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# Stress Assessment in Video Games Using Players' Behavioural and Physiological Data

Susanna Brambilla, Giuseppe Boccignone,
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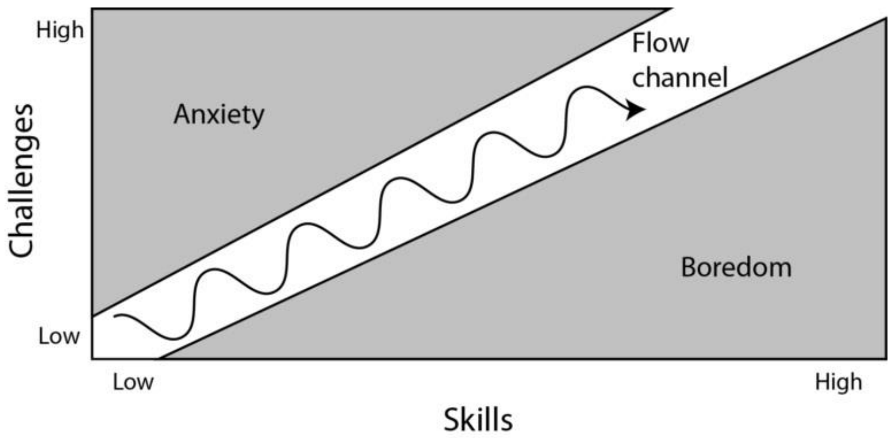
# Introduction

*Goals:*

- **Entertainment**: improve the players experience by keeping them in the **flow** state (CSIKSZENTMIHALYI, 1990)
- Support the development of **emotion-driven** video game **adaptation**




*Idea:*

Detect in **real-time stress level** of the players by collecting their **motion behavioural and physiological data.**

# State-of-the-Art

Past works (e.g.):

- data considered: **pressure** on the game pad (Sykes and Brown, 2003), **pressure and sliding velocity** on a graphic tablet (Frommel et al. 2018)

Results:

- **Pressure** is **harder** when people are stressed
- **Sliding velocity** on tablet **higher**
- **good accuracy** in classification tasks

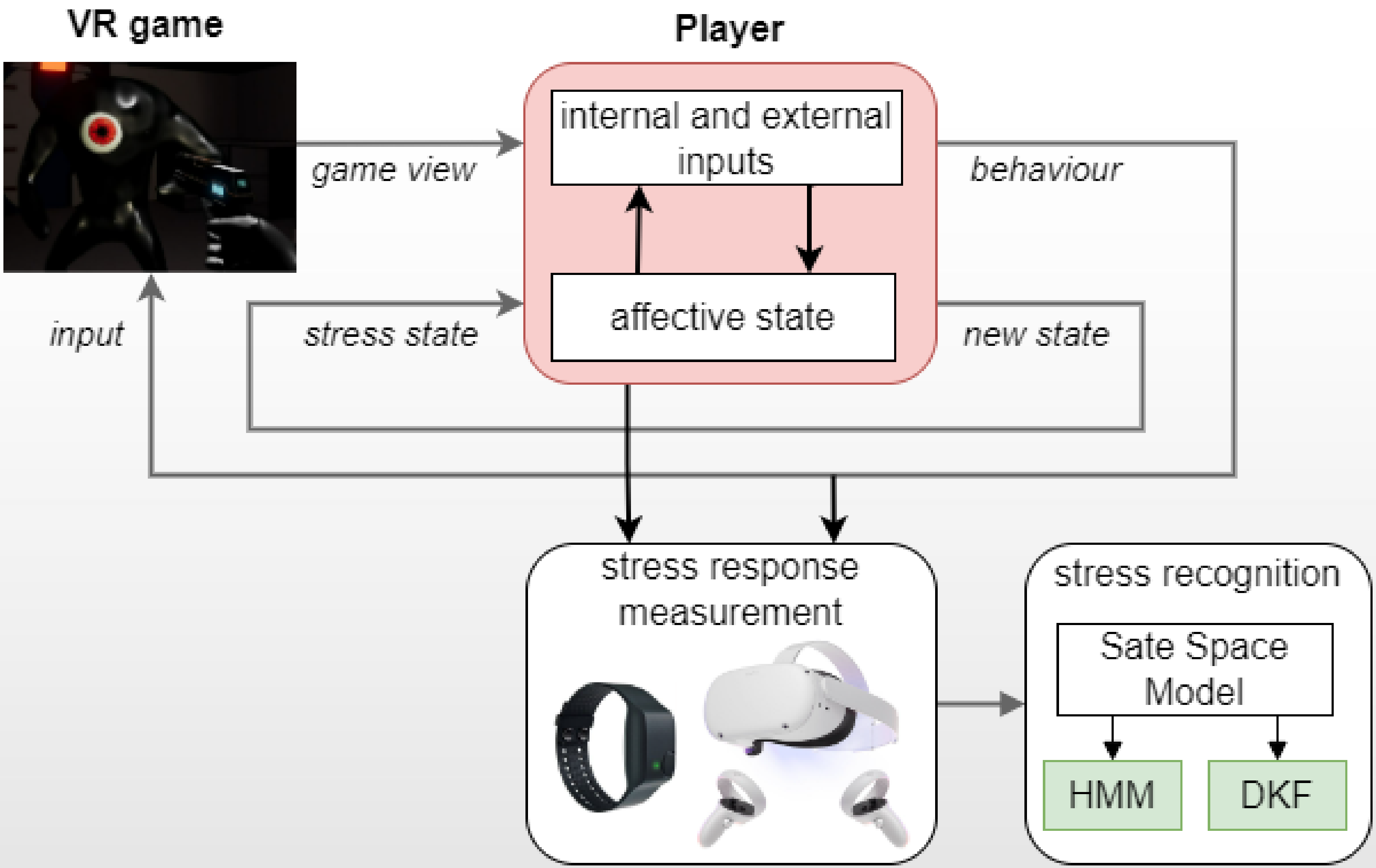
Limitations:

- **Stress** not characterized in its **evolution over time**
- No **VR environment** considered

