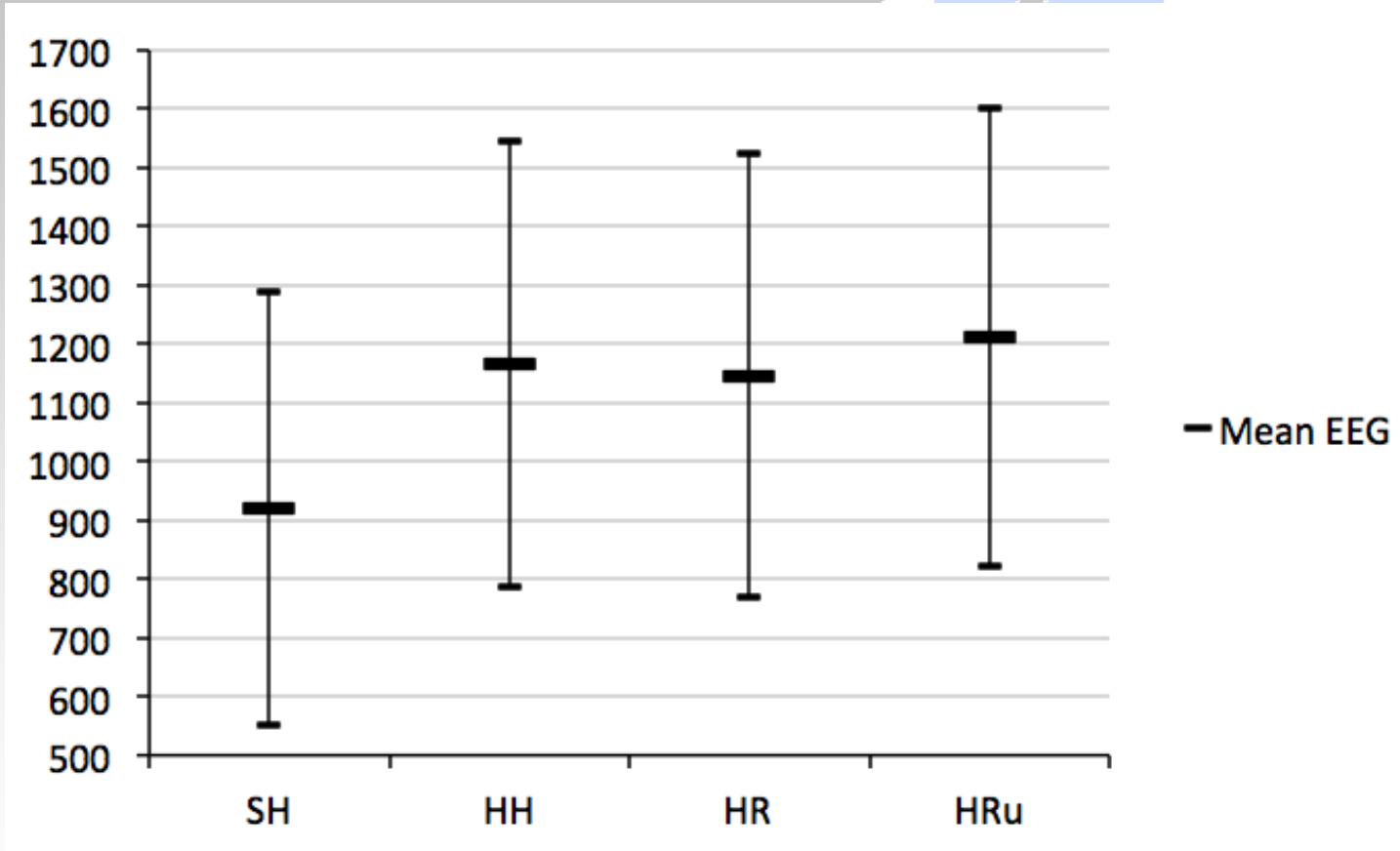
Good indicator of positive valence (pleasure)

