# Emotion assessment from physiological signals for adaptation of games difficulty

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**Based on:**

• G. Chanel, C. Rebetez, M. Betrancourt, T, Pun, “Emotion assessment from physiological signals for adaptation of games difficulty”, IEEE Trans. on Systems, Man, and Cybernetics - Part A: Systems and Humans, submitted, June 2009; revised 2010.

• G. Chanel, C. Rebetez, M. Betrancourt, T. Pun, "Boredom, engagement and anxiety as indicators for adaptation to difficulty in games", 11th MindTrek Conf., MindTrek 2008: Entertainment and Media in the Ubiquitous Era, October 7-9, 2008, Tampere, Finland.

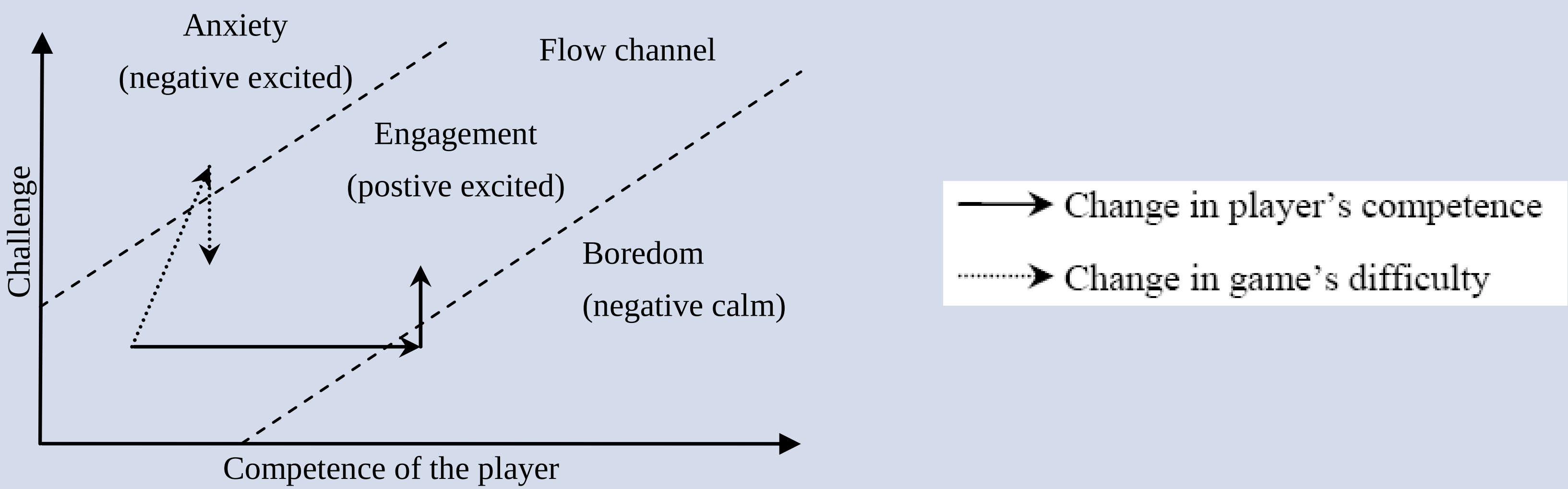
# Content

- Objectives and hypotheses
- Acquisition protocol
- Feature extraction
  - EEG's
  - Peripheral signals
- Analysis of questionnaires
- Analysis of physiological features
- Classification
  - Features selection
  - Peripheral signals, EEG's
  - Fusion
  - Effect of trial duration
- Game over
- Conclusions and future work

## Objectives and hypotheses

### "Flow of experience" theory [Csikszentmihályi]

- complete engagement in task, positive feelings, loss of sense of time;
- appears when the challenge of a task meets the "user's" skill.



# Objectives and hypotheses

**To maintain the level of involvement and pleasure by:**

- assessing the emotional state of user through monitoring of physiological signals;
- controlling the difficulty of the task to influence challenge;
- here: task is a game, Tetris.

**Why Tetris?**

- known to elicit strong emotional responses;
- possibility to control the difficulty of the task (25 speed levels);
- well known so different gamer competences available;
- can be played with one hand.

# Objectives and hypotheses

**Hypotheses**

- H1 : playing at different levels of difficulty induces one of 3 emotional states (boredom, engagement, anxiety);
- H2 : as the skill increases, the player will switch from the engagement state to the boredom state;
- H3 : these emotional states can be assessed using central and peripheral physiological signals.