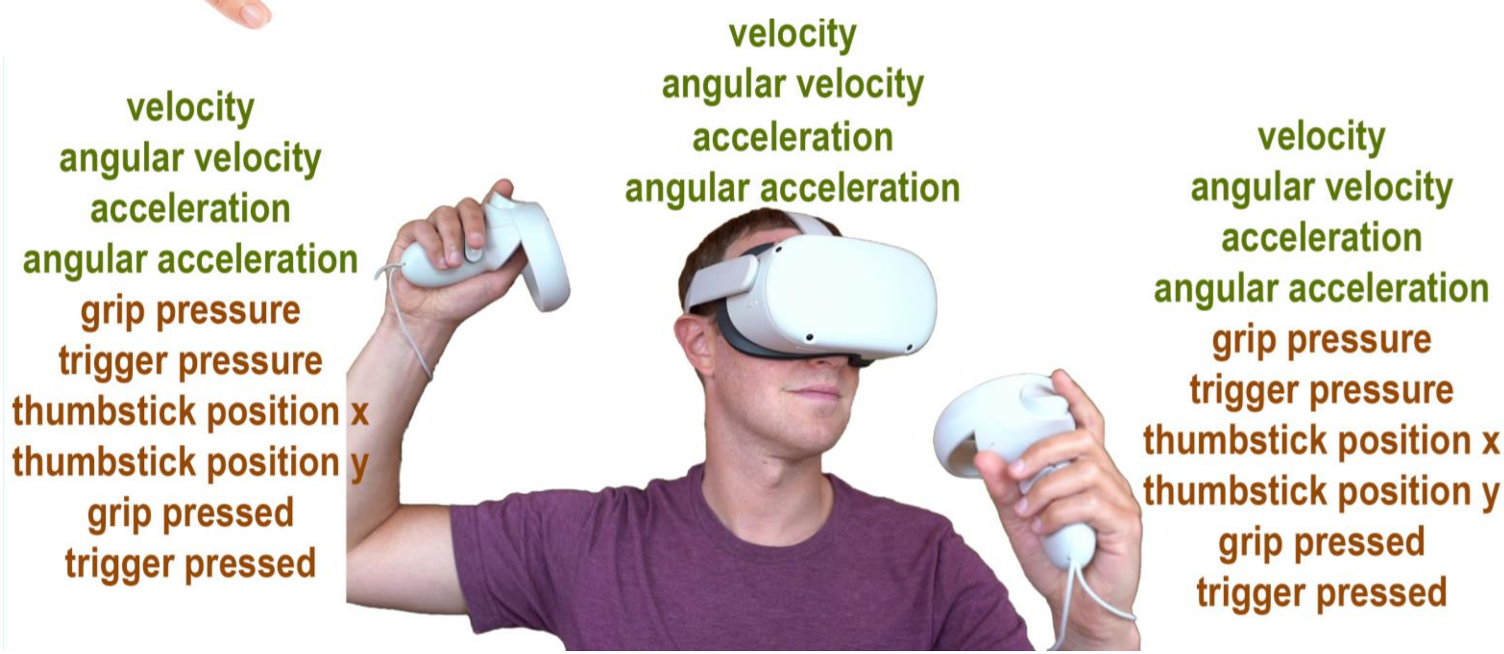
**Our contributions:**

- **Evolution of the stress** level considered in terms of **state-space dynamics**
- **VR** environment: high level of **immersivity** and richer **interaction data**

# System Structure

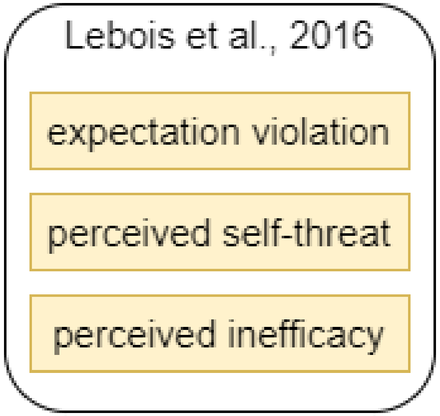


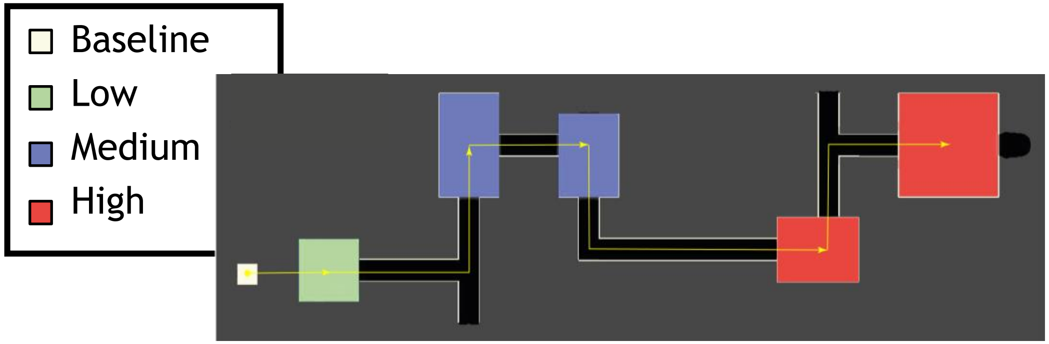
# Data Collected

# Design of the Video Game

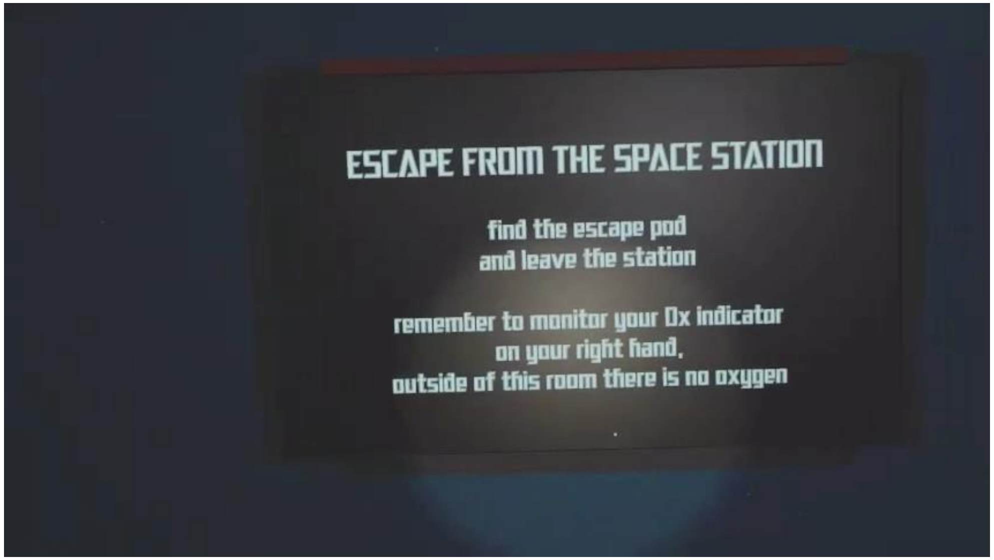
*Players' goal*: escape from an abandoned space station, facing enemies in a hostile environment, surviving with few resources.




**Stress elements:**

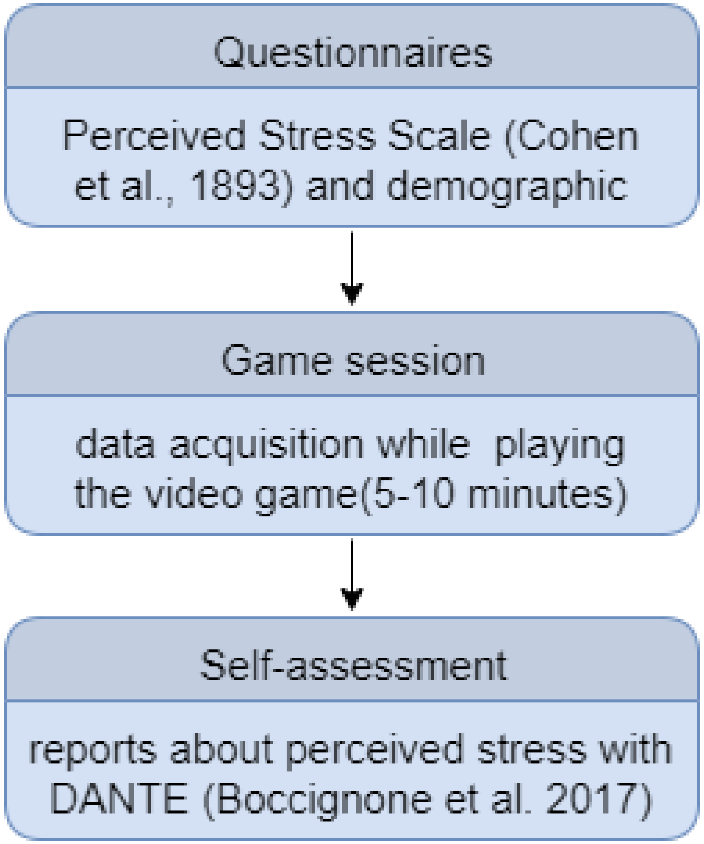
- Monstrous enemies
- Scary sounds and music
- Dim lights
- Lack of oxygen
- Scarcity of resources

