Potential of wearable devices for mental workload detection in different physiological activity conditions.

Presentation · September 2017

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Potential of wearable devices for mental workload detection in different physiological activity conditions

Franziska Schmalfuß, Sebastian Mach, Kim Klüber, Bettina Habelt, Matthias Beggiato, André Körner, & Josef F. Krems (TU Chemnitz)

Rome, 29th September 2017
Project

- Factory2Fit - Empowering and participatory adaptation of factory automation to fit for workers
- H2020 Factories of the Future, FoF-4 project
- 1.10.2016 – 30.9.2019
- 9 Partner
- EU funding 4,3 M€
- Coordinator Dr. Eija Kaasinen, VTT Technical Research Centre of Finland
Mental Workload identification at work

Market success of wearable devices (IDC, 2017)

High potential for health monitoring (Marakhimov & Joo, 2017)

Some devices aim on identifying mental state

Wrist-worn devices at work, in the car...

To reduce mental workload and stress (e.g., Swan, 2012)

Can wearable devices help to identify high mental and physical workload?
Heart Rate parameters as indicators for workload

**Workload and HR parameters**

- increased **mental workload** and growing levels of **physical activity** are an **increase in Heart Rate (HR)** and **decrease in Heart Rate Variability** (HRV, Mulder, 1992; De Waard & Brookhuis, 1991)
- Higher mental workload reflects in HRV parameters when sitting, standing, cycling and walking (Sun et al., 2012)

**Potential of Wearable Devices**

- HR measures of different wearable devices (e.g., Mio Alpha, Microsoft Band, Fitbit Charge HR) **correlate highly** with the criterion measure and with each other, **even when people walk or run** (Stahl, An, Dinkel, Noble, & Lee, 2016)
- wearable devices proved satisfying HRV measurements for differentiation between high and low demanding cognitive tasks (Barber, Carter, Harris, & Reinerman-Jones, 2017)
- HRV parameters of wearables are too inaccurate for identifying increased mental workload (Reinerman-Jones, Harris & Watson, 2017)

→ **H1**: HR increases and HRV parameter decrease when mental demand is increased
→ **H2**: Higher physical demand should reflect in higher HR and lower HRV

HFES Annual Meeting, Rom, 29th October 2017
Methods

Participants ($N = 32$)
- 31 (18 female) usable data sets
- 25 years old ($SD = 5.5$)
- 87% were right-handed

Design
- 2 (mental workload) x 4 (activity) factorial within-subject design
  - Mental workload: no additional task vs. arithmetic task (Meinel, 2013)
  - Physical activity: sit vs. stand vs. step vs. cycle
- DV: HR parameters (HR, IBI, SDNN, RMSSD, pNN50, LF, HF, LF/HF ratio)
Methods

Apparatus and material
HR measurement
• SUEmpathy® (SUE),
• Microsoft Band 2 (MB2),

Activity
• Step board
• Roller fix frame
• Metronome (Yixiang, 2015)

Questionnaires
• NASA TLX (Hart & Staveland, 1988),
• Socio-demographic questionnaire
Methods

Procedure

• 90 - 120 min
• Socio-demographic questionnaire, disqualification criteria, position devices
• Instructions via LabView, start of data and video recording
• Sequence of activities varied using Latin square

Procedure for every activity: sitting, standing, stepping, cycling
(practice phase only for stepping and cycling)

- Practice
- Activity (Baseline)
- Activity + Arithmetic Task
- Nasa TLX
- Recovery
Results – low accuracy of MB2 measurement

- **SUEmpathy100** (SUE1-4.36j Scientific; SUESS Medizin-Technik Aue, 2009)
- **Kubios** (Version 3.0.2; Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014)
- **Outlier Analysis** (Grubbs, 1969)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation Coefficient</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit</td>
<td>.83**</td>
<td>[0.58; 0.93]</td>
</tr>
<tr>
<td>Sit+MWL</td>
<td>.70**</td>
<td>[0.24; 0.88]</td>
</tr>
<tr>
<td>Stand</td>
<td>.86**</td>
<td>[0.65; 0.95]</td>
</tr>
<tr>
<td>Stand+MWL</td>
<td>.66*</td>
<td>[0.13; 0.86]</td>
</tr>
</tbody>
</table>

→ Acceptable accuracy of HR only for sitting and standing condition
Results – hypotheses partly confirmed

IBI results (as example)

Physical workload
Mean IBI
\[ F(3, 84) = 368.8, p = .000, \eta^2_p = .93 \]
\[ F(1.3, 23.7) = 17.9, p = .000, \eta^2_p = .19 \]

Mental workload
Mean IBI
\[ F(1, 28) = 68.8, p = .000, \eta^2_p = .71 \]
\[ F(1, 19) = 4.0, p = .060, \eta^2_p = .17 \]

Significant interaction
\[ F(2.4, 66.8) = 4.9, p = .007, \eta^2_p = .15 \]
Results – other HR parameters and subjective workload

• **Main effect for physical workload** for all parameters and devices, but...
  - often no difference between cycling and stepping
  - less significant pairwise comparisons for MB2

• **Opposite direction of mental workload effect** for many other parameters
  - Higher mental workload was connected with higher values of SDNN, RMSSD (only MB2), LF and HF

• Higher (physical) workload reflected in higher NASA-TLX scores
  (overall: $F(1.99, 59.71) = 18.67, p = .000, \eta_p^2 = .384$
  (physical: $F(2.00, 60.13) = 82.72, p = .000, \eta_p^2 = .734$)

• Significant lower mental workload in sitting condition
  (mental: $F(2.34, 70.22) = 4.93, p = .007, \eta_p^2 = .141$)

• No significant correlations between subjective workload and HR parameters
Summary of results and implications

• Surprisingly low accuracy of MB2 data, inconsistent to earlier findings (Stahl et al., 2016)
  • real-time data assessment using the Microsoft SDK is only developed for reliable measurements when resting
  • even in the less active conditions reliability was not as high as in other studies (Barber et al., 2017)

• Hypotheses confirmed for physical workload, only HR and IBI measures of stationary device could support mental workload hypothesis

• Reverse effect of mental workload on HR parameters due to arithmetic task? (Schubert, 2009)

→ Used wearable device with rather low potential for a fine-grained monitoring of physical and mental load at work
→ Future research might concentrate on identifying rather long-term changes that indicate stress


Thank you for your attention!

Any questions?

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