**Validation**:

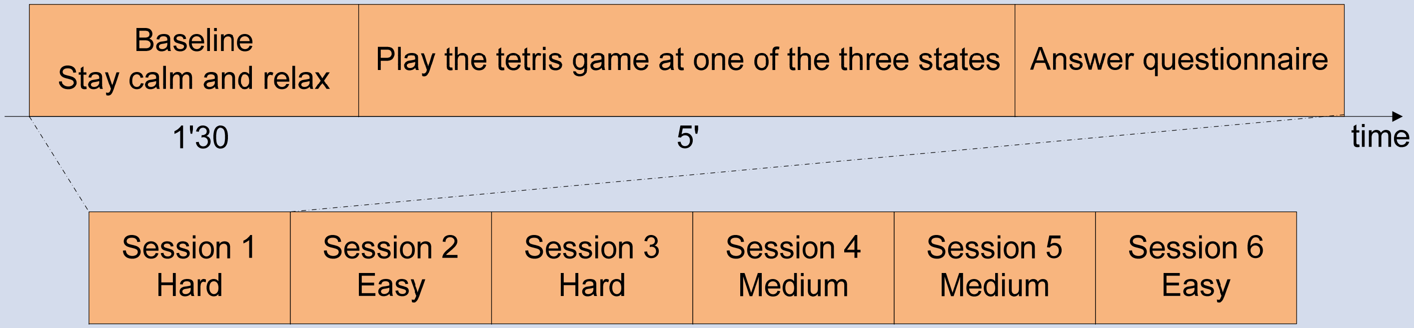
- from questionnaires and physiological data analysis;
- 20 participants (incl. 14 with EEG recordings).

# Acquisition protocol

**Determination of 3 gaming conditions (threshold method):**

- medium (engagement) : levels 11 to 20;
- hard (anxiety) : medium level + 8, max 25;
- easy (boredom) : medium level – 8, min 5.

**Schedule of the protocol :**




Random permutation of difficulty for each participant

# Acquisition protocol

**Physiological signals from:**

- peripheral nervous system: GSR, blood pressure, respiration, temperature;
- central nervous system: EEG, 19 electrodes (Bioesmi Active II).

**Why ?**

- physiological signals cannot be easily faked;
- part of emotional processes are cognitive;
- fusion of modalities improves results.

# Feature extraction – EEG's

**EEG features:**

- energy in 3 bands alpha, beta, theta, related to emotional processes (e.g. alpha lateralization for approach-withdrawal);
- *EEG_W*, related to workload, engagement, attention, fatigue.

| Feature for electrode i | Frequency band |
|---|---|
| $\theta_i$ | 4-8 Hz |
| $\alpha_i$ | 8-12 Hz |
| $\beta_i$ | 12-30 Hz |

$$EEG\_W = \log\left(\frac{\sum_{i=1}^{N_e} \beta_i}{\sum_{i=1}^{N_e} \theta_i + \alpha_i}\right)$$

# Feature extraction - Peripheral

**GSR:**

- mean value;
- mean of derivative;
- sum of negative derivatives;
- % of negative samples in derivative.

**Respiration:**

- main frequency;
- max – min (range);
- standard deviation.

**Temperature:**

- mean value;
- mean of derivative.

**Blood pressure:**

- mean value;
- standard deviation.

**Heart rate:**

- mean value;
- heart rate variability;
- variance;
- mean of derivative.

# Feature extraction - Peripheral

| Peripheral signal | Feature name | Extracted feature | Comment |
|---|---|---|---|
| GSR | $\mu_{GSR}$ | Mean skin resistance | Estimate of general arousal level |
| | $\delta_{GSR}$ | Mean of derivative | Average GSR variation |
| | $f_{GSR}^{DecRate}$ | Mean of derivative for negative values only | Average decrease rate during decay time |
| | $f_{GSR}^{DecTime}$ | Proportion of negative samples in the derivative vs. all samples | Importance and duration of the resistance fall |
| | $f_{GSR}^{NbPeaks}$ | Number of resistance falls in the signal | - |
| Blood pressure | $\mu_{BVP}$ | Mean value | Estimate of general pressure |
| | $\sigma_{BVP}$ | Standard deviation | Blood pressure variation |

# Feature extraction - Peripheral

| | | | |
|---|---|---|---|
| Heart rate | $\mu_{HR}$ | Mean of heart rate | - |
| | $\delta_{HR}$ <br> $\sigma_{HR}$ | Mean of heart rate derivative <br> Standard deviation of heart rate | Estimations of heart rate variability |
| | $f_{HR}^{LF}$ | Energy in 0.05Hz-0.15Hz band | Parasympathetic and sympathetic activity |
| | $f_{HR}^{HF}$ | Energy in 0.15Hz-1Hz band | Parasympathetic activity |
| | $f_{HR}^{LF/HF}$ | Ration of energy in the LF and HF bands | Ratio of parasympathetic and sympathetic activity |
| Respiration | $f_{Resp}^{Rate}$ | Frequency with the highest energy | Respiration rate |
| | $\sigma_{Resp}$ | Standard deviation | Variation of the respiration signal |
| | $f_{Resp}^{DR}$ | Maximum value minus minimum value | Dynamic range or greatest breath |
| Skin Temperature | $\mu_{Temp}$ | Mean value | - |
| | $\delta_{Temp}$ | Mean of derivative | Estimation of temperature variability |

# Analysis of questionnaires

**Description:**

- 30 questions, with Likert scale ranging from 1 to 7;
- related to emotions : “I was stressed”, “I had pleasure”,…
- related to involvement : “I was focused on the game”, “I was motivated”, …

**30D factor analysis to obtain axes with maximum variance:**

- 56% of variance with first 2 components;
- 1st component >0 correlation with pleasure, interest, motivation, focus: **valence**
- 2nd component >0 correlation with excitation, pressure, <0 correlation with calm, control: **arousal**