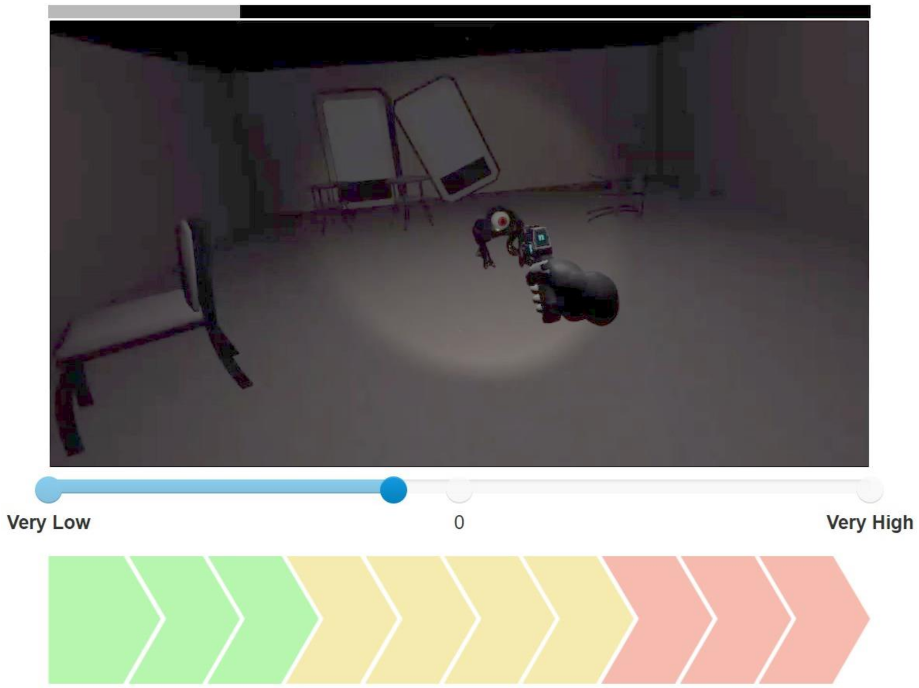


# Testing
## Data Collection

16 volunteer testers, in the range of 22 and 29 years (mean age of 24.7).

- Participants read and signed a **consent form** prior to the test.
- No **motion sickness**



# Data Analysis

**Data preparation:**

- **filtering and segmentation** using a sliding window (6s size, 1s stride)
- **feature extraction** of statistical features:
  - **VR:** mean, standard deviation, minimum and maximum values, and mean of the number of times a button is pressed
  - **EDA**: mean, standard deviation, minimum and maximum values, slope, dynamic range, mean of the SCR/SCL components, and correlation between SCL and time

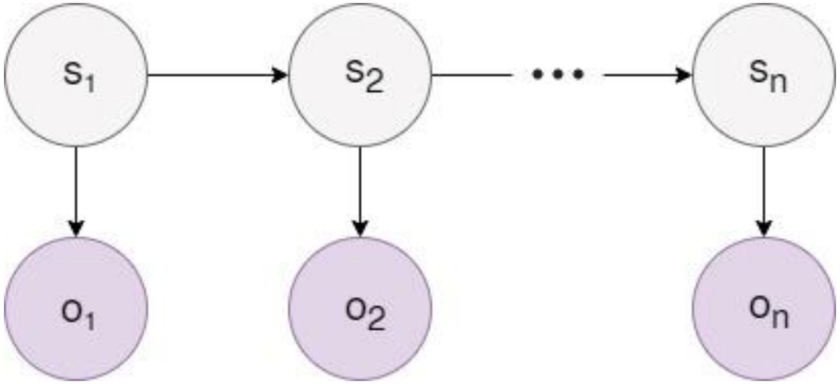
**Statistical analysis:**

- **Pearson correlation** with **matrices** computation
- **Selection** based on correlations (73 VR features and 7 EDA features input to the models)

# Modeling Stress Level Dynamics

**State Space Model (SSM)** for stress level dynamics in which each hidden state $s_t$ generates physiological and behavioral observations (vector $o_t$) at each time step.

SMM to perform posterior inference about hidden states (stress level state estimation).




Problems:

- **classification**, where the stress level is a discrete variable → **Hidden Markov Model (HMM)**
- **regression,** where the stress level is a continuous variable → **Discriminative Kalman Filter (DKF)**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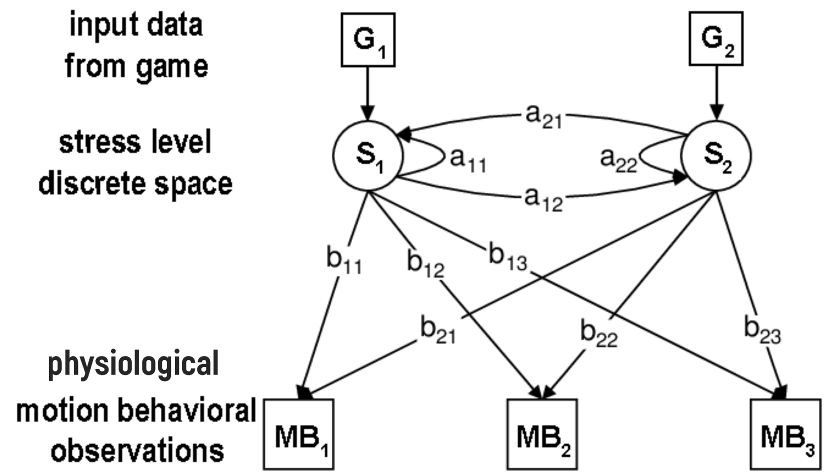
# Stress Assessment Models
## Hidden Markov Model (Bishop, 2006)

Parameters:

- initial probabilities of each state, π
- state **transition probabilities** A
- **emission probabilities** B

gaussian distribution of observations

*Training*: **Baum-Welch** algorithm




- Label values were **discretized** (between 0 and 1) and different experiments with different number of **discrete states**
  - **Binary:** stress *vs* no-stress (0-0.3, 0.3-1)
  - **Three classes:** no-stress *vs* low stress *vs* high stress (0-0.25, 0.6-1)
  - **Four classes:** no-stress *vs* low stress *vs* medium stress *vs* high stress (0-0.25, 0.25-0.5, 0.5-0.75, 0.75-1)
- **Leave-One-Out Cross-Validation (LOOCV)**
- **Log-likelihood** computation and classification of each test sequence
- **Accuracy** comparing the predicted labels to the actual labels