GSR



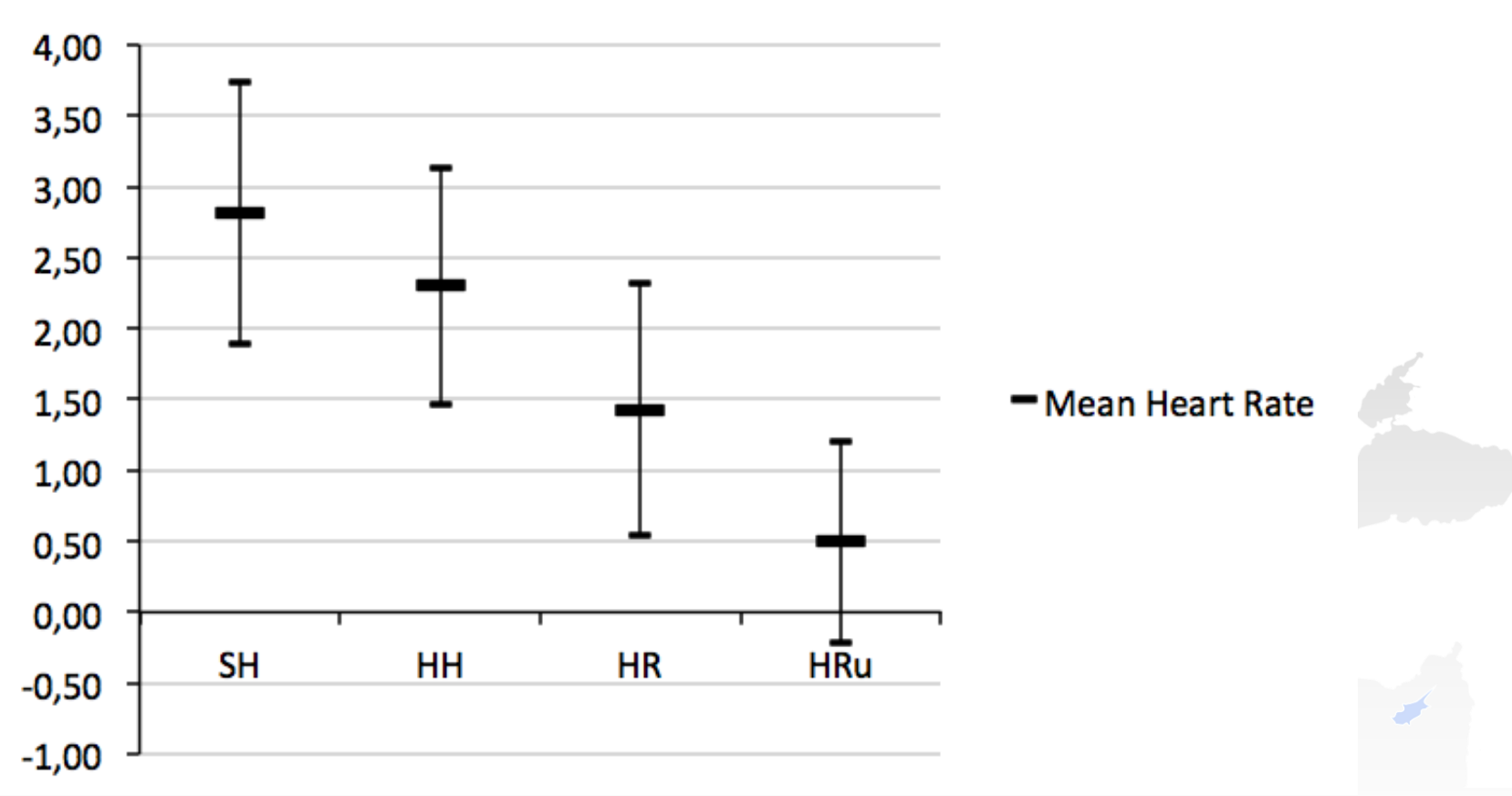
Good indicator of arousal

EEG



Good indicator on mental activity and attention

Heart Rate



Good indicator of arousal, especially
for negative valence (displeasure)

