



## Visual Stress Analysis System

# Research Model Results

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# 1 Introduction

The primary goal of the research is to predict various stress states based on detection of physiological patterns in response to psychological triggers.

The study protocol included triggers that stimulated cognitive, emotional (positive and negative) activity and triggers that proactively reduce cognitive and emotional activity (in favor of defining and diagnosing a neutral stress of a subject), in order to isolate as much as possible, the physiological response patterns related with each type of detected stress.

The current study has been focused on identifying the stress types described in Table 1.

Table 1: Stress Types

Stress Type	Description
Neutral	<ul style="list-style-type: none"><li>Relaxation stimuli</li></ul>
Cognitive	<ul style="list-style-type: none"><li>Tasks that require concentration and thinking, like Math calculations, situation appraisal, etc.</li></ul>
Positive Emotional	<ul style="list-style-type: none"><li>Triggers that stimulate positive emotions (happiness, joy, satisfaction...) like pleasant memory, something funny, positive situation appraisal etc.</li></ul>
Negative Emotional	<ul style="list-style-type: none"><li>Triggers that stimulate negative emotions (fear, sadness, anger...) like unpleasant memory, feel of danger, negative situation appraisal etc.</li></ul>

The subjects that participate in the trial are men and women aged 18-55. During the experiments the data collection included video record and bio-sensors data of the subject in order to validate the results of the analysis.

## 2 Experiments Data Description

During the study the following data were collected:

- 103 hours of video that include four types of triggers.
- 103 hours of bio-sensors data records.

After the experiments are completed, the video recordings are processed in order to extract relevant physiological features. Data editing were performed in order to clean up the artifacts and reducing irrelevant periods for data analysis (such as recovery from triggers periods).

## 3 Research Outcome and Model Accuracy

The data analyzation and machine learning methods based on 89 hours of video (after cleanup) of 172 subjects.

Different types of machine learning algorithms were applied in order to find the most accurate method of stress predictions.

The outcomes that described above are the method with the highest accuracy and high performance relatively to the other methods tested.

The data prediction is divided into two layers:

- First Layer: 3 Stressors Classification model - Neutral, Cognitive and Emotional stresses:
- Second Layer: 2 stressors classification - Emotional Negative vs Emotional Positive.

### 3.1 First Layer: 3 Stressors Classification Model

#### **Model Accuracy**

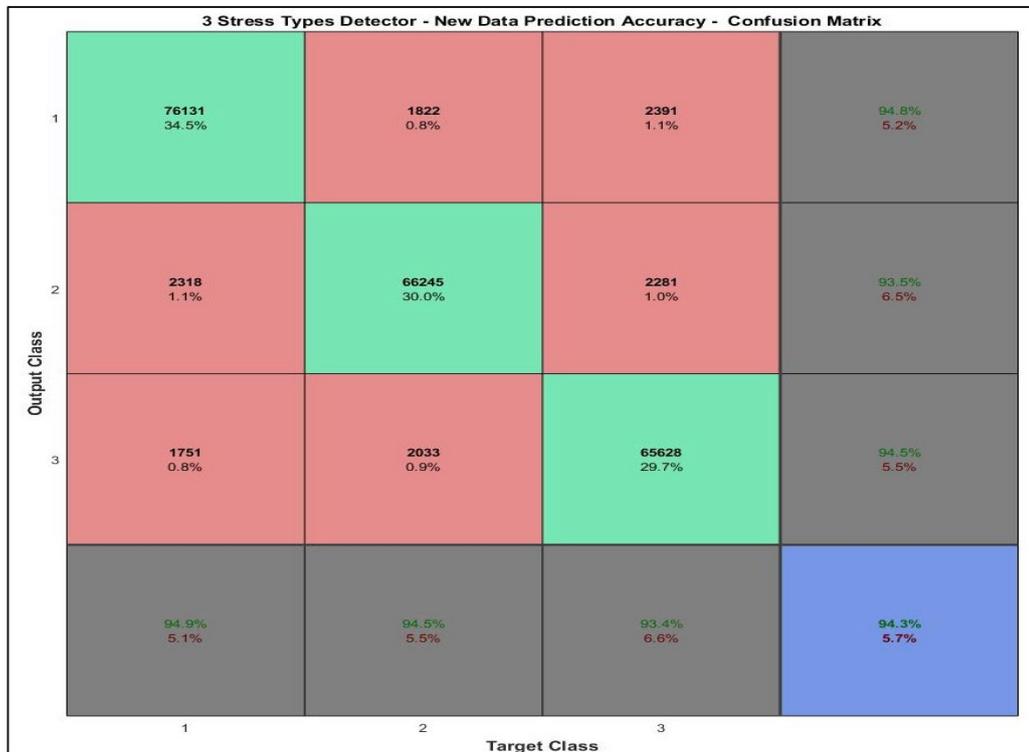
The model was validated using test cases that were not included in training set. The following is a confusion matrix of test cases.