# Stress Assessment Models
## Discriminative Kalman Filter (Burkhart et al., 2020)

Recursive algorithm

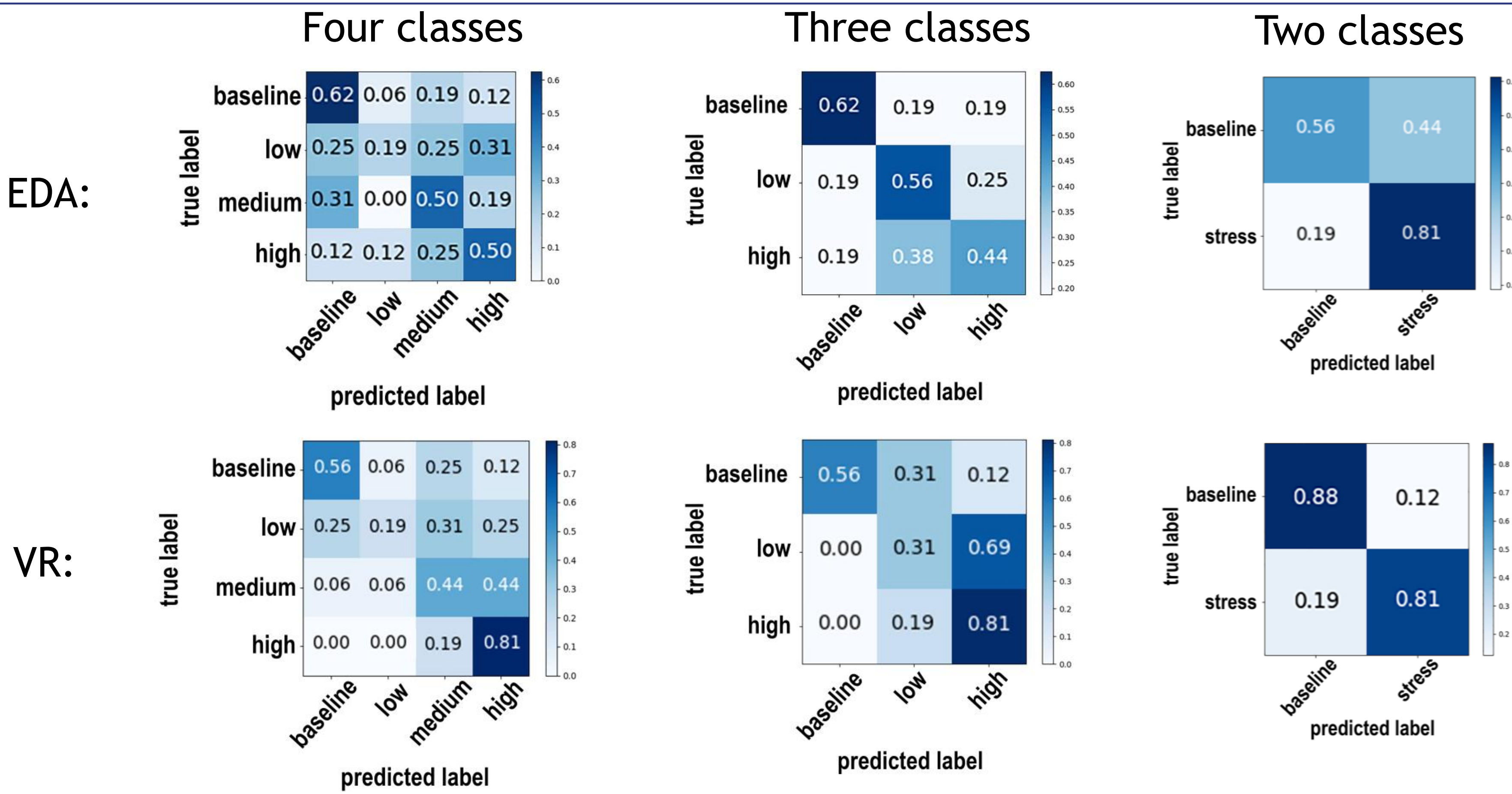
- **prediction phase:** next state and errors estimation using current state and error covariance
- **update phase:** estimates correction using the measurement observation

**DKF:**

An **approximation** for models with linear, gaussian dynamics but nonlinear, nongaussian observations

- **Leave-One-Out Cross-Validation (LOOCV)**
- **normalized Root Mean Squared Error (nRMSE)**

# Discrete SSM Results



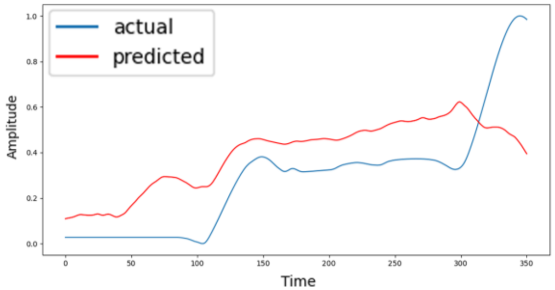

| | four classes | three classes | two classes |
|---|---|---|---|
| data | ACCURACY SCORE | | |
| EDA | 45.3 | 54.1 | 68.8 |
| VR | 50.0 | 56.2 | 84.4 |

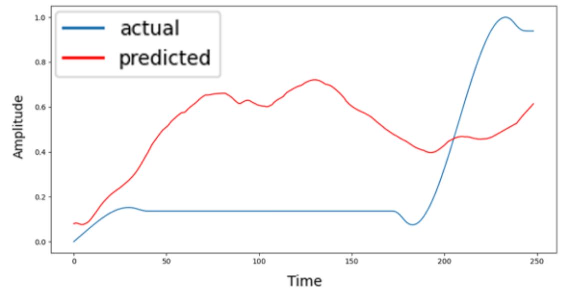
# Continuous SSM Results

subject 13

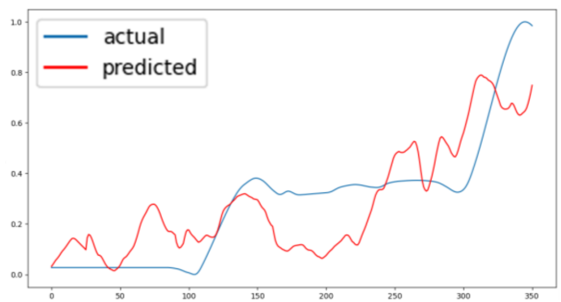
subject 15

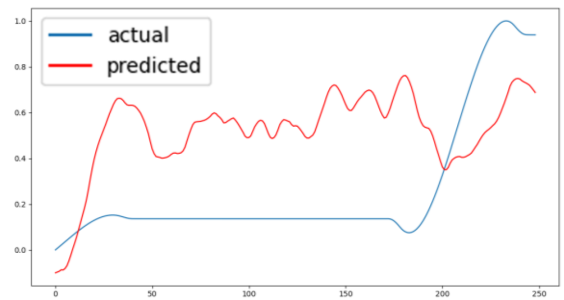
EDA




VR




time

time

nRmse computed for each trial:

| | EDA | VR |
|---|---|---|
| subj | nRMSE | |
| 01 | 0.35 | 0.44 |
| 02 | 0.65 | 0.39 |
| 03 | 0.45 | 0.59 |
| 04 | 0.68 | 0.42 |
| 05 | 0.39 | 0.61 |
| 06 | 0.44 | 0.49 |
| 07 | 0.69 | 0.89 |
| 08 | 0.48 | 0.57 |
| 09 | 0.48 | 0.60 |
| 10 | 0.67 | 0.73 |
| 11 | 0.36 | 0.50 |
| 12 | 0.43 | 0.45 |
| 13 | 0.54 | 0.43 |
| 14 | 0.54 | 0.44 |
| 15 | 1.0 | 1.0 |
| 16 | 0.56 | 0.80 |
| AVG | 0.54 | 0.57 |

