Towards Establishing Relationships between Human Arousal Level and Motion Mass

Sven Nõmm[1], Tiit Kõnnusaar[2], and Aaro Toomela[2]

[1] Department of Computer Science, Tallinn University of Technology,
Akadeemia tee 15a, 12618, Tallinn, Estonia
sven.nomm@ttu.ee
[2] Institute of Psychology, Tallinn University,
Narva mnt, Tallinn, Estonia
Narva mnt. 25, 10120
tiit@print.ee, aaro.toomela@tlu.ee

Abstract. Preliminary results describing the relationship of the human arousal level with the amount and smoothness of their locomotion are reported in this paper. While there is a number of solid results indicating that in many cases arousal level may influence motor activities, measuring the strength, and modeling such relation remains relatively neglected area. The main weakness of the existing results is, that unlike the measurements of the arousal level which are described by the measured value of skin conductance, the locomotion parameters are determined on the basis of human observations and therefore contain certain degree of subjectiveness. Approach proposed in this paper targets to eliminate such subjectiveness. Trajectories of the limb joints will be recorded by the motion capture system. Amount and smoothness of the locomotion will be expressed by means of so-called *motion mass* parameters computed on the basis of recorded trajectories. Then relations between the arousal level and amount of locomotion will be studied.

Keywords: Neural activity, Arousal level, Motion Mass, Modeling, Electrodermal activity, Skin conductance.

1 Introduction

Pilot results, on the establishing relationship between the arousal level on the one side and the locomotion amount of the human limbs on the other side, are reported in this paper. Usually measured value of skin conductance (SC) is used to describe arousal level of a human being. It has been found that electro dermal activity is related to activation of several brain regions including those responsible for locomotion [1],[2]. This relationship is especially remarkable in performing tasks that require effort [3]. In clinical studies of intensive care the skin conductance value of the patients has been found to be related to motor activity [4]. Skin conductance is also related to everyday motor activities, such as drivers' brake pressure during driving [5]. Skin conductance and its relation to the different neuropsychological processes has been extensively studied [6], [7], [8].

C.K. Loo et al. (Eds.): ICONIP 2014, Part I, LNCS 8834, pp. 19–26, 2014.

While the SC were always measured by the special equipment, up to a recent time locomotion amount was assessed on the basis of human made observations and expressed in terms of some kind of motor activity assessment scale. In the best of the author's knowledge there are just a few contributions available where level of locomotion is described by means of objectively measured parameters. For example in [5] angle of the steering wheel and break pressure were measured.

Approach proposed in this paper targets to relate measured values of the skin conductance to the observed locomotion amount of the human limbs. Locomotion amount will be measured using motion capture system which will exclude any possible subjectiveness introduced by human made observations. The *Motion Mass* parameters, which provide numeric measure of the amount and the smoothness of the human limb movements [9], will be calculated on the basis of raw data recorded by motion capture system. Once arousal level and amount of the locomotion are described numerically one may formally describe the strength of the relationship and if possible build the model to estimate one parameter on the basis of the other. In [9] it was demonstrated that values of the *Motion Mass* parameters reflect changes observed during the learning of a new motor activity and in turn describe changes in the quality of motion planning. Human actions are usually target to achieve a certain goal [10], [11]. When motor activity is required, planning of the motions possesses a crucial importance in achieving the goal [12]. Obviously inadequate motions planning may not only be the obstacle to achieve the goal of the action but also lead to unwanted consequences like traumas etc. At the same time measuring the SC usually requires special equipment which in turn limits human movements. In this context ability to estimate arousal level on the basis of measured parameters of the motion may allow to detect higher arousal levels without imposing any limits on human locomotion. In [5] it was pointed out, that higher levels of arousal do not always reflected by the changes of motor activities and *vice versa*. This leads another direction of the research. Namely determine the types of arousal which influence amount and the smoothness of the the human motions.

The organization of the paper is as follows. Main goals of the paper are formulated in Section 2. Mathematical tools and experimental setting are described in Sections 3 and 4 respectively. Analysis of the achieved results is presented in Section 5. Concluding remarques are drawn in the last section.

