Mobile Stress Recognition and Relaxation Support with SmartCoping: User-Adaptive Interpretation of Physiological Stress Parameters

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www.smartcoping.net
Agenda

1. Background and objectives
2. Mobile stress warnings based on vital data
3. Context data and history analysis
4. Biofeedback for relaxation support
5. Field test
6. Summary and outlook
Stress is a huge societal problem

- Chronic stress is widespread
- Associated diseases: burn-out, depression, addiction
  - high health costs
  - high economic costs (absenteeism, early retirement etc.)
Support for (Patient) Self-Management

Main goals:

• help people enhance their self-perception: recognize when they suffer from stress
• give hints in which situations people have significantly high stress: help develop avoidance and coping strategies
• help people relax via a biofeedback component

Target scenarios:

• prevention of chronic stress
• therapeutic and rehabilitation support for conditions caused by stress
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Physiological stress indicators

• stress hormones: increased levels of cortisol, adrenaline, alpha-amylase
• increased skin conductance
• increased facial skin temperature
• higher blood pressure
• change in facial expression
• change in speech
• lower heart rate variability (HRV)
• Increased heart rate
HRV: Heart Rate Variability

HRV is the variation of time intervals between two heartbeats.

Stress leads to lower HRV

Example:
\[ t_0 = 60s \]
\[ t_2 = 30s \]
\[ t_3 = 30s \]
\[ \rightarrow \text{every 30 seconds new values} \]
HRV Measurements

- Body sensor with >250 Hz ECG signal
- Transmission of heartbeats to smartphone
- Artifact detection and correction
- Several time-based HRV parameters:
  - SDNN: standard deviation of RR intervals in a time frame
  - RMSSD: root mean square difference of successive RR intervals in time frame
  - PNN50: percentage of pairs of adjacent RR intervals differing by more than 50 ms in a time frame
Architecture of the SmartCoping system

- **Vital parameters:** HRV, heart rate
- **Activity, location**

**Smartphone App**

- **Visualises stress history**
- **Backend:**
  - Determines stress levels from input data
  - Analyses history data
- **Stress alerts:**
  - Vibration
  - Audio-visual signals

**Coach, therapist, physician**

**Patient client**
Problem: There is no HRV threshold that indicates “normal”

HRV differs from person to person. Therefore we cannot set any general threshold.

Solution:
The app calibrates itself to the individual user.

This is where SmartCoping goes beyond the state of the art
The SmartCoping system: Initial calibration phase

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Associate perceived stress levels with measured HRV values

During initial calibration phase:

1. get user feedback on perceived stress levels
2. relate measured HRV and HR with user feedback
3. do this with as few user feedbacks as possible
4. only consider user feedback for segments with sufficient measurement quality
5. make use of background knowledge:
   highest stress level $\rightarrow$ lowest HRV
   lowest stress level $\rightarrow$ highest HRV
Calibration: Relate measured HRV with user feedback

For each HRV parameter and heart rate:
Set thresholds to minimize the overall error (RMSE)

\[
RMSE = \sqrt{\frac{\sum_{1}^{n}(x1 - x2)^2}{n}}
\]
Combine the different parameters into a stress level function

• for each parameter
  SDNN, RMSSD, PNN50, heart rate
  calculate a weight according to their predictive accuracy
  → individually for each user

• final stress level function:
  take the weighted mean of the single stress level functions learned for each of those parameters:

\[
s_{level}(v_{sdnn}, \ldots, v_{pnn50}) \leftarrow \frac{\sum_{p \in hrvp} w_p \cdot s_{level_p}(v_p)}{\sum_{p \in hrvp} w_p}
\]
Screen for user feedback

We are currently learning from you. Please give us feedback when you are stressed or not.
Generate feedback prompts to accelerate learning (1)

Objective:

Generate feedback prompts to cover the range of HRV and HR values

Approach – general guidelines:

• suppress prompts during an initial period to determine the range of values
• suppress prompts during or after physical exercise
• number of prompts per day is limited
Generate feedback prompts to accelerate learning (2)

Approach – specific algorithms:

Capture minimum and maximum values:
1. values that exceed previous min/max values trigger a prompt
2. relax after some time to 90% of previous min/max values
3. reiterate

Capture maximum value changes:
1. a decrease/increase that is bigger than any before triggers a prompt (within 90 seconds)
2. relax after some time to 90% of previous increments
3. reiterate
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Associate stress levels with contextual data

Physical activity:
• to suppress stress warnings

Location, location changes:
• to characterize typically high/low stress situations
History analysis

• When and where are stress levels significantly high or low?

• Visualize stress history

• Various granularities (days, weeks, months)
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Stress reduction with biofeedback

**Principle:**
increase coherence between breathing and heart rate

**Method:**
breathing pacer that is set to four heartbeats for breathing in, two heartbeats for breathing out

Studies have shown the relaxation effect of HRV biofeedback
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Field test

Objective:
Show effects of SmartCoping app on perceived stress
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Summary

Innovation in the following aspects:

• Calibration to the individual user

• Active learning: Minimal number of user feedbacks required

• Relaxation support

• Correlation of recurrent high-stress situations with context data

• Field test to show effectiveness
Outlook

• Find better sensors than chest strap
• Conduct a clinical study
• Combine with other stress parameters
• Explore the relation between stress and sleep