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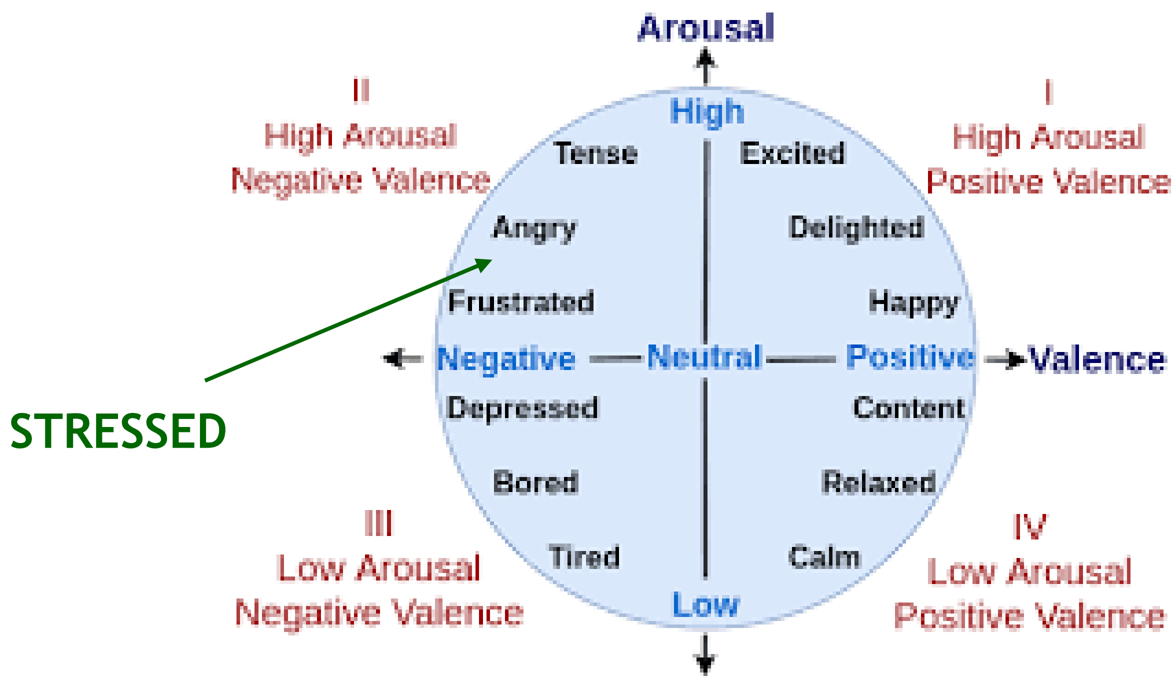
# Tracing Stress and Arousal in Virtual Reality Games Using Players' Motor and Vocal Behaviour

Riccardo Lombardi, Giuseppe Boccignone, N. Alberto Borghese, Susanna Brambilla, Eleonora Chitti, Riccardo Lombardi, Laura A. Ripamonti

# Key Concepts
## (Russell, 2003; Csikszentmihalyi, 1990)

- *Valence:* emotional pleasure (from negative to positive)
- *Arousal:* emotional excitement (from low to high)



# Introduction

*Idea*: integrate **stressors and voice interaction** in a Virtual Reality game to assess player **arousal and stress**

*Research questions*:

1. Evaluate the **relation** of players' **actual arousal level with their actual stress level**
2. understand if **stress and arousal can be estimated** from players' behaviours (players' movements/action and voice)

*Goals*:

- **Entertainment**: improve the players experience (flow)
- Support the development of **emotion-driven** video game **adaptation**



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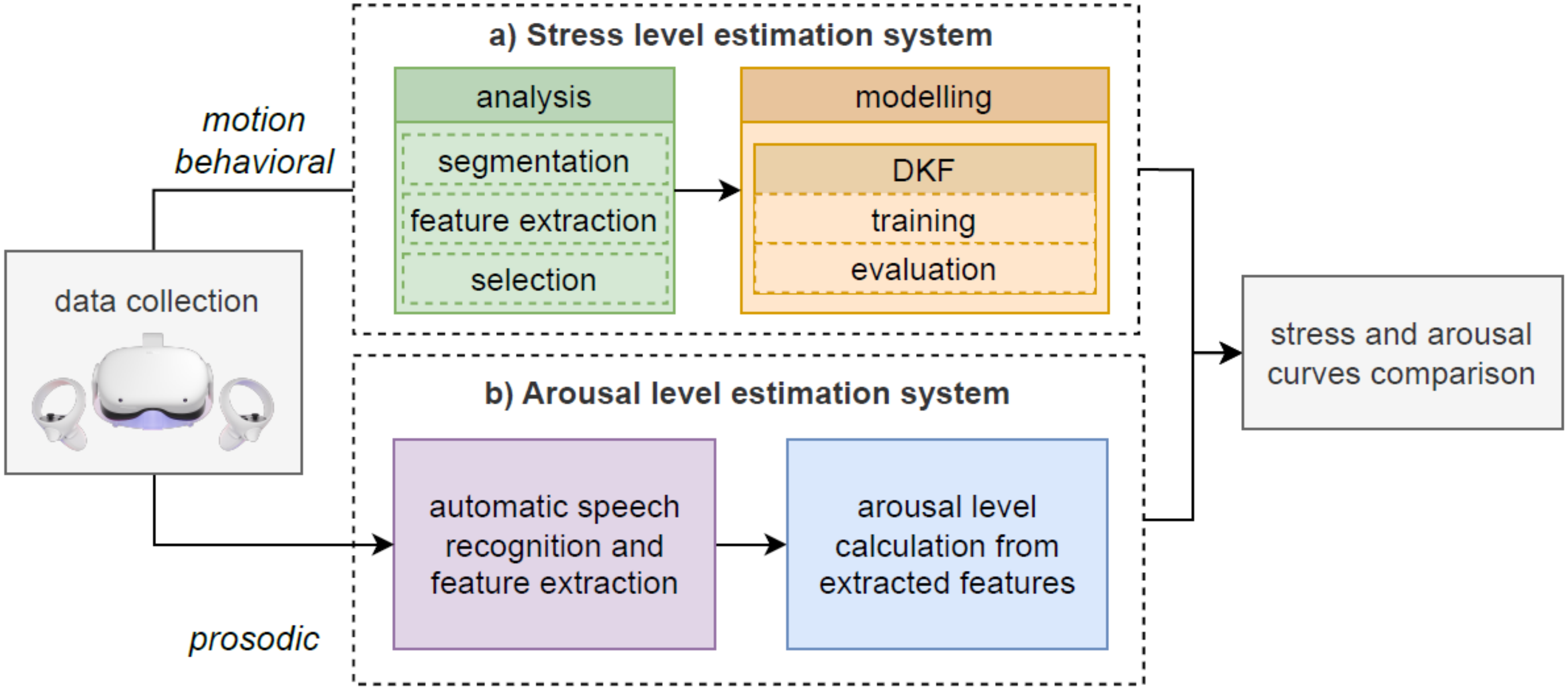
# System Overview



# Video Game Voice Commands

A layer of **vocal interactions** added to the game

*Minerva* -> artificial intelligence of the space station

- **Analyzes** the **sentence**
- **Extract** the needed **keywords**

Two types of commands:

1. **Players ask Minerva for resources.**
    1. Available at any time in the game
    2. by pronouncing «Minerva» and one specific command, Minerva provides what it is requested (e.g., ammunition, oxygen, …)
2. **Minerva asks a question**
    1. Available in different stages of the game
    2. The AI asks the players to answer a specific question (e.g., at the beginning of the game to collect baseline data players are aksed to introduce themselves)

# Speech recognition

*Automatic Speech Recognition (ASR)* or *Speech-to-text*: feature that allows a program **to process human speech** into a **written format.**

***DictationRecognizer:*** functionality of the *Unity Speech Recognition* library, which exploits the *Windows Online Speech Recognition* technology (Cortana) to perform the Speech-To-Text operation

Values:

- **Fundamental frequency $F_0$ (Hz)** -> calculated from frequencies, over time on a specific audio channel
- **Intensity (dB)** of players' voice -> calculated from amplitude of the sound over time on a specific audio channel

# Arousal from Voice

Fundamental frequency and intensity values collected used to calculate:

- *μ* : the mean of the values,
- *σ*: the standard deviation,
- *min*: the minimum value of the voice recording,
- *max*: the maximum value of the voice recording,
- *R*: the  range, namely, the difference between max and min.