2 Problem Formalisation

It has been found, as we showed above, that for large groups of individuals there is a relation between the arousal levels and locomotion parameters, at least for the arousals caused by certain stimuli types. It is usually assumed that group-level results apply to individual level as well. If this hypothesis proved true, then for the certain cases it would be possible to develop a model estimating value of the SC based on the measured amount and smoothness of the locomotion and in turn determine the arousal level based on the parameters of captured motions. Pilot study is required to determine which *Motion Mass* parameters provide better ground for modeling of the SC values, cluster individuals by their responsiveness to the different stimuli and analyze which stimuli cause arousal levels to influence locomotion activity. This leads following goals of the present research

- Cluster the group of individuals by the values of correlation coefficient between the chosen *Motion Mass* parameters and the amount of SC changes.
- For the individuals demonstrating strong correlation between the *Motion Mass* parameters and amount of SC change attempt to construct the model to estimate amount of SC change as a function of *Motion Mass* parameters.

3 Mathematical Tools

Main goal of the present research requires one to possess an ability to measure the both arousal level, and locomotion amount. While SC measurements are widely accepted to represent level of arousal, up to now there is no widely accepted technique to measure locomotion amount on the basis of captured motion data. In [9] the notion of the *Motion Mass* was proposed as the measure of the amount and smoothness of the movements associated with the motion or motor activity. In order to make this paper self-sufficient let us briefly remind the definition and meaning of this notion. In [9] *Motion Mass* is defined as the set of four parameters; *Trajectory Mass*, *Acceleration mass*, *Combined Euclidean Distance* and length of the motion in time.

$$M_J = \big\{T_J, A_J, E_J, t\big\}. \tag{1}$$

Denote $J = \{j_1, j_2, \ldots, j_n\}$ the set of joints describing certain limb or limbs. Let T_{j_i} be the length of the trajectory of the joint j_i, observed during the motion then *Trajectory Mass* is defined as the sum of the trajectory lengthes of each joint of the set J.

$$T_J = \sum_{i=1}^{n} T_{j_i}. \tag{2}$$

Acceleration Mass and *Combined Euclidean Distance* are defined in the similar way as follows

$$A_J = \sum_{i=1}^{n} A_{j_i}. \tag{3}$$

$$E_J = \sum_{i=1}^{n} E_{j_i} \tag{4}$$

Trajectory mass describes amount of the limb movements associated with motion and *acceleration mass* describes their smoothness. It was demonstrated in [9] that the values of the *Motion Mass* reflect changes of human motor functions while individual learning new motor activity. Therefore, those parameters are suitable as the measure of the locomotion amount. To compute numeric values of the *Motion Mass* parameters, actual trajectories of the limb joints are required. Motion capture system was used to record trajectories of the limb joints. In such setting all the measures will be collected by computerized systems, therefore human subjectiveness is excluded.

Unlike the measured value of SC, which is recorded for each instance of time, parameters of the *Motion Mass* are associated with time intervals. In order to compare SC to the *Motion Mass* parameters one has to choose from a two following alternatives. The first one is to introduce the analogue of the *Motion Mass* parameters for each time instance. The second one, is to derive the parameters describing amount and/or smoothness of the SC changes for a given time interval, similarly to those of the *Motion Mass* (1). Present contribution pursues the second alternative. Define the amount of the changes in SC associated with the certain time interval in the similar way to *Trajectory Mass*. Denote C_i amount of the changes of SC during time interval i. In the case of SC the amount of changes and smoothness would strongly correlate, therefore there is no sense to compute the last one.

4 Experimental Setting

For the pilot research, a group of 10 individuals was randomly chosen from a population of eighth grade adolescents. The entire range of the motion activities human may perform is too wide to be considered in a single paper, therefore results reported in the present contribution are narrowed to the studies of upper right limb motions of a seated individual. Performed activity was limited to the manipulation with the computer mouse. Individual was asked to play game and respond on different stimuli by mouse clicks. During the experiments the individual was exposed to the sequence of different stimuli, whereas irritating stimulus was always followed by the stimulus which usually has calming effect. For example one of the irritating stimuli was frightening and it was archived by showing the video of frightened cat. Calming stimulus was usually provided by the video of trees during the autumn. The sequence of stimuli consisted totally of a 21 interval. For each time interval SC, was recorded together with the trajectories of the right hand joints.