Statistical Analysis

- One-way analysis of variance (ANOVA), $\alpha = 0.01$

Sensor	Significance (* is significant)
EEG	0.716
Heart Rate	0.001*
EMG corrugator	0.564
EMG zygomatic	0.405
GSR	0.000*

Statistical Analysis

- Post-hoc analysis using Fisher's least significant difference, $\alpha = 0.01$

		HH	HR	HRu
GSR	SH	0.001*	0.348	0.062
	HH		0.000*	0.000*
	HR			0.345
Heart Rate	SH	0.393	0.022	0.000*
	HH		0.146	0.003*
	HR			0.122

CONCLUSIONS

Is there a difference between with or without robots?

- EMG sensors show a clear increase in activation for positive and negative valence in HRu.
- Very small differences for HR compared to without robots.
- No clear differences in arousal. Heart rate indicates decreased arousal with robots.
- Increased mental load and attention for all collaborative tasks rather than with/without robots.

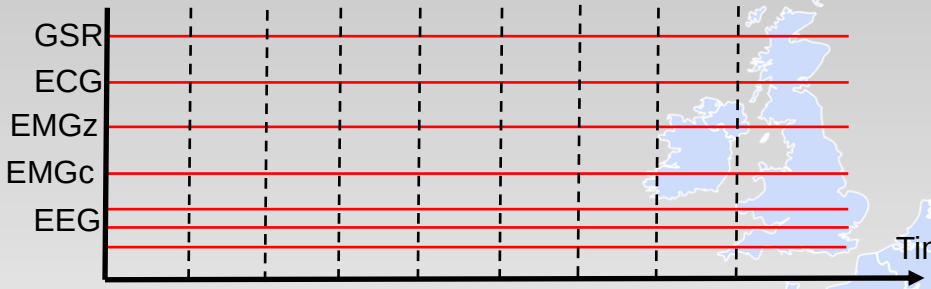
Limitations 1

- Emotions are short-lived affective states.
- Lots of things can happen during a game that lasts 2-3 mins.
- Mean values fail to detect spikes.
- Analysis on shorter time segments, for example per move, can give better results and give insight into contradictions.

Limitations 2

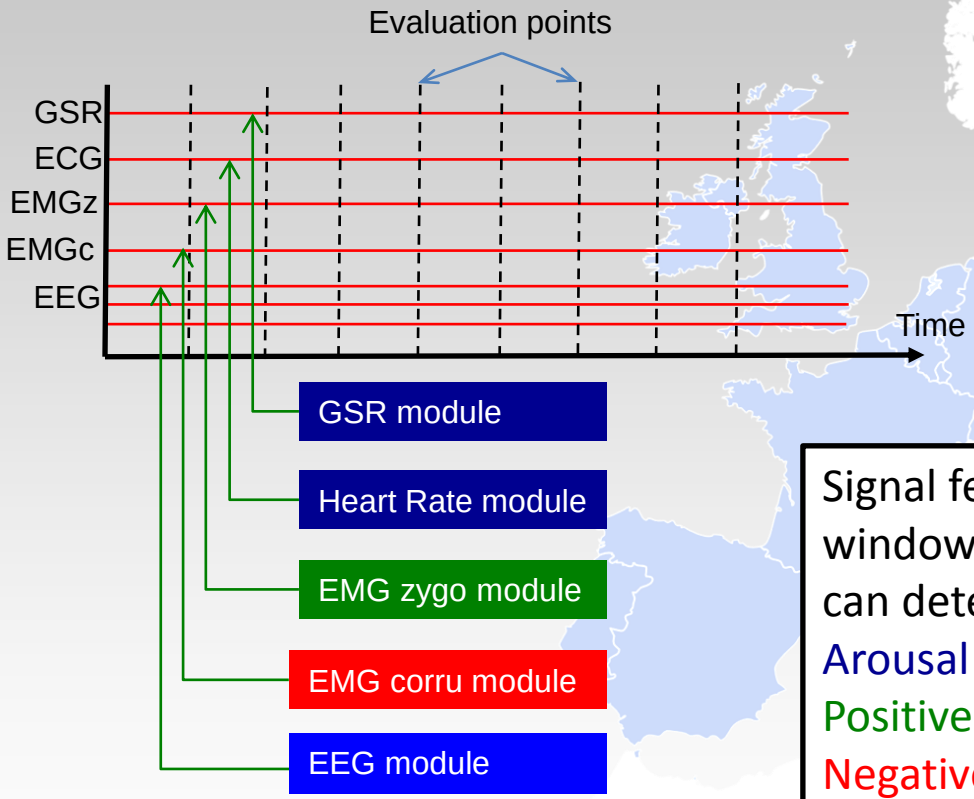
- EMG activity increases progressively from the beginning to the end of a task.
- A linear regression baseline could give better, more significant results compared to a constant baseline.