The Confusion Matrix of model prediction includes: Confusion matrix of the model predictions includes:

- Class/target 1 – neutral stress
- Class/target 3 – emotional stress
- Class/target 3 – cognitive stress

An example of the Confusion Matrix is shown in Figure 1.

Figure 1: Confusion Matrix of Model Predictions



**Accuracy Values Calculations**

The calculations are:

$$Recall = \frac{\text{True positives}}{\text{True positives} + \text{False Positives}}$$

$$Precision = \frac{\text{True positives}}{\text{True positives} + \text{False Negative}}$$

$$False\ Positives = 1 - Precision$$

The model accuracy for the 3 Stressors Model are listed in Table 2

Table 2: 3 Stressors Model Accuracy

Item	Measure	%
Model Accuracy	208,004 out of 220,600	94.3%
Neutral stress recall	76131 out of 80,200	94.9%
Neutral stress precision	76131 out of 80,344	94.8%

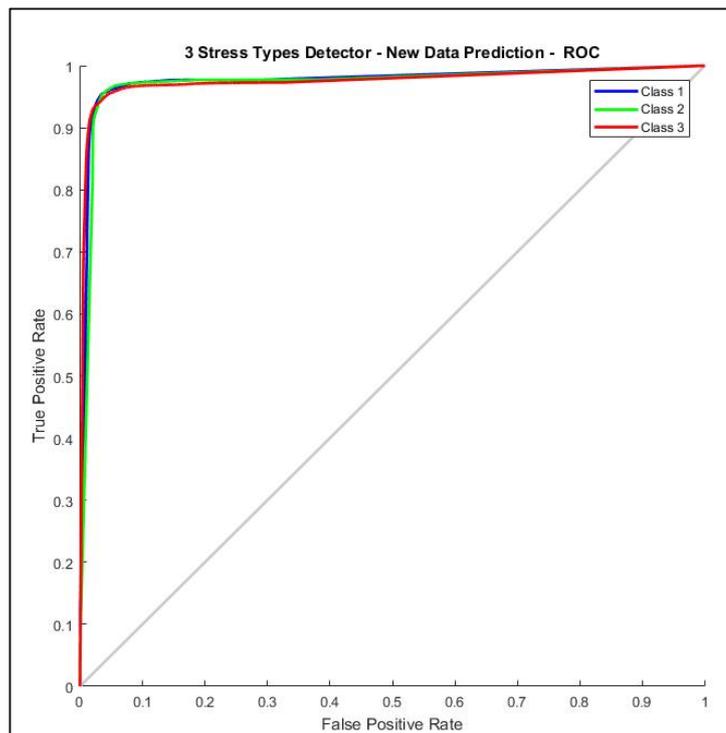
Item	Measure	%
Neutral stress false positive	4,213 out of 80,344	5.2%
Emotional stress recall	66245 out of 70,100	94.5%
Emotional stress precision	66245 out of 70,844	93.5%
Emotional stress false positive	4,599 out of 70,844	6.5%
Cognitive stress recall;	65628 out of 70,300	93.4%
Cognitive stress precision	65628 out of 69,412	94.5%
Cognitive stress false positive	3,784 out of 69,412	5.5%

The Receiver Operating Characteristic curve of test cases observations. The classes are:

- Class 1: Neutral stress,
- Class 2: Emotional stress,
- Cclass 3: Cognitive stress.

The Receiver Operating Characteristic curve chart is shown in Figure 2.