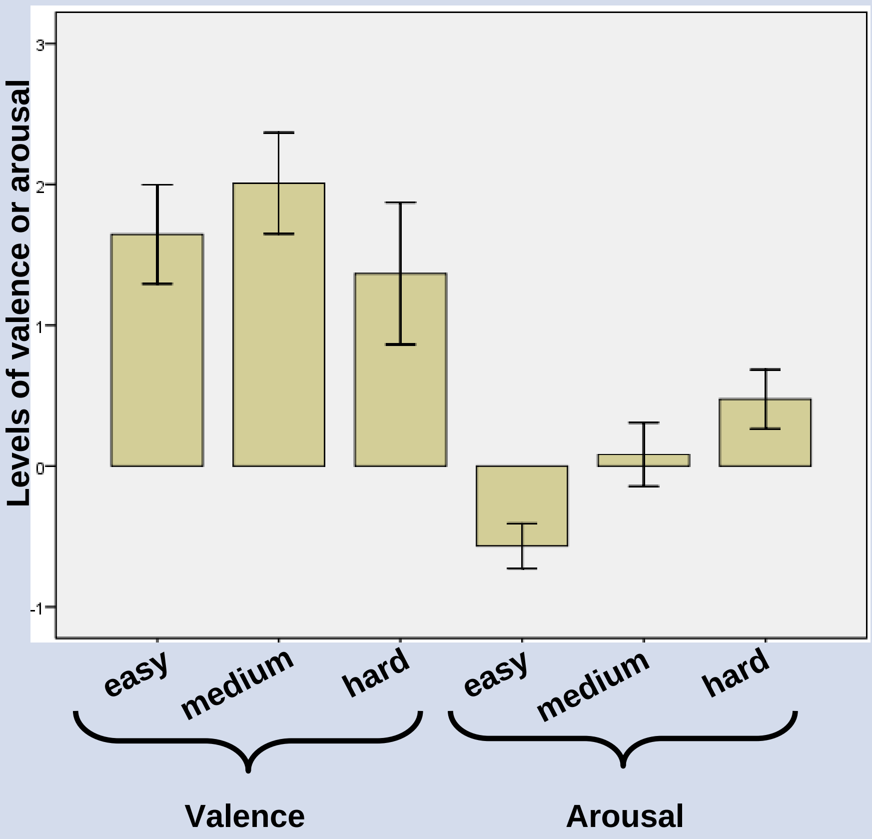
# Analysis of questionnaires

**Results from participants:**

- lower valence felt in the easy and hard conditions than in the medium one;
- the more difficult the game is, the higher is the arousal.

Three conditions do exist:

⇨ **H1 validated by self-assements**



# Analysis of physiological features

Trend on the most relevant physiological features, easy-to-medium, and medium-to-hard conditions:

| Feature | F-value | p-value | Trend of the mean |
|---|---|---|---|
| $\mu_{GSR}$ | 4.4 | 0.01 | ↘→ |
| $\delta_{GSR}$ | 2.7 | 0.07 | ↘→ |
| $f_{GSR}^{DecRate}$ | 3.1 | 0.05 | ↘→ |
| $f_{GSR}^{DecTime}$ | 6.7 | < 0.01 | →↗ |
| $f_{GSR}^{NbPeaks}$ | 18.3 | < 0.01 | ↗→ |
| $\mu_{HR}$ | 3.4 | 0.04 | →↗ |
| $f_{HR}^{LF}$ | 2.4 | 0.09 | ↘↗ |
| $\sigma_{Resp}$ | 5.8 | < 0.01 | →↗ |
| $\mu_{Temp}$ | 9.4 | < 0.01 | ↘↘ |
| $\delta_{Temp}$ | 10 | < 0.01 | ↘↘ |

- increase for easy-to-medium,
- stable for medium-to-hard

**Results from peripheral physiological features:**

- increase of arousal btw. medium and hard conditions but less than btw. the easy and medium conditions;
- increased arousal for increasing game difficulty;
- peripheral physiological data also **supports H1**.