Biofeedback system (in progress)



Runtime reading of signals.

Biofeedback system (in progress)



Signal features for last 15 sec window are fed to modules which can detect:

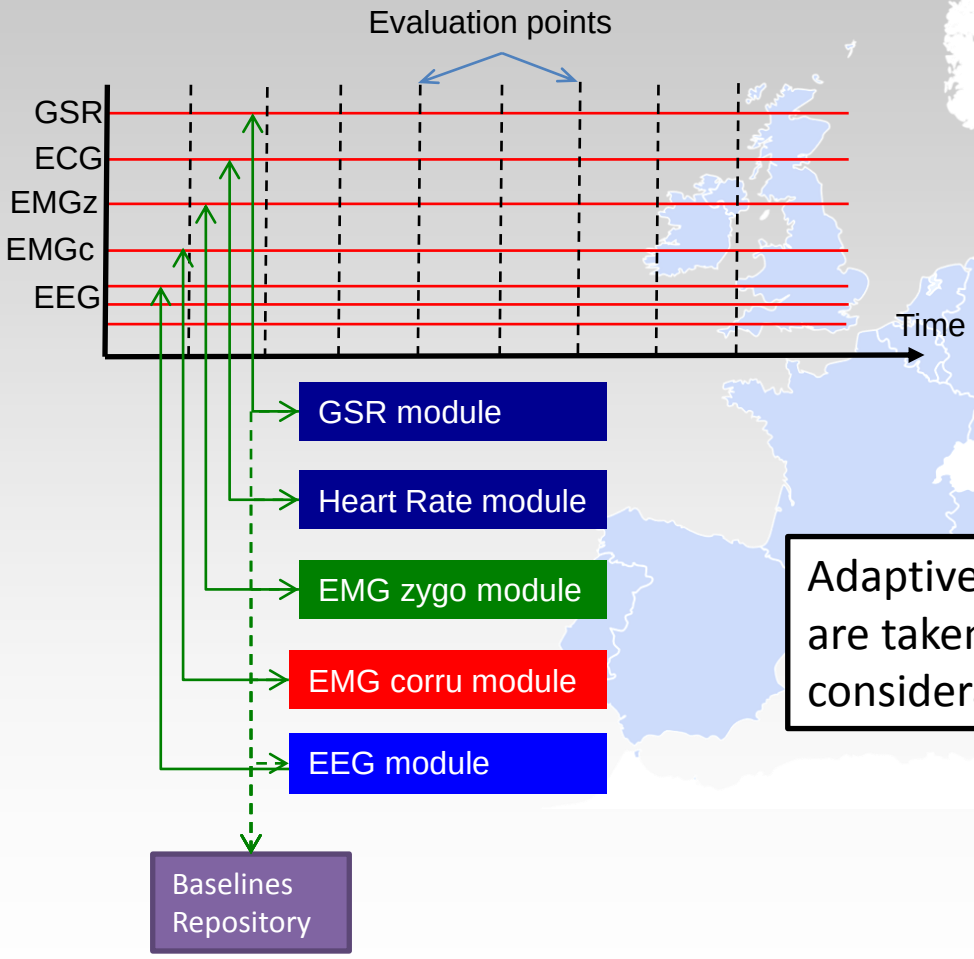