Figure 2:ROC Curve of 3 stressors Model Analysis



### 3.2 Second Layer: 2 Stressors Classification Model

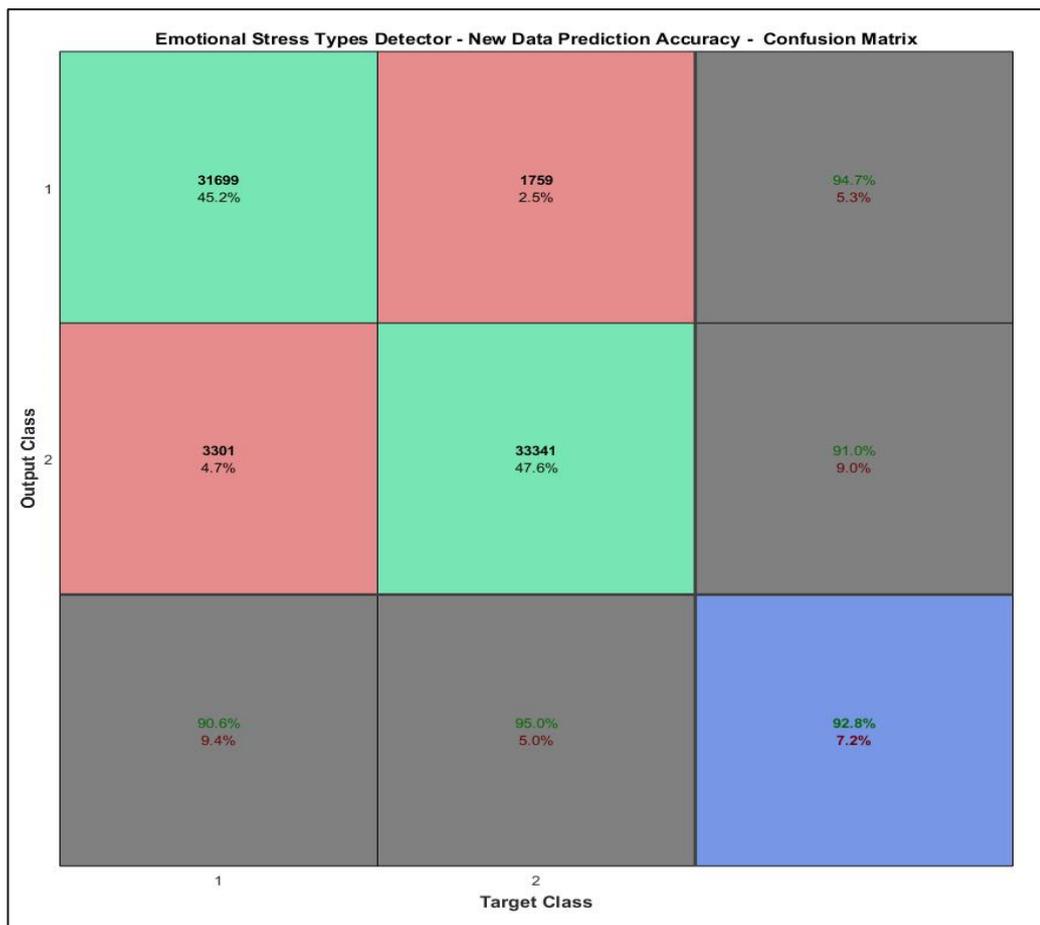
The layer includes - Emotional Negative vs Emotional Positive.

The Confusion Matrix summarized the results of the model analysis and includes:

- Class/target 1 – positive emotional stress
- Class/target 3 – negative emotional stress

The model was validated using cases that were not included in the training. The Confusion Matrix of Emotional Stress Model is shown in Figure 3.