The **arousal** obtained is a number between -1 and 1 -> compared to baseline and evaluated in **real-time**

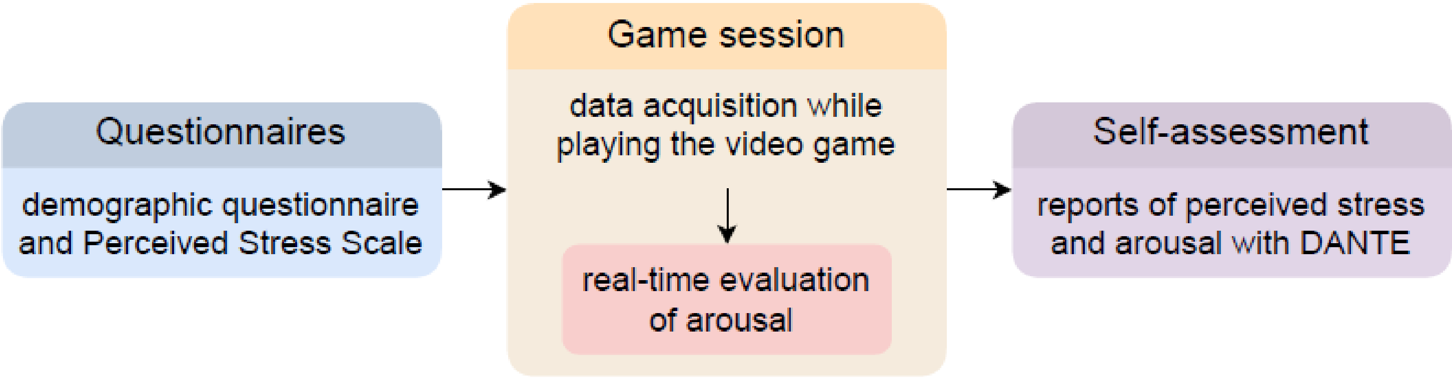
$$a_i(n) = \mathrm{sgn}(x_i(n) - \underline{x_i})$$

$$\overline{a(n)} = \frac{1}{N_x} \sum_{i=1}^{N} a_i(n)$$

# Testing

16 volunteer testers, average age 25.

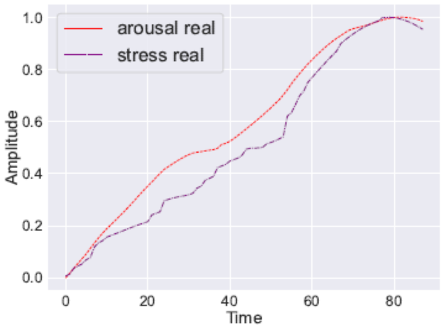
- Participants read and signed a **consent form** prior to the test.



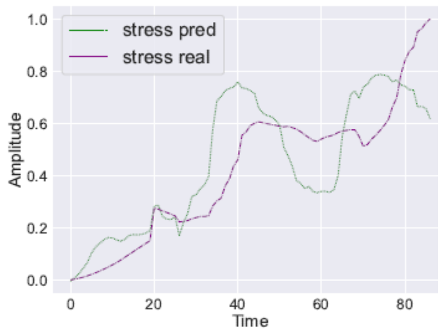

*DANTE* (Dimensional Annotation Tool for Emotions) [Boccignone et al. 2017]:

- watch gameplay video
- continuous self-assessment of stress and arousal

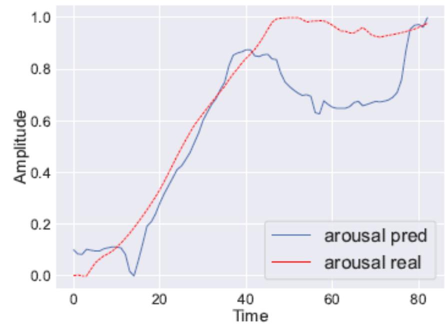
# Results



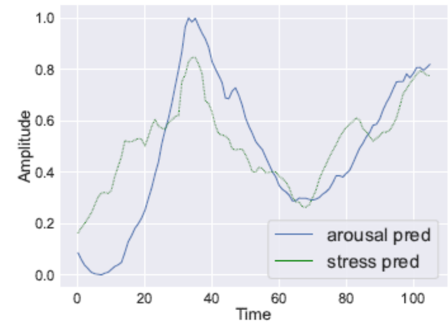

(a) Curves related to subject 08.



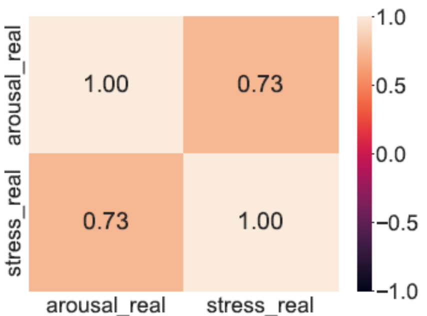

(b) Curves related to subject 12.

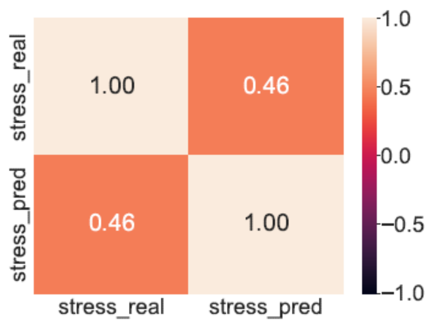


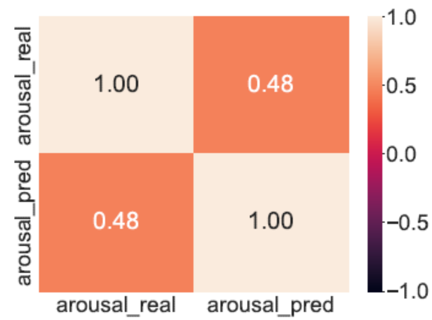

(a) Curves related to subject 07.

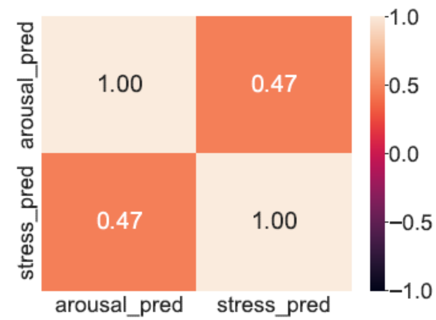



(b) Curves related to subject 16.