Arousal

Positive valence

Negative valence

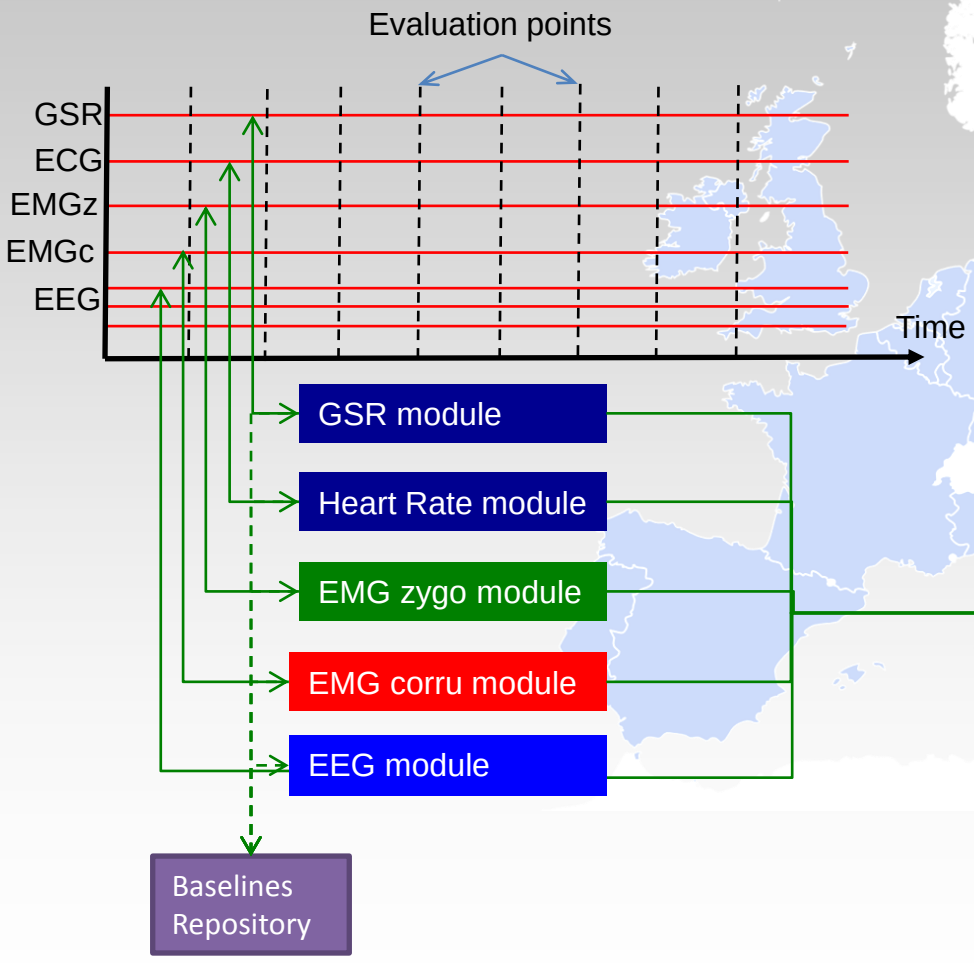
Cognitive load

Biofeedback system (in progress)



Adaptive baselines are taken into consideration.