Figure 3: Confusion Matrix of Emotional Stress



The model accuracy for the 2 Stressors Model are listed in Table 2

Table 3: 2 Stressors Model Accuracy

Item	Measure	%
Model accuracy	65,040 out of 70,100	92.8%
Positive emotional stress recall	31,699 out of 35,000	90.6%

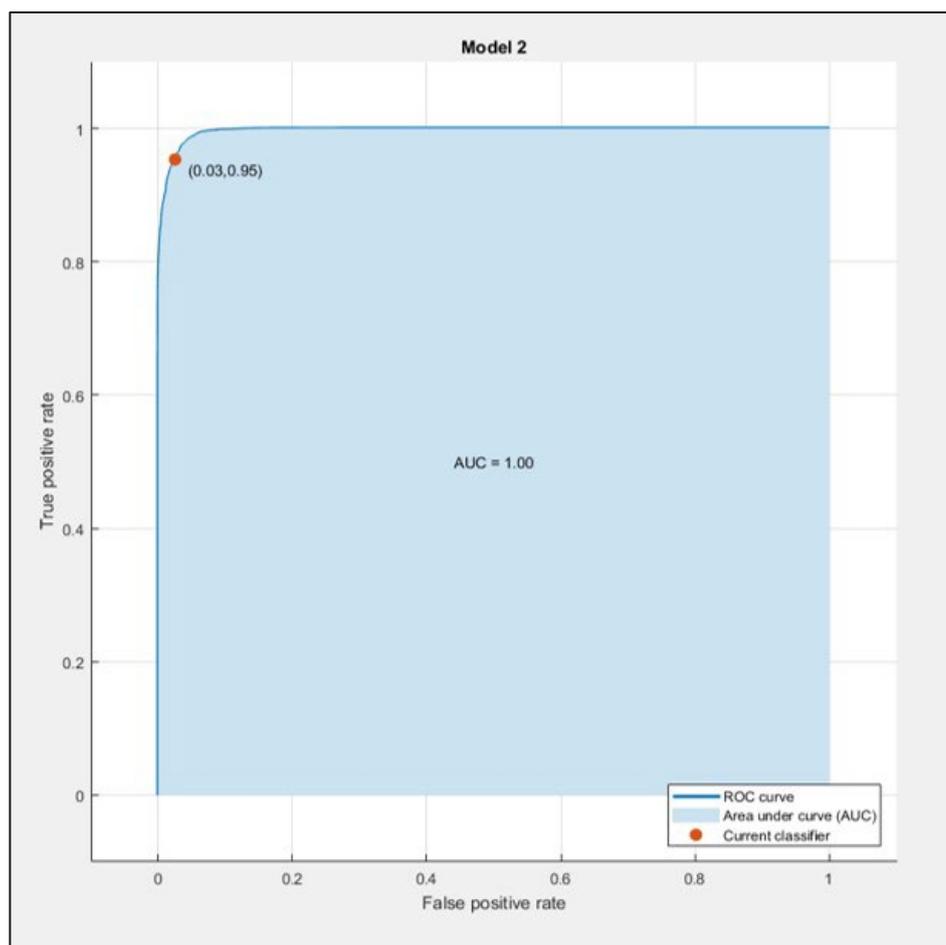
Item	Measure	%
Positive emotional precision	31,699 out of 33,458	94.7%
Positive emotional false positive	1759 out of 33,458	5.3%
Negative emotional stress recall	33,341 out of 35,100	95.0%
Negative emotional stress precision	33,341 out of 36,642	91.0%
Negative emotional stress false positive	3,301 out of 36,642	9.0%

The chart of Receiver Operating Characteristic curve of test cases observations includes:

- Positive emotional stress
- Negative emotional stress

The Receiver Operating Characteristic Curve is shown in Figure 4.