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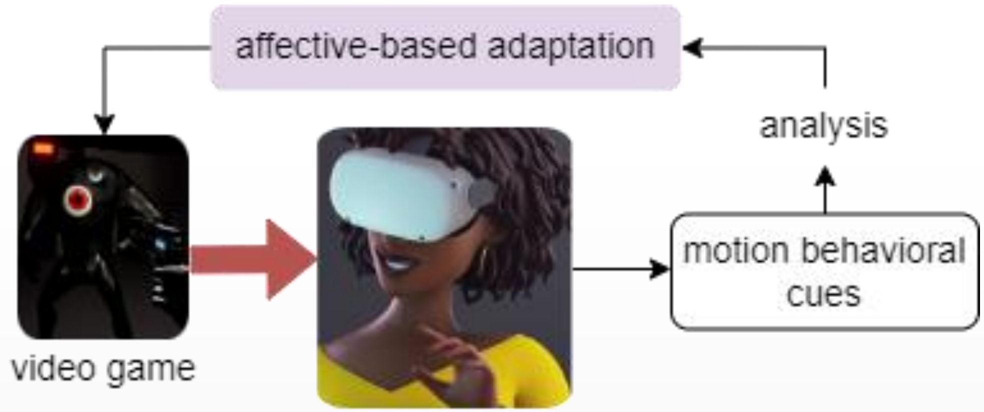
# StrEx: Towards a Modulator of Stressful Experience in Virtual Reality Games

*Daniele Croci*, *Giuseppe Boccignone, N. Alberto Borghese, Susanna Brambilla, Laura A. Ripamonti*

# Introduction

**Affective Gaming (AG):**

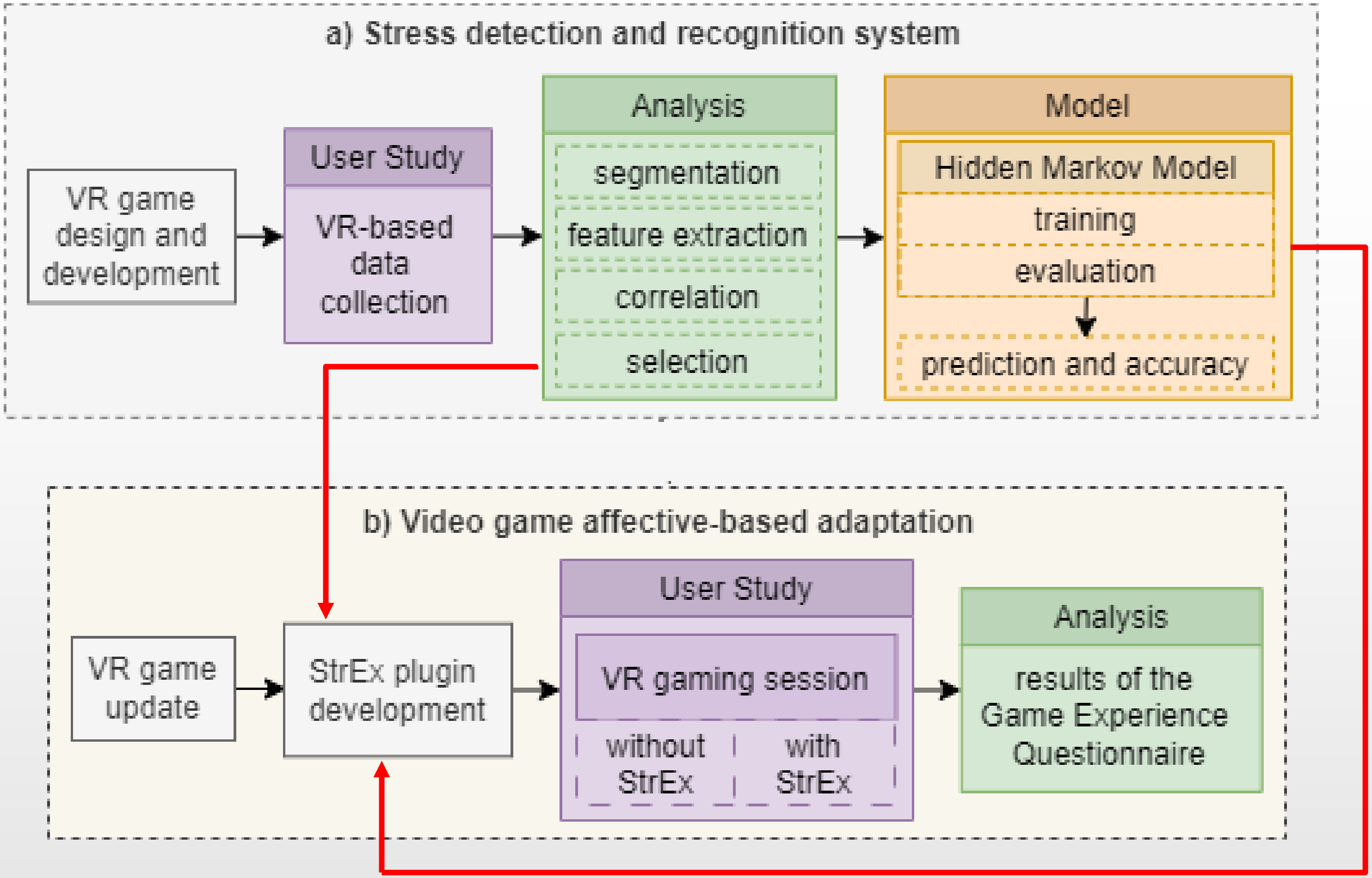



*Idea:* design and develop a system that **dynamically adapts** a virtual reality game content based on **players' stress**

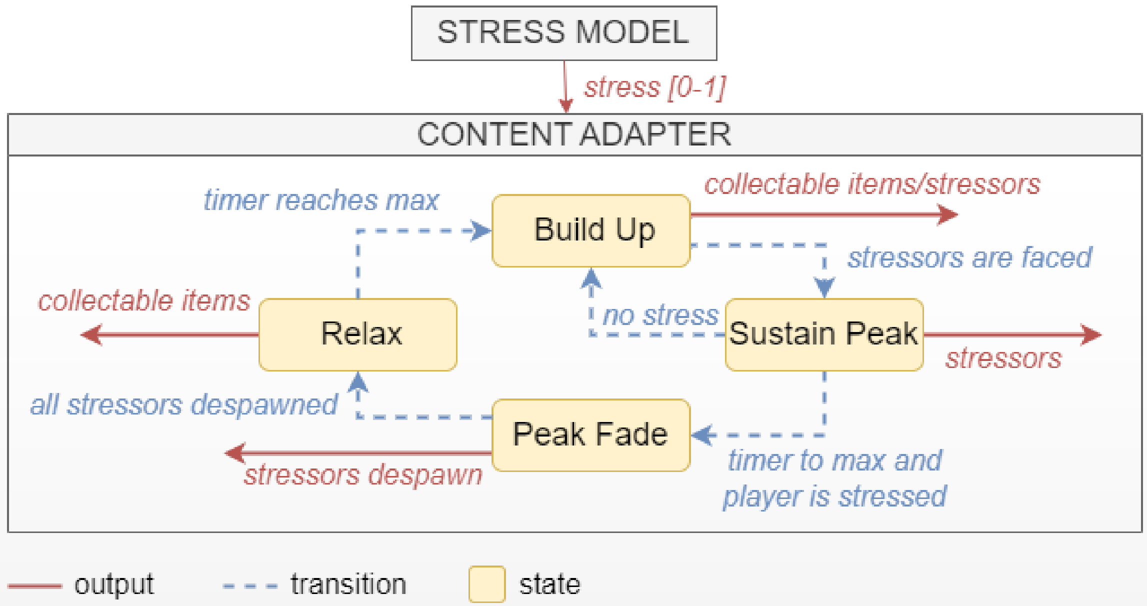
*Goals:*

- Previous **model validation**, HMM binary model trained with **motion behavioral data** (Brambilla et al., 2022)
- **Evaluate** impact on players' **experience**