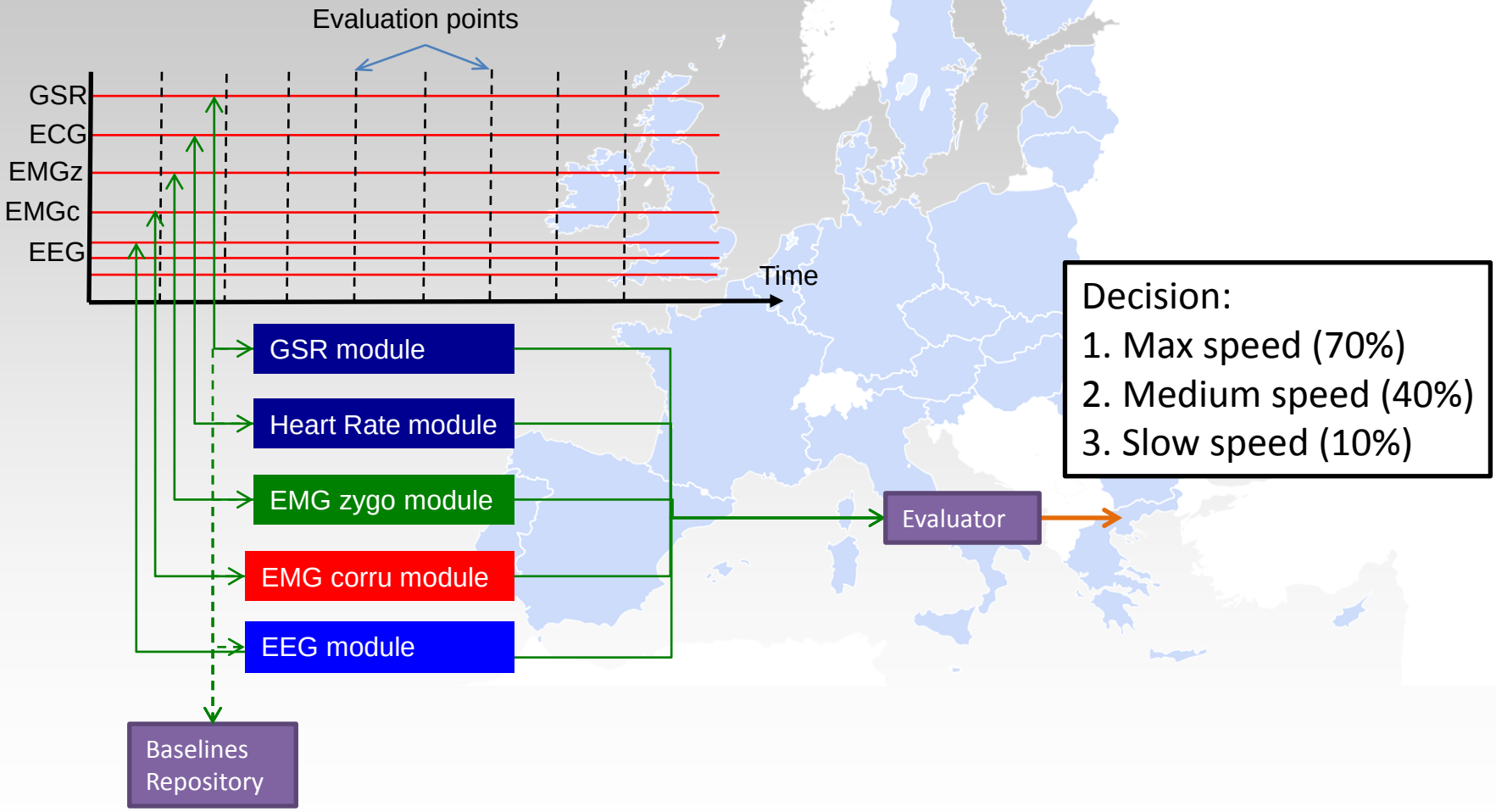
Biofeedback system (in progress)



Aroused & Pos Valence?
Aroused & Neg Valence?
Not Aroused?

Rule-based

Biofeedback system (in progress)



Thanks for the attention!

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