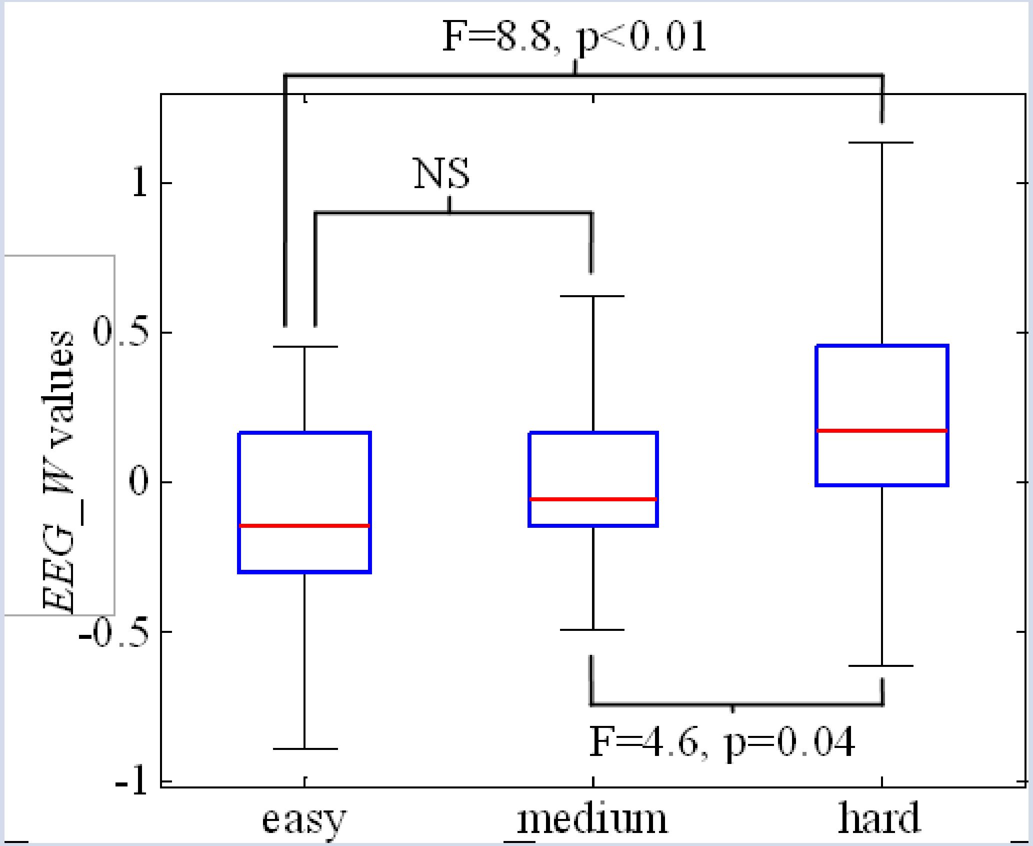
# Analysis of physiological features

**EEG features:**

- alpha-band: no difference btw. the 3 conditions;
- beta and theta bands: several features show differences;
- EEG_W:
  - median increases as difficulty increases;
  - significant differences btw. easy and hard conditions, medium and hard conditions;
  - median not higher for medium condition: EEG_W more related to workload than engagement;
- EEG data also **supports H1**.

# Analysis of physiological features

*EEG_W* values for the 3 gaming conditions:



# Analysis of physiological features

**H2: as skill increases, switch from engagement to boredom.**

Test on data from 2 consecutive medium-condition games:

- questionnaires: significant decrease for questions “I had pleasure to play” and “I had to adapt to the interface”;
- peripheral signals: decrease in GSR peaks, increase in average temperature and average derivative of temperature.

Conclusions:

- decrease of arousal and increase in skills btw. successive games;
- **tends to validate H2**, but is the game boring or is the competence increased ?

# Classification

Classifiers:

- LDA – Linear Discriminant Analysis;
- QDA – Quadratic Discriminant Analysis;
- SVM – Support Vector Machines with RBF kernel.

Ground truth: 3 difficulties corresponding to 3 emotional states.

Remarks:

- "small" number N of users (20): classifiers trained on N-1, tested on 1 (cross-validation);
- player independent.

# Classification

Features selection:

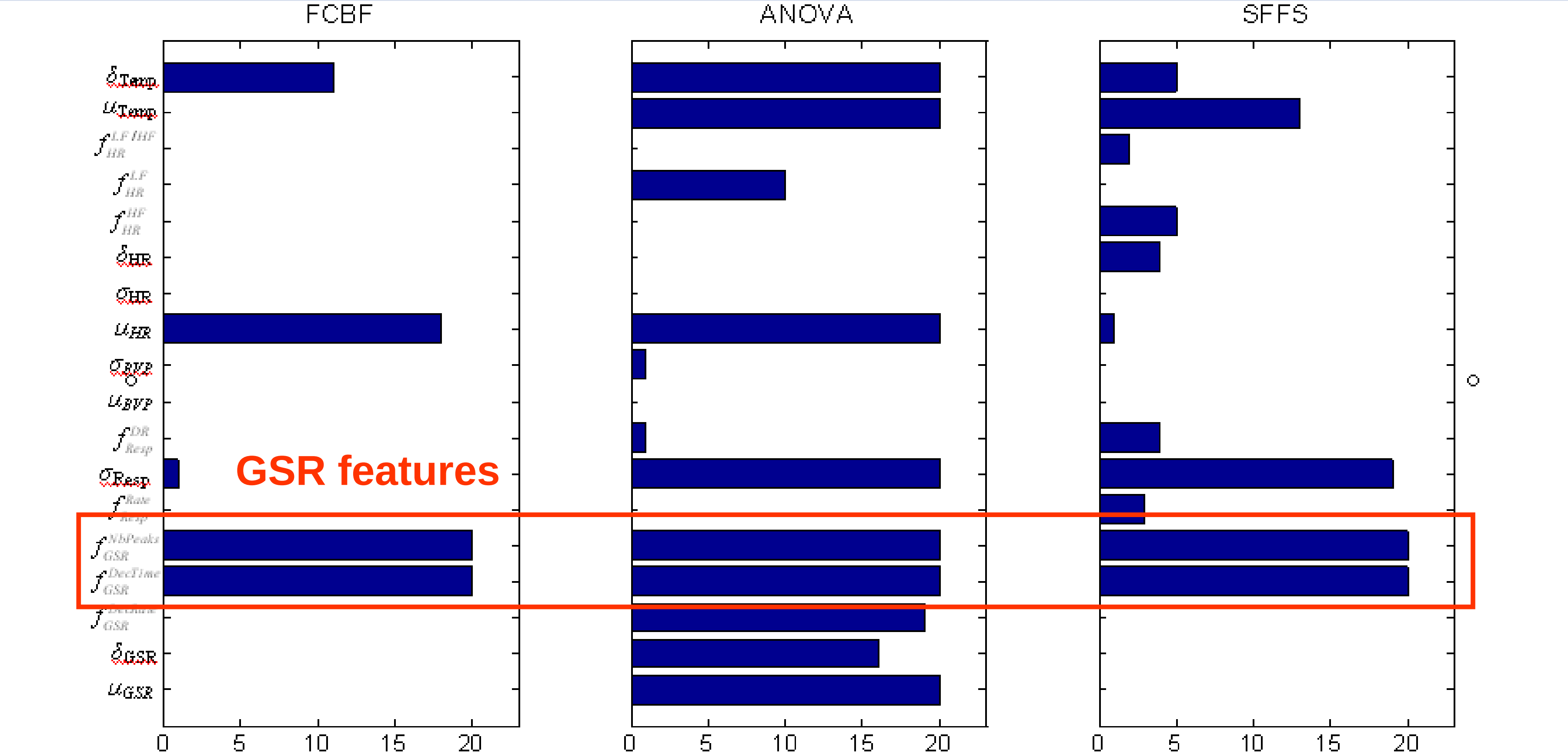
- FCBF - Fast Correlation Based Filter: removes features having low correlation with class concept;
- ANOVA;
- SFFS – Sequential Floating Forward Search: evaluates feature subsets.

Fusion of EEG and peripheral signals:

- at the decision level;
- Bayes belief integration: classifiers weighted by their average error.

