Eustress or Distress: An Empirical Study of Perceived Stress in Everyday College Life

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Presented by Jennifer Ling
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What’s new?

- data
- focus/aim
data: background

- stress ↔ behavioral factors
  - physical activities
  - application usages
  - multitasking

- natural experiment (daily life stress)
data: equipment
data: equipment
data: equipment

1. Heart rate data
2. Accelerometer data
3. Screen activity data
4. Call activity data
5. Smartphone and computer usage data
6. Survey data
1. 3 sensor devices
2. 7 subjects
3. sex: 5 male, 2 female
4. age: 22-28
5. research students and staffs
6. 5 days during waking hours
1,410,109 heart rate data

5,058,233 accelerometer data

14,746 smartphone and computer usage data

10,851 screen activity data

878 call activity data

252 survey data
1,410,109 heart rate data

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1,410,109 heart rate data

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14,746 smartphone and computer usage data

10,851 screen activity data

878 call activity data

252 survey data

App: StressSurvey
<table>
<thead>
<tr>
<th></th>
<th>Data Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heart rate data</td>
<td>1,410,109</td>
</tr>
<tr>
<td>2</td>
<td>Accelerometer data</td>
<td>5,058,233</td>
</tr>
<tr>
<td>3</td>
<td>Smartphone and computer usage data</td>
<td>14,746</td>
</tr>
<tr>
<td>4</td>
<td>Screen activity data</td>
<td>10,851</td>
</tr>
<tr>
<td>5</td>
<td>Call activity data</td>
<td>878</td>
</tr>
<tr>
<td>6</td>
<td>Survey data</td>
<td>252</td>
</tr>
</tbody>
</table>
### Table 1: Statistic of each participant

<table>
<thead>
<tr>
<th>Subj</th>
<th>Survey</th>
<th># of reports (1-5)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stress</td>
<td>1 1 3 1 0</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>1 1 3 3 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>2 5 5 1 3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Stress</td>
<td>10 3 2 2 0</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>0 1 6 8 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>4 7 4 2 0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Stress</td>
<td>1 6 6 1 0</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>0 1 7 6 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>0 4 9 1 0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Stress</td>
<td>3 9 22 4 2</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>0 5 19 14 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>0 10 20 9 1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Stress</td>
<td>7 17 5 1 0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>0 2 17 11 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>4 9 9 8 0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Stress</td>
<td>2 3 1 9 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td>9 13 1 3 0</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>5 8 12 0 1</td>
<td></td>
</tr>
</tbody>
</table>

**143 survey data** (removed incomplete data)
Figure 3: Average of inter-subject computer and smartphone usage (duration) and survey value.
What’s new?

data

focus/aim
Eustress

term stress generally referring to negative stress

concept of positive stress is incomplete

“healthy, positive, constructive results of stressful events and stress response” (Selye)

positive cognitive response to a stressor which associated with positive feelings and a healthy physical state (Lazarus)

stress is beneficial to performance until some optimal level is reached, after which performance will decline (inverted U shape diagram) (Yerkes-Dodson Law)
**eustress**

positive cognitive response to a stressor which **associated with positive feelings** and a healthy physical state (Lazarus)

**state of better mood**

stress is **beneficial to performance** until some optimal level is reached, after which performance will decline (inverted U shape diagram) (Yerkes-Dodson Law)

**urge for better performance**
classification
- goal: differentiate eustress from other kind of stress -
• Multinomial Logistic Regression (MLR), *linear classifier*
• Support Vector Machine (SVM), *non-linear classifier*
• Random Forest (RF), *ensemble classifier*
features:

- remove obvious error (e.g. heart rate < 40)
- remove RR-interval differences > 20%
- interpolation by moving average
- heart rate: aggregation over 60-minute windows
- applications: hourly aggregation
<table>
<thead>
<tr>
<th>Modality</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate measure</td>
<td>AVHR, SDHR, AVNN, SDNN, RMSSD, PNN50, VLF, LF, HF, LF/HF</td>
</tr>
<tr>
<td>Motion</td>
<td>AVMI, SDMI</td>
</tr>
<tr>
<td>Screen</td>
<td>Duration of screen on time (secs), frequency of screen on event</td>
</tr>
<tr>
<td>Call</td>
<td>Number of call, answered call; Duration of off-hook</td>
</tr>
<tr>
<td>Application</td>
<td>Duration of each category: social, entertainment, internet, communication, study, email</td>
</tr>
</tbody>
</table>
classification

inter-subject z-score normalization ➞ increase model generality

• \( z - \text{score} > 0 \) ➞ ‘stressed’ else ‘not stressed’
• 2 kind of eustress:
  1. combination of “moderate stress level” with high performance
  2. combination of “moderate stress level” with high mood
• “moderate stress level” ➞ \( z - \text{score} = 0 \pm 1 \)
classification

1. inter-subject z-score normalization $\rightarrow$ increase model generality

2. correlation matrix $\rightarrow$ eliminate redundant features ($\text{corr} > 0.75$)