Figure 4: Receiver Operating Characteristic Curve



## 4 Bio-sensors Qualitative Validation

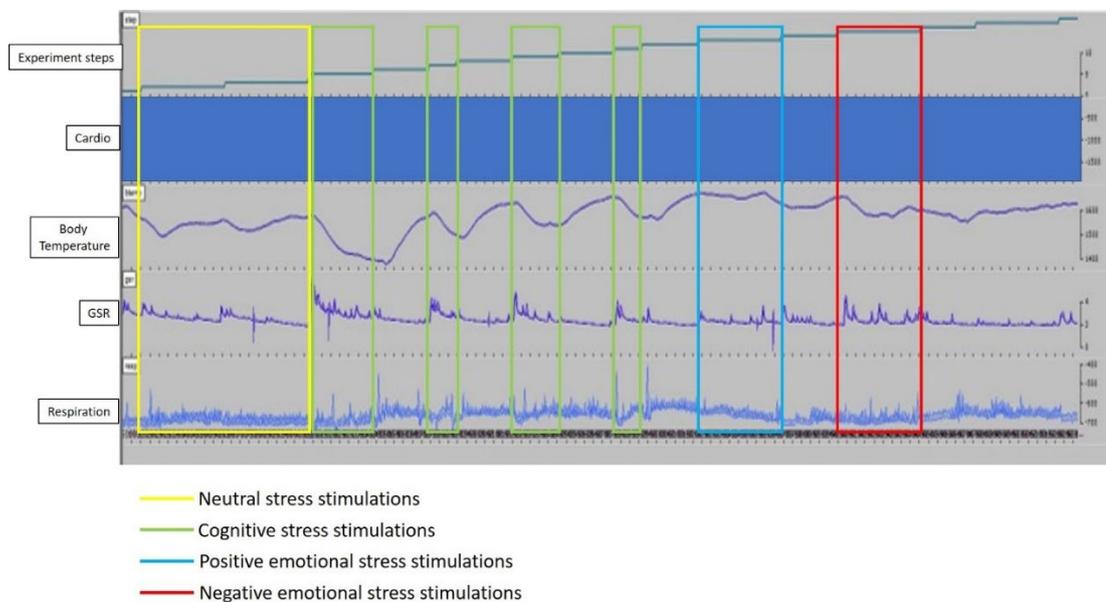
Each predicted case was compared to the related biosensors records in order to ensure that the predictions are correlated to the actual physiological response as measured by biosensors system.

Below is an analysis of one of the cases.

### Case ID – OD01062018

As noted earlier, signals of these measurements allow us to determine whether the psychological trigger has indeed influenced (i.e., provoked a physiological response) and the characteristics of the physiological response (to what kind of stress this response is related). Due to the confidentiality of information we will not be able to display and explain all the characteristic signals and measurements. The Bio-sensor chart is shown in Figure 5.

Figure 5: Bio-sensors records graph of case OD01062018



In figure 5 we can see, a physiological response that can be divided into three different patterns:

The part of neutral stress (marked in yellow) that characterized by a certain type of cardio signals, body temperature with minor increases and decreases that does not change the baseline and GSR with minor responses relatively to the other responses in GSR.

The second part (marked in green) that characterizes a typical physiological response to cognitive stress with a certain type of change in cardio, decreases in body temperature and rapid recovery that eventually changes the base line of body temperature (after trigger termination) and a significant GSR response in the beginning of each trigger period.

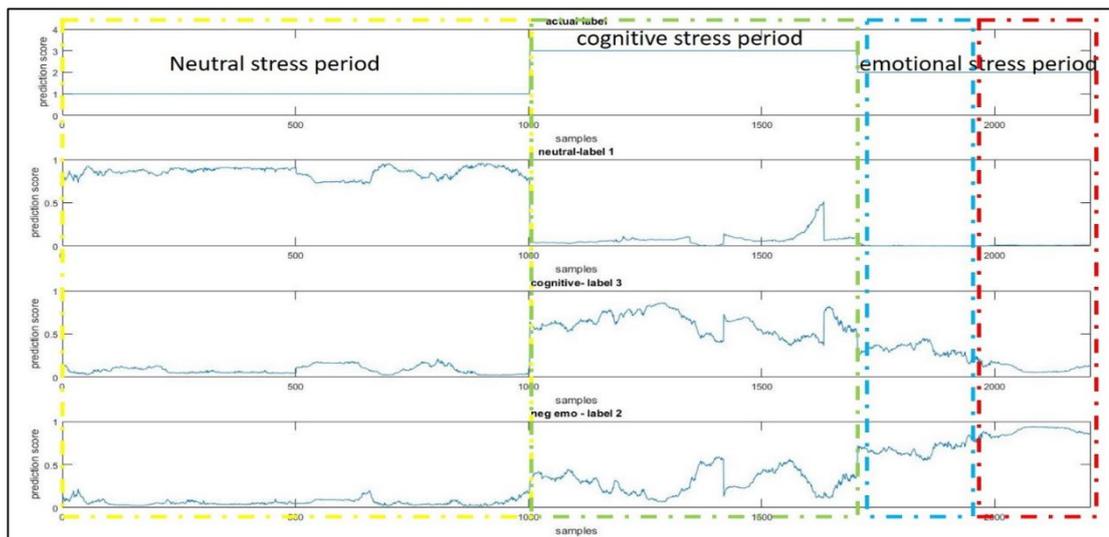
The third part characterizes a response to stimulations that trigger emotional stress. This response pattern is characterized by a certain type of change in cardio (relative to the period of relaxation) and changes in body temperature as follows: a) In the positive emotional part (marked with blue), there is almost no change in body temperature and even an expected increase in temperature; b) In part of negative emotional stimulations (marked in red) there is a significant decrease in temperature without recovery until the end of the experiment (physiological slow or none recovery characterizes emotional response).

