Unobtrusive Monitoring of Knowledge Workers for Stress Self-regulation

Saskia Koldijk[1,2], Maya Sappelli[1,2], Mark Neerincx[1,3], Wessel Kraaij[1,2]

[1] TNO, The Netherlands. {name.surname}@tno.nl
[2] Radboud University Nijmegen, The Netherlands
[3] Technical University Delft, The Netherlands

Abstract. In our connected workplaces it can be hard to work calm and focused. In a simulated work environment we manipulated the stressors time pressure and email interruptions. We found effects on subjective experience and working behavior. Initial results indicate that the sensor data that we collected is suitable for user state modeling in stress related terms.

Keywords: Experiment, stress, knowledge worker, user state modeling.

1 Introduction

In our connected environments, it can be hard to work in a calm and focused manner. Ruff (2002) speaks of 'plugged in compulsion' and 'hurry sickness', which easily cause interruptions and time pressure. Mark, Gudith and Klocke (2008) investigated the cost of interruptions and came to the conclusion that "after only 20 minutes of interrupted performance people reported significantly higher stress, frustration, workload, effort and pressure". Certainly, some amount of stress is not harmful and might even be beneficial to gain concentration and focus. However, extended periods of stress can be a danger to health. Bakker et al. (2012) explain that stress can either directly lead to illness through its physiological effects or indirectly, through maladaptive health behavior, like smoking, poor eating habits or lack of sleep.

In SWELL[1] we aim to improve well-being at work by supporting knowledge workers, who use and produce information as their main task, working on computers. We intend to use unobtrusive and easily available sensors to infer the user's state (Koldijk, Neerincx & Kraaij, 2012). This information will then be used to help knowledge workers maintain a healthy stress level. With the experiment and explorative analyses presented in this paper, we aim to gather insight in the concept of stress at work and ways in which it could be measured.

Stress is a broad concept referring to mental and physiological processes during emotional and cognitive demanding situations. We follow a pragmatic approach and

1 http://www.swell-project.net

hypothesize that *perceived stress* is a concept related to: (1) the *cognitive task load*, which poses demands on the worker, (2) the *mental effort*, which the worker needs to handle the task and (3) the *emotional response* that is raised, in terms of arousal and valence. In our experiment we manipulate the demands by providing external stressors in the form of email interruptions and time pressure. Given that the resources of the participants remain unchanged, we expect that the stressor conditions cause stress according to the resources-demands model of Karasek (1979). First, we investigate which effect our stressors have on subjective experience of task load, mental effort, emotions and perceived stress. Secondly, we investigate how we could measure stress and related aspects with unobtrusive sensors.

2 Experiment

We simulated a knowledge work scenario in which participants used a computer to write reports and make presentations on six specified topics (e.g. experience and opinion about healthy living). They were allowed to use the internet and a set of stored documents. While the participant worked, we collected data with several sensors: computer logging, cameras, Kinect 3D, heart rate and skin conductance sensors.

In a within-subject design each participant worked under the following conditions: 1) Neutral (pre-test without stressor), 2) Time pressure, in which they had less time to finish the tasks and 3) Interruptions, in which 8 emails were sent to the participant during the tasks (e.g. "When was Einstein born?" or "There is a meeting this afternoon."). The neutral condition was always presented first in order to get a natural, uninfluenced baseline for each participant. The order of the time pressure and interruption conditions was counterbalanced.

Before each condition, participants watched a nature film clip of 8 minutes to relax. After completion of a condition, they were asked to fill in a questionnaire and were allowed to take a short break. For measuring subjective experience we combined several validated questionnaires for assessing task load, mental effort and emotion (i.e. NASA-TLX, RSME and SAM). Perceived stress was measured with a Visual Analog Scale from 'not stressed' to 'very stressed'. This procedure of relaxation, tasks execution and questionnaire was then repeated for the two other conditions, yielding an experiment duration of about 3 hours. 25 students (8 female, average age = 25, stdv = 3.25) who are representative of knowledge workers participated.

3 Results and Conclusions

A statistical comparison (paired t-tests) of the time pressure and neutral condition showed that participants experienced significantly higher temporal demand ($p = .033$) and higher arousal ($p = .001$) under time pressure, which was in line with our expectations. The stressor email interruptions yielded reports of more mental effort ($p = .011$), but also more positive valence ($p = .042$) and dominance ($p = .016$), which we did not expect. Our emails might have caused a feeling of being connected and glad to help, but it is unclear whether this holds for office mail in general. Moreover, we

found differences in computer-use behavior. Under time pressure we see significantly more key strokes ($p = .005$) than in the neutral condition, and under interruptions we see more application changes ($p = .001$) and left clicks ($p = .014$), so both stressors create typical behavioral patterns. Perceived stress did not differ significantly between the stressor and neutral conditions. Either our stressor conditions were not suitable to cause the typical feeling of stress, or the neutral condition was stressful, too, as it was always the first condition and many participants did not finish all required tasks.

The relation between different variables was analyzed by calculating Pearson correlations. We found that perceived stress is moderately related to task load in terms of mental demand ($r = .464$), temporal demand ($r = .490$) and frustration ($r = .535$). Moreover, stress is related to emotion in terms of valence ($r = -.398$) and arousal ($r = .371$, for all $p < .001$). Explorative correlation analysis of the sensor data thus far indicates that estimating 'perceived stress' from our sensors directly is probably difficult, due to weak correlations. However, moderate correlations (with $p < .001$) were found for mental effort with several facial features[2]. When working in a condition with higher mental effort, participants looked more disgusted ($r = .505$) and sad ($r = .402$) and they showed more activation in the facial action units LidTightener ($r = .492$), UpperLipRaiser ($r = .462$), BrowLowerer ($r = .422$) and CheekRaiser ($r = .412$).

As a conclusion, the experiment presented in this paper gave us insights in the effects of stressors at work and the relations among perceived stress and related concepts. Even though we used a simplified work scenario in a lab setting, the stressors changed aspects of subjective experience and behavior. Therefore, the collected sensor data can and will be used for user state modeling in stress related terms.

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