Experiment environment is presented in Figure 1. Recording time for each individual took 20 minutes. The hardware setting consists of two devices connected to the PC. Values of SC were measured and recorded by MP150WSW with GSR100C amplifier produced by BIOPAC Systems, Inc. SC was recorded in micro Siemens, which is standard measure for such experiments, whereas frequency was 200Hz. Low pass filter was applied then to smoothen the data and eliminate nonspecific electrodermal reactions (sparks). Within the frameworks of present contribution Kinect sensor was used to capture human motions and record trajectories of the limb joints. In spite of its simplicity it has proved itself to be precise enough to be applied in such delicate area like medicine [13]. After necessary processing, for each of 21 interval amount of SC changes and parameters of the *Motion Mass* were computed.

Fig. 1. Hardware setting

5 Analysis

Present research concentrate its attention on *Trajectory Mass* and *Acceleration mass*, which leads the square matrix, with the rows corresponding to the intervals and columns to the amount of SC change, *Trajectory Mass* and *Acceleration mass*. Pearson correlation coefficients r together with corresponding $p-$values

Table 1. Relation between *Trajectory Mass* and amount of SC changes

ID	r	p-value	Corresponding linear model
41	0.51	0.0272	
3	0.74	0.0001	$C(i) = 1.31T_J(i) + 7.76$
52	0.79	$2.2e - 05$	$C(i) = 0.07T_J(i) + 0.11$
57	0.44	0.0486	
42	0.81	$9.9e - 06$	$C(i) = 0.42T_J(i) + 0.04$
47	0.84	$1.4e - 06$	$C(i) = 0.2T_J(i) + 2.11$
46	0.53	0.0128	
24	0.82	$5.2e - 06$	$C(i) = 0.17T_J(i) + 0.42$
40	0.78	$3e - 05$	$C(i) = 0.09T_J(i) + 0.31$
11	0.74	0.0001	$C(i) = 0.39T_J(i) + 2.79$

computed between the amount of SC change and *Trajectory Mass*, for each individual, together with corresponding linear models wherever applicable, are presented in Table 1. Table 2 describes similar relation between the Acceleration mass and amount of the SC changes.

Let us now turn our attention to the standardized residuals. Figure 2 depicts standardized residuals computed for the models describing relation between the

Table 2. Relation between *Acceleration Mass* and amount of SC changes

ID	r	p-value	Corresponding linear model
41	0.51	0.0176	
3	0.73	0.0001	$C(i) = 0.001A_j(i) + 8.89989656$
52	0.86	$4.9e-07$	$C(i) = 0.0002A_j(i) + 0.012423054$
57	0.50	0.0203	
42	0.84	$1.5e-06$	$C(i) = 0.0007A_j(i) - 0.004897169$
47	0.83	$3.0e-06$	$C(i) = 0.0003A_j(i) + 2.313445807$
46	0.53	0.0119	
24	0.84	$1.6e-06$	$C(i) = 0.0002A_j(i) + 0.36474467$
40	0.78	$2.1e-05$	$C(i) = 0.0002A_j(i) + 0.313465413$
11	0.76	$5.7e-05$	$C(i) = 0.0005A_j(i) + 3.375591976$

Trajectory Mass and the amount of SC change and Figure 3 depicts standardized residuals for the case when models describe relation between the *Acceleration mass* and the amount of SC change.