**The conclusion from a qualitative analysis of the bio-sensors records is that the psychological stimuli did indeed evoke appropriate physiological responses during the stimulations.**

**Predictions of case OD01062018**

The predictions of case OD01062018 (via first layers: 3 stressors model): 2nd graph- neutral stress signal, 3rd graph- emotional stress signal (positive and negative), 5th graph - cognitive stress signal are shown in Figure 6.

Figure 6: Predictions of case OD01062018



In figure 6 we can see the predictions based on 3 stressors (neutral, cognitive and emotional stresses) model. The samples that were tested in the model are only from relevant periods that marked in figure 5. In this figure we can see the accuracy of the predictions.

The model detected the neutral, cognitive and emotional physiological patterns (as explained in figure 5) during the related periods (each period marked in the same colors as in figure 5)

and predicted as dominant stresses in those periods while other types of stresses are negligible.

## 5 Bio-sensors Quantities Validation

To quantitatively compare between bio-sensors and signals extracted from video, signals correlation analysis of HRV mean (that were extracted from BVP sensor) were performed and correlation coefficient were calculated.

A summary of the correlation coefficient is shown in table

Table 4: Bio-sensors Quantities Validation Correlation Coefficient

Var1	HRV Coefficient
AB07052018.csv	0.992565002
AK07052018.csv	0.80200084
AL10062018-test2.csv	0.943012101
AM16052018.csv	0.992873284
AP03062018.csv	0.987474472
AP27062018.csv	0.924144163
AR30052018-test2.csv	0.972182348
AS30052018-test2.csv	0.981550389
AV24052018-test2.csv	0.906685235
AZ12062018-test2.csv	0.953631404
AZ15062018.csv	0.992630753
DN15062018-test2.csv	0.921814875
DZ14052018.csv	0.985704167
EA31052018-test2.csv	0.920476848
GS07062018-test2.csv	0.846078126
GT09072018.csv	0.987643031
HD30052018-test2.csv	0.910592974
HY01062018-test2.csv	0.927010142
ID22052018.csv	0.991583851
KB27062018-test2.csv	0.944008741
LR30052018-test2.csv	0.988550515
LSH30052018-test2.csv	0.844885852

<b>Var1</b>	<b>HRV Coefficient</b>
LT23052018-test2.csv	0.995609311
MB22052018-test2.csv	0.446144298
MG15052018.csv	0.917037385
MK23052018-test2.csv	0.980540015
MS24052018.csv	0.981969054
OB08062018-test2.csv	0.984998957
OB11062018-test2.csv	0.988832371
OD01062018-test2.csv	0.957098197
OSH12062018-test2.csv	0.821701004
OV11052018.csv	0.868207533
OY01062018.csv	0.935008831
RA07052018.csv	0.931502434
RB22052018-test2.csv	0.973589602
RSH17052018-test2.csv	0.980530314
RT30052018-test2.csv	0.982777125
SA05062018-test2.csv	0.990556455
SA09052018.csv	0.952937033
SB10062018-test2.csv	0.978903895
SHA13062018-test2.csv	0.99076223
TB16052018.csv	0.900546889
VB07052018.csv	0.977220333
YPH15062018-test2.csv	0.967710013
YV06062018-test2.csv	0.991506814
<b>Average</b>	<b>0.938061982</b>