Towards continuous mental stress level estimation from physiological signals

J. Wijsman^{a,b}, B. Grundlehner^b, H. Liu^b, J. Penders^b, H. Hermens^a

^aUniversity of Twente, Faculty of Electrical Engineering, Mathematics and Computer Science, Enschede, The Netherlands

^bHolst Centre/imec, Eindhoven, The Netherlands

It is well known that chronic mental stress can cause health problems. Early stress detection can help prevent these problems. We propose and compare two approaches to estimate stress level from physiology. We have measured physiological signals in three different artificial stressful conditions involving problem solving under time pressure and memorizing exercises. Rest periods were included in the protocol to avoid crossover effects over the stress conditions. The recorded signals were: electrocardiogram (ECG), respiration, skin conductance and electromyogram (EMG) of the upper trapezius muscles. About 40 min of data were recorded from 30 healthy subjects. Subjective stress levels were measured using questionnaires. We followed a feature selection process to choose 5 physiological features to be used in the analysis. A 2-minute sliding window was used to extract the features by 1-s steps. The feature values were normalized to eliminate baseline and reactivity differences among subjects. The dataset was divided five times randomly in an 80% training set and a 20% test set. The different stress estimation approaches were evaluated and compared using three metrics. First, the classification accuracy in distinguishing between stress and rest conditions was calculated. Second and third, the root mean square error (RMSE) and the correlation were calculated against the subjective stress levels that the subjects indicated during the protocol.

Logistic regression and linear regression were applied to obtain an estimation of the stress level. The logistic regression model provided a probability between 0 and 1 of a data point belonging to a stress condition. Three concepts were tested to extend the outcome towards a continuous stress level estimation. In the first method, the probability values were interpreted directly as stress levels ranging from 0 to 1. In the second method, the relative amount of time that the measurements were classified as stress condition in the past 2 min was calculated. In the third method, the average of the probability values of the past 2-minutes was calculated. Linear regression was performed against subjective stress levels measured by questionnaires. For classification we chose the optimal threshold that resulted in the highest classification accuracy to classify the estimated stress levels into the known rest and stress conditions.

Results are shown in Table 1. The values in the table correspond to the average numbers over the five different training and test sets.

Figure 1. Examples of continuous stress level estimations using logistic regression (top) and linear regression (bottom).

Examples of continuous stress level estimations using methods 1 and 4 are shown in Figure 1.

Method 4 (linear regression) resulted in the highest classification rate and the lowest RMSE. Method 1 showed the highest correlation with the subjective stress levels. Overall, we conclude that both linear and logistic regressions are possible candidates to provide a continuous estimation of stress level. Logistic regression has the advantage that it does not need a subjective reference like questionnaires. The approach of interpreting the probability of the logistic regression model as an estimate of the stress level has, to our knowledge, not been reported before. Our results suggest that it may provide a good estimate, but this needs to be validated in further investigations.

Table 1

Results of the four methods for stress estimation.

Method	Classification %	RMSE	Correlation
1. Probability	82.7	3.715	0.417
2. Relative time in stress	79.1	4.324	0.230
3. Average probability	73.6	3.701	0.330
4. Linear regression	86.4	3.253	0.302

doi:10.1016/j.ijpsycho.2012.07.158

Sensitivity of premature newborn auditory cortex to acoustically modified syllables

M. Carlier, T. Harmony, M. Colmenero, J. Ricardo-Garcel

Unidad de Neurodesarrollo del Instituto de Neurobiología – Universidad Nacional Autónoma de México, Mexico

The auditory analysis of spoken language is an important aspect of language acquisition. Research investigating the spectrotemporal properties of speech highlights the fact that crucial linguistic information within the auditory signal is coded by brief, rapid and successive spectrotemporal events, emerging as a result of consonantal articulation. A body of work has suggested that premature infants are at greater risk for later cognitive impairment than full term infants. These deficits are often manifested in speech and language development. Deficient auditory processing of rapid speech sounds during early development could represent a factor for language related cognitive deficits. The present research aimed to examine the perception of syllables that are presented to the Central Nervous System at fast- versus slow-rate by means of concurrent electrophysiological (EEG) and hemodynamic (near-infrared spectroscopy) recording. Thirty-five premature infants, mean gestational age 31.6 weeks (SD 1.9 weeks, range 28 a 35) were tested at 36.8 weeks, mean postconceptional age (SD 3.3 weeks, range 33 at 40.4 weeks), listening to fast- versus slow-rate syllables. The infant samples were at the Sala de Incremento de Peso (Room for weight increase) of the Hospital del Niño y la Mujer, of Querétaro, México, and they were enrolled in a study at the Unidad de Investigación en Neurodesarrollo (Neurodevelopment Research Unit) of the Instituto de Neurobiología of the Universidad Nacional Autónoma de México.

The Ethics committee of the Instituto de Neurobiología of the Universidad Nacional Autónoma de México approved this study, which also complies with the Ethical Principles for Medical Research Involving Human Subjects established by the Declaration of Helsinki.

The phonetic stimuli consisted of consonant–vowel syllables (i.e.,/pa/) spoken by a female adult whose mother tongue was Spanish, and the same syllables acoustically modified to lengthen the duration and highlight phonetic contrasts. The intensity of the syllables at the