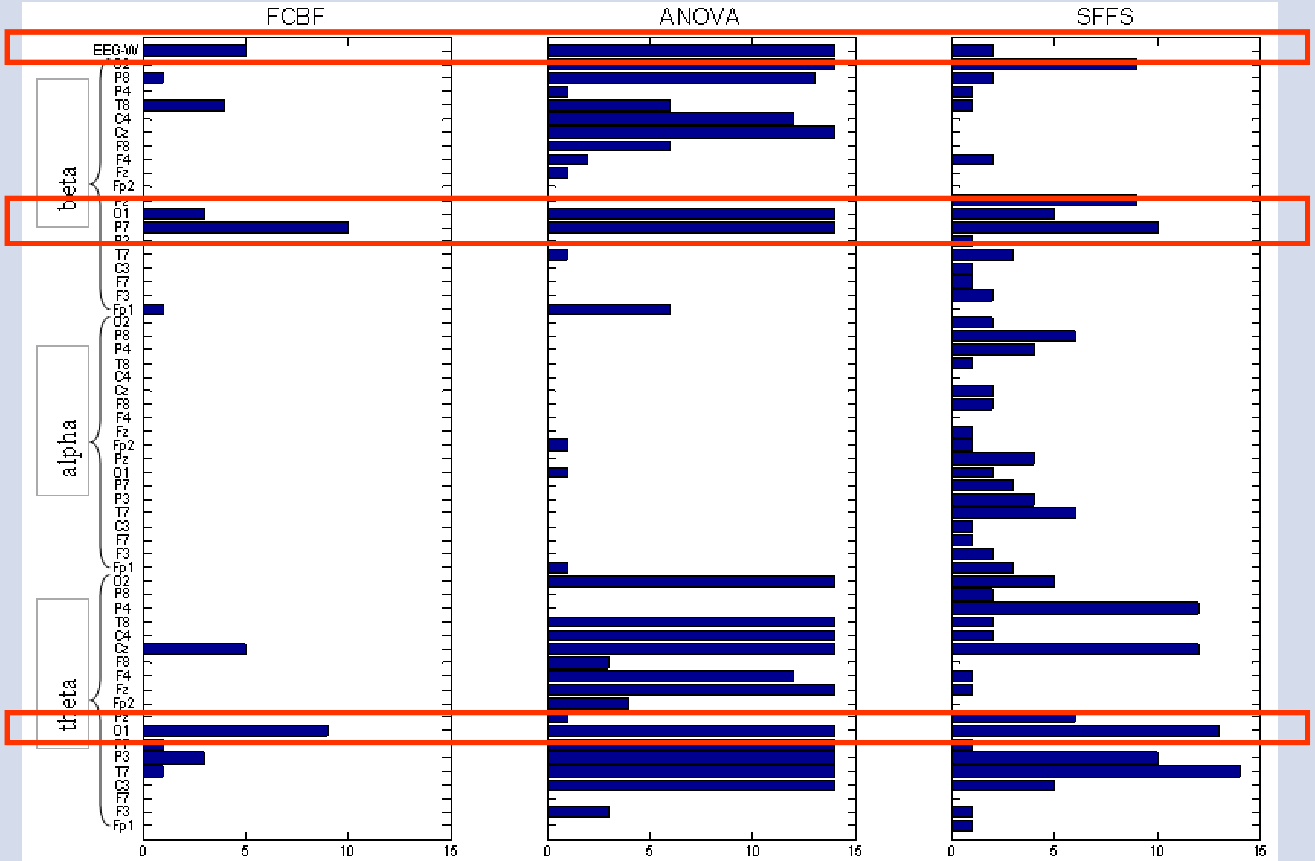
# Classification – Features selection

Peripheral features selection (nr. of times a feature was selected):



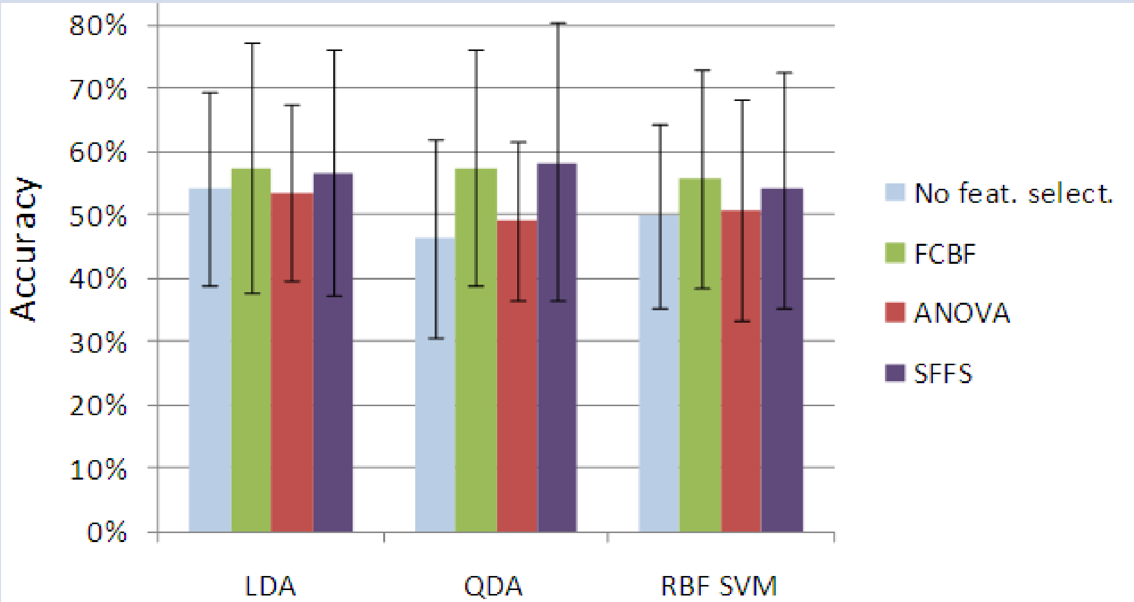
# Classification – Features selection

EEG features selection (nr. of times a feature was selected):



## Classification – Peripheral signals

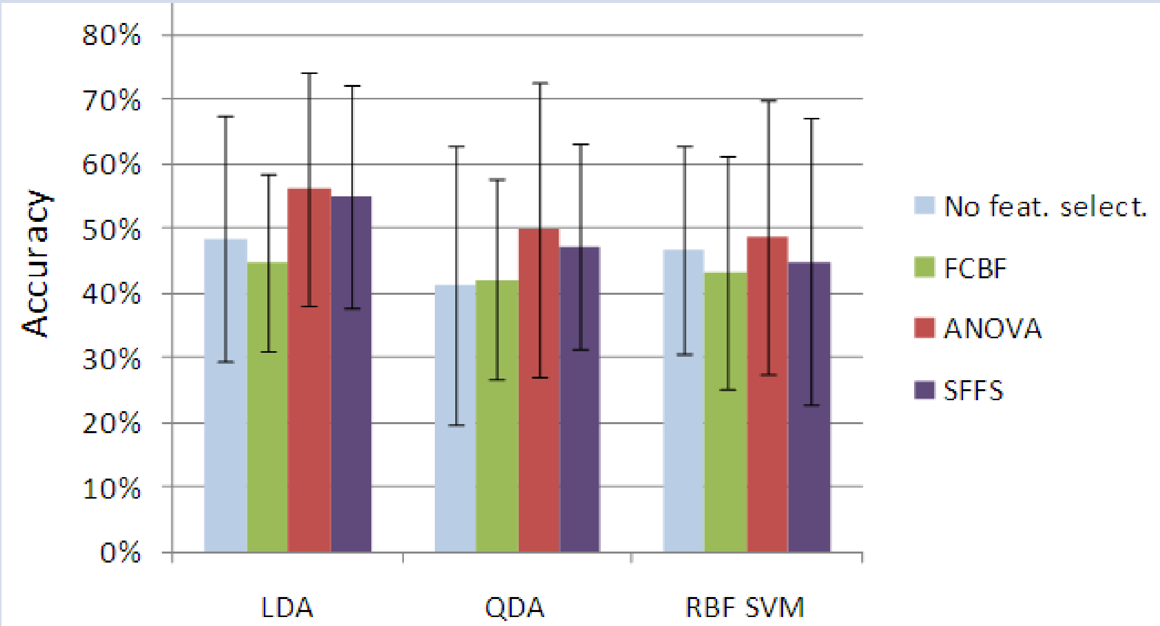
Peripheral features classification, confusion matrix for “FCBF + QDA”:




| True \ Estimated | Easy (Boredom) | Medium (Engagement) | Hard (Anxiety) |
|---|---|---|---|
| Easy (Boredom) | 80% | 10% | 10% |
| Medium (Engag.) | 37% | 33% | 30% |
| Hard (Anxiety) | 21% | 19% | 60% |

# Classification – EEG's

EEG features classification, confusion matrix for “ANOVA + LDA”:




| Estimated / True | Easy (Boredom) | Medium (Engagement) | Hard (Anxiety) |
|---|---|---|---|
| Easy (Boredom) | 57% | 43% | 0% |
| Medium (Engag.) | 21% | 50% | 29% |
| Hard (Anxiety) | 19% | 19% | 62% |

# Classification – Fusion

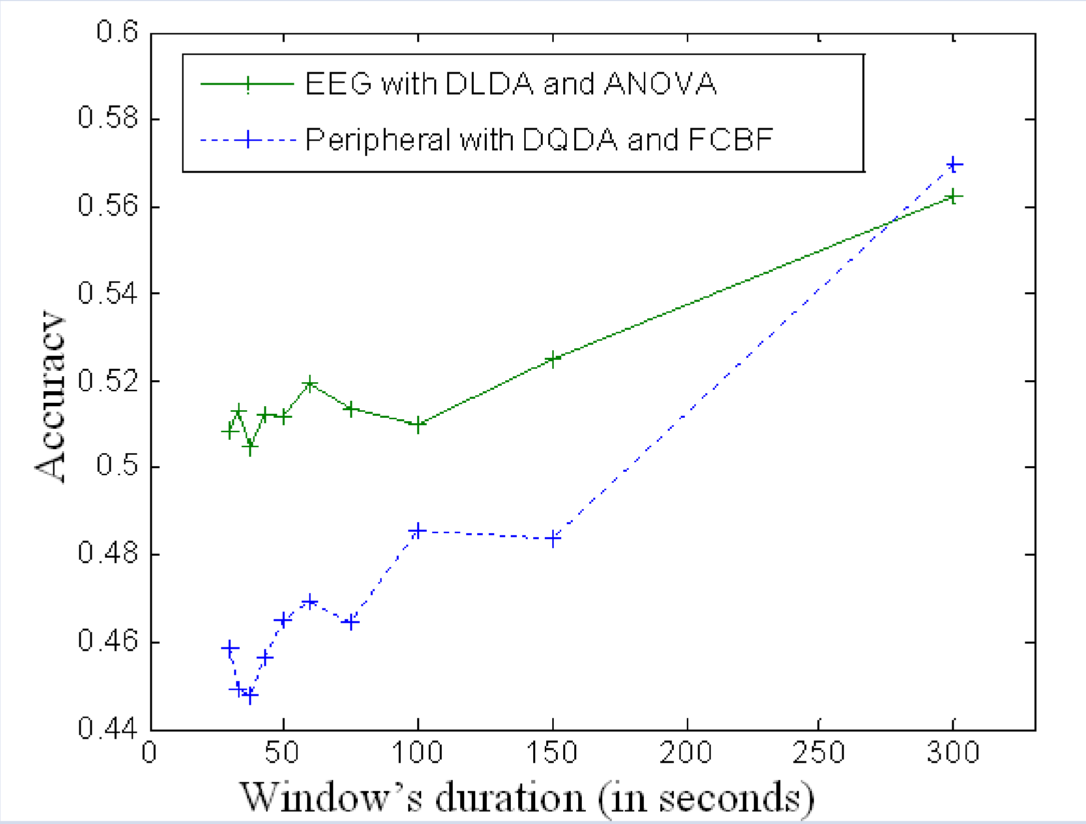
**Fusion** of EEG and peripheral features with Bayes Belief Integration:

- 5% increase of average accuracy;
- 2% (7%) increase for the easy (hard) conditions;
- 11% decrease for medium condition comp. with EEG's, but 6% increase comp. with peripherals features;
- only 4% error in classifying easy as hard, or hard as easy.

| Estimated / True | Easy (Boredom) | Medium (Engagement) | Hard (Anxiety) |
|---|---|---|---|
| Easy (Boredom) | 82% | 14% | 4% |
| Medium (Engag.) | 29% | 39% | 32% |
| Hard (Anxiety) | 4% | 27% | 69% |