3. feature selection by exhaustive search with 10-fold cross-validation using Random Forest

4. apply Synthetic Minority Over-Sampling Technique (SMOTE) $\rightarrow$ avoid over-fitting, deal with unbalanced data distribution

5. dimension reduction with Principle Component Analysis (PCA) $\rightarrow$ eliminate linearly dependent features
classification

- Physiological ➞ mental stress (heart rate)
- Physical ➞ behavioral (smartphone and computer usage)

- any set of features before and after dimension reduction (PCA)
- evaluation: leave-one-subject-out cross-validation
classification

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø (with PCA)</td>
<td>82.75%</td>
<td>96.93%</td>
</tr>
<tr>
<td>Best All: SVM</td>
<td>83.22%</td>
<td>97.90%</td>
</tr>
<tr>
<td>Physiological (Ø)</td>
<td>81.59%</td>
<td>96.27%</td>
</tr>
<tr>
<td>Physical (Ø)</td>
<td>84.85%</td>
<td>99.03%</td>
</tr>
</tbody>
</table>

competitive accuracy
Eustress classification

<table>
<thead>
<tr>
<th>Metric</th>
<th>All Performance</th>
<th>All Mood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>67.13%</td>
<td>55.25%</td>
</tr>
<tr>
<td>Recall</td>
<td>42.75%</td>
<td>56.22%</td>
</tr>
</tbody>
</table>

Highly unbalanced data result in poor recall rate on eustress classification → model not general enough
classification

![Bar charts showing classification accuracy for different features and classifiers.](image)

- **2-Class Stress**
  - All Features
  - Physiological
  - Physical

- **Eustress (Performance)**
  - All Features
  - Physiological
  - Physical

- **Eustress (Mood)**
  - All Features
  - Physiological
  - Physical

**Classifier**
- Random Forest
- SVM
- MLR
data  eustress

limitations

• initial study
• natural experiment & finer granularity of time series ➔ noisier data/decreased performance
• small sample size
• self-reported surveys as ground truth ➔ inconsistent between subjects
• concept of eustress is unclear
data classification eustress

- 84.85% accuracy for general stress
- 71.33% accuracy for urge for better performance
- 57.34% accuracy for state of better mood
Feature: pRR50

percentage of differences higher than 50 ms in RR intervals

\[ p_{RR50} = \frac{\text{Count}(\mid RR_{i+1} - RR_i \mid > 50\text{ms})}{N} \times 100 \]

(N = number of RR intervals)
Feature: pRR50

- increase \( \rightarrow \) more parasympathetic activity \( \rightarrow \) restful events dominate
- pNNx Family of HRV Statistics
- pNNx statistics: \( x < 50 \rightarrow \) more robust against outlier (Mietus et al., 2006)
Feature: pRR50

- high correlation with RMSSD

\[ RMSSD = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (RR_{i+1} - RR_i)^2} \]

\[ pNN50 = \frac{\text{Count}(\mid RR_{i+1} - RR_i \mid > 50\text{ms})}{N} \times 100 \]

- RMSSD/pRR50: differences of RR-interval length
- Fitbit aggregates HR-value over 5 seconds
  ➔ summarizes the RR-interval lengths within these 5 seconds
Vortrag
ÖPNV
Nacharbeit
Ö
Physio
Ö
Arbeit
Ein kauf en
Ö
Spazier gang
RMSSD 09.01.17
RMSSD [s]
0.06
0.05
0.04
0.03
0.02
0.01
0.00
08:00 10:00 12:00 14:00 16:00 18:00 20:00
time [hh:mm]
0.02
0.01
0.00
pRR50 09.01.17
pRR50 [%]
25
20
15
10
5
0
08:00 10:00 12:00 14:00 16:00 18:00 20:00
time [hh:mm]
13x387 pRR50
Stila (computed stress)

pRR50
week analysis with pRR50

pRR50 of 09.01.17: 1.8576% presentation
pRR50 of 10.01.17: 4.2943%

pRR50 of 11.01.17: 4.5623% sports/physical activity (2h)
pRR50 of 12.01.17: 4.8385%
pRR50 of 14.01.17: 3.4263% presentation
pRR50 of 16.01.17: 1.9937%

sports/physical activity (2h)
Stila (computed stress)

pRR50

sports
Sources

- Mietus, Joseph E. "Time domain measures: from variance to pNNx." Beth Israel Deaconess Medical Center, Harvard Medical School, Boston (2006).
- https://openclipart.org/download/262417/hp-android_smartphone.svg
- http://www.hr v24.de/HRV-Interpretation.htm
- http://www.qhrv.de/dt_hrv1_de.htm
- https://www.polar.com/hk-en/products/accessories/H7_heart_rate_sensor
- https://www.researchgate.net/profile/Herbert_Jelinek2/publication/265461491/figure/fig1/AS:214125746626560@1428062964655/A-typical-ECG-signal-showing-the-RR-interval.png
- http://www.magicaldaydream.com/2013/06/the-introvert-brain-explained.html
- https://www.physionet.org/physiotools/pNNx/