# Overall System



# StrEx Structure




**Build up**: the AI generates stressful elements and items near the player; when the player faces an external stressor -> Sustain Peak

**Sustain peak**: if a threshold of the stress level is exceeded by players (in a predefined time period) -> Peak Fade; else -> Build Up

**Peak fade**: all stress elements the players are not facing are removed -> Relax

**Relax**: no stressful elements are generated, only items; after a recovery time (30-45 seconds) -> Build Up

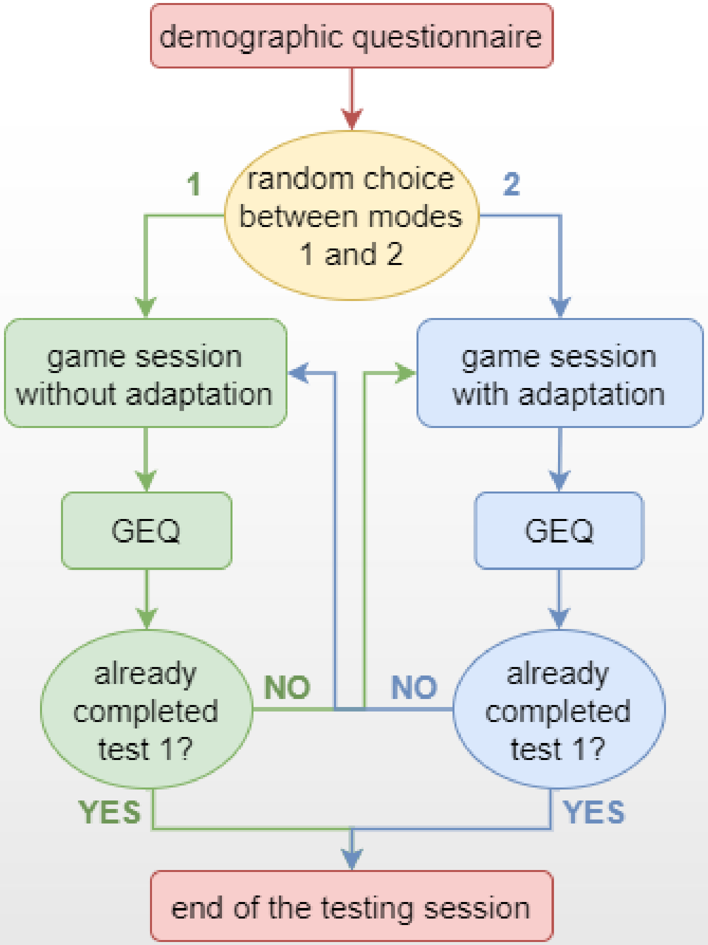
# Testing

13 volunteer students, age 18-29

**Game Experience Questionnaire** (GEQ)

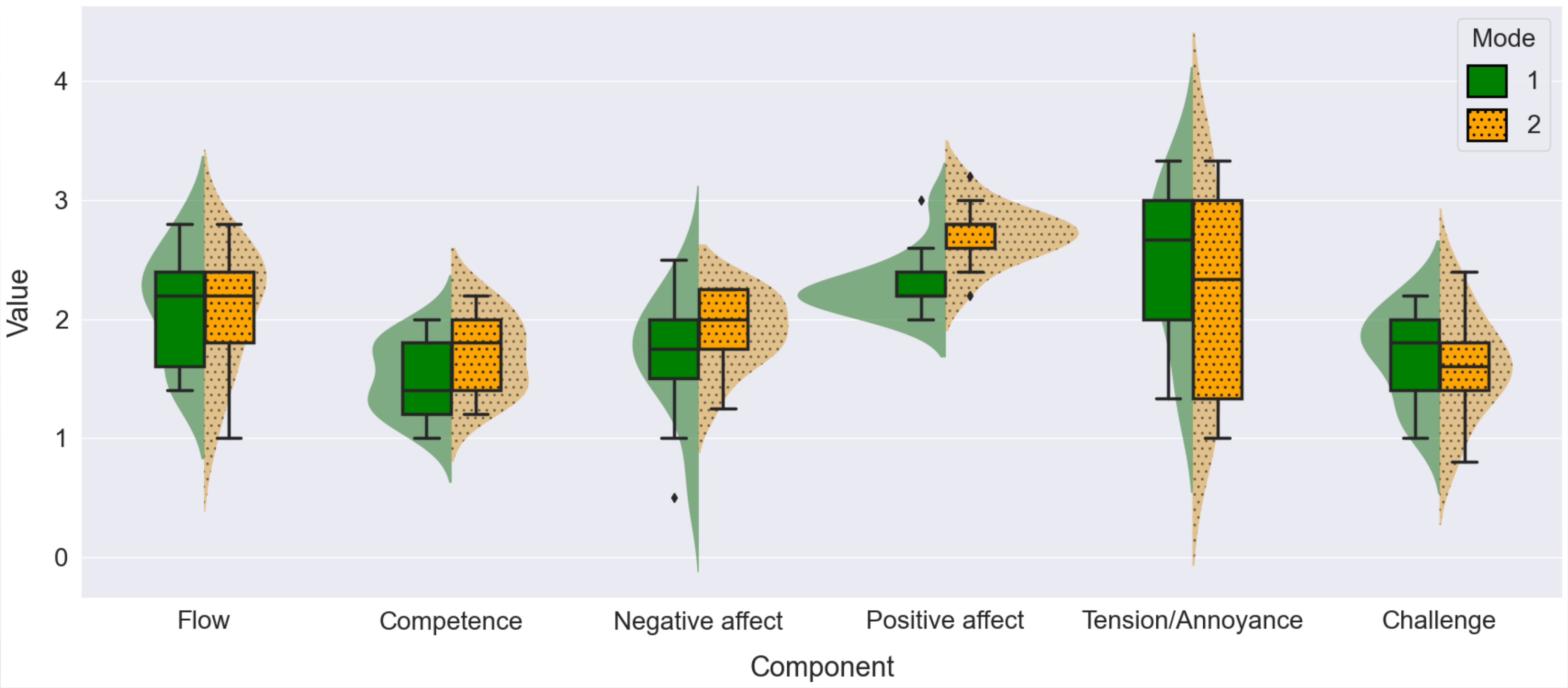
Components:

- **Sensory/imaginative immersion** ✗
- **Flow** ✓
- **Competence** ✓
- **Positive affect** ✓
- **Negative affect** ✓
- **Tension/annoyance** ✓
- **Challenge** ✓



# Results

Violin plots: **distribution** of the average score for the different components using all subjects, **comparing** the two **game modes**



# CONCLUSIONS

Promising results:

- **potential** for using **voice interaction** and **motion behavioral data** as methods to assess players' **affective states** during VR game play
- Stress-based adaptation could **improve** players' **perceived competence** and the game becomes **less frustrating and challenging** which results in a **decrease in tension/annoyance**

Future works:

- gather **data** from more subjects
- include information for players **personalization**
- inclusion of other **channels**

# Thanks for your attention