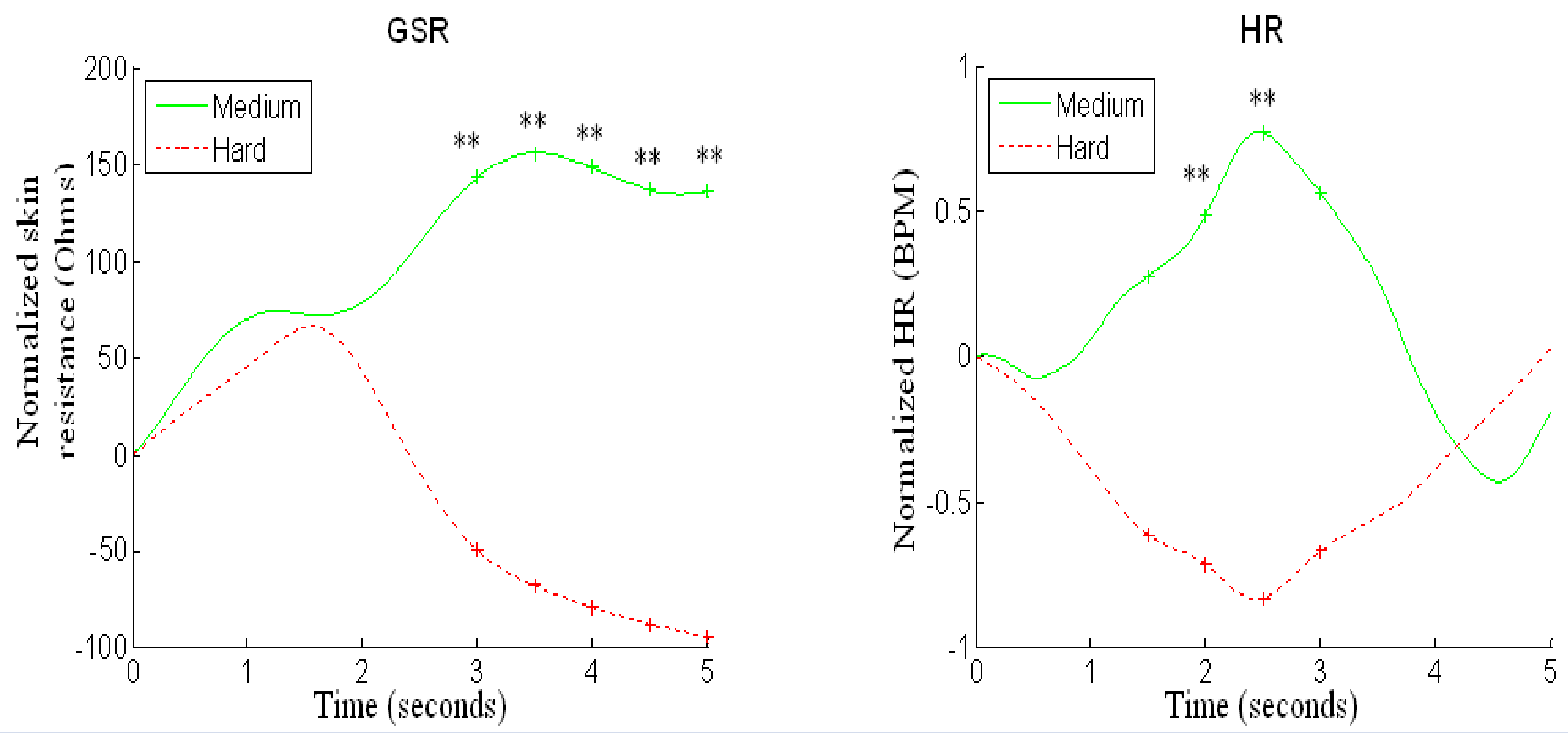
# Classification – Effect of trial duration

**Classification accuracy as a function of trial duration**:
EEG features are more robust for short-term assessment.



# Game over

## GSR and HR in the 5s following game over:



## Game over

Possible interpretations:

- GSR: low for high difficulty, which might indicate more arousal and stress to start a new game known to be difficult;
- HR: often higher for unpleasant stimuli, which might indicate here deception of losing a game at medium difficulty.

Thus different patterns of peripheral activity exist btw. sessions where users reported:

- higher motivation and pleasantness, or
- high pressure and less motivation.

Could be used to distinguish engaged from stressed states.

## Conclusions and future work

**Research hypotheses:**

- H1 verified: playing Tetris at different levels of difficulty induces different emotional states;
- H2 somehow verified: is the change of emotional state due to boredom, or to an increase of competence?
- H3 somehow verified: accuracy >> chance levels, interest of fusion, of EEG’s for short-term analysis.

**Emotional states:**

- easy condition: boredom (low valence, arousal, and motivation, and high dominance);
- medium condition: engagement (high arousal-valence);
- hard condition : anxiety (neg. valence, low dominance, high arousal until gives up).

## Conclusions and future work

**Others:**

- engagement can decrease if game difficulty does not change;
- analysis of game-over: distinct patterns of GSR and HR in 5s following end-game (to distinguish engagement from stress?).

**Future work:**

- increase classification accuracy: feature selection, player dependant framework;
- fusion with other modalities, e.g. voice, body;
- user and context modeling: goals, personalities;
- temporal information: mood, previous emotional state and game events;
- develop affective Tetris (and other games).