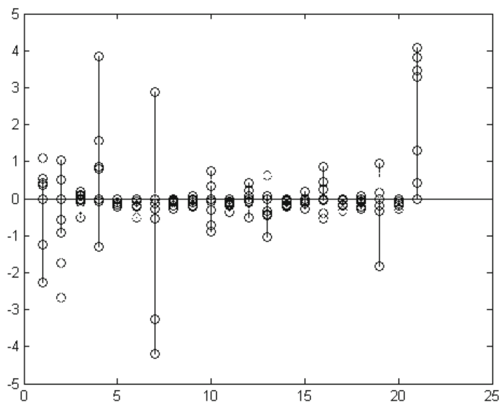

Fig. 2. Standardized residuals for the $C(i) = aT_J(i) + b$ type models

One may easily see that for many models standardized residuals corresponding to the computer task intervals 1, 2, 4, 7 and 21 are in absolute value greater than 2, which indicates that corresponding observation points may be outliers. Remind here that each interval corresponds to the different type of stimulus, therefore analysis of standardized residuals may allow to determine stimuli which cause arousal levels with lesser or greater influence on motor functions.

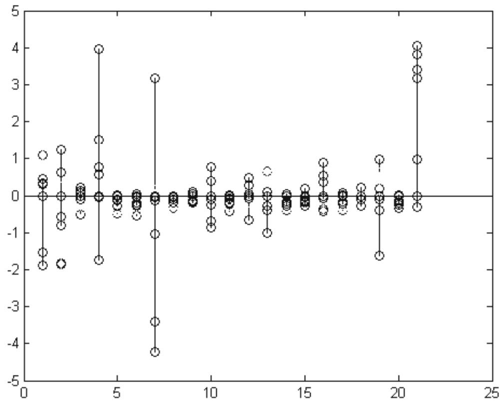

Fig. 3. Standardized residuals for the $C(i) = aA_J(i) + b$ type models

6 Conclusions

Results of the pilot research reported in this paper has clearly demonstrate that amount and smoothness of the locomotion was significantly related to the level of arousal in all cases. The strength of such relationship allows to divide individuals in to two groups. For those who demonstrate higher strengths of such relations models to estimate amounts of SC changes were developed. Studies of the corresponding standardized residuals has revealed that certain types of stimuli cause abnormal arousal levels. In other words, arousal types which either are not related to locomotion or influence locomotion too much. On the one hand, ability to relate machine measured locomotion parameters to the level of arousal provides an alternative approach to measure the last one without limiting human motor activities. On the other hand such ability allows to study in detail influence of the arousal level on the motions planning process.

Acknowledgments. S.Nõmm was supported by the Research Funding Project of the Tallinn University of Technology B37. A. Toomela was supported by the ETAG Institutional Research Funding project IUT 3-3.

References

[1] Frederikson, M., Furmak, T., Olsson, M.T., Fisher, H., Andersson, J., Långström, B.: Functional neuroanatomical correlates of electrodermal activity: A positron emission tomographic study. Psychophysiology 35, 179–185 (1998)

[2] MacIntosh, B.J., Mraz, R., McIlroy, W.E., Graham, S.J.: Brain activity during a motor learning task: An fmri and skin conductance study. Human Brain Mapping 28(12), 1359–1367 (2007)

[3] Mochizuki, G., Hoque, T., Mraz, R., MacIntosh, B., Graham, S., Black, S., Staines, W., McIlroy, W.: Challenging the brain: Exploring the link between effort and cortical activation. Brain Research 1301, 9–19 (2009)
[4] Günther, A., Bottai, M., Schandl, A., Storm, H., Rossi, P., Sackey, P.: Palmar skin conductance variability and the relation to stimulation, pain and the motor activity assessment scale in intensive care unit patients. Critical Care 17(2), 1–7 (2013)
[5] Helander, M.: Applicability of drivers' electrodermal response to the design of the traffic environment. Journal of Applied Psychology 63(4), 481–488 (1978)
[6] Roy, J., North Atlantic Treaty Organization. Scientific Affairs Division: Progress in electrodermal research. NATO ASI series: Life sciences. Plenum Press (1993)
[7] Alvarsson, J.J., Wiens, S., Nilsson, M.E.: Stress recovery during exposure to nature sound and environmental noise. International Journal of Environmental Research and Public Health 7(3), 1036–1046 (2010)
[8] Boucsein, W.: Electrodermal Activity. The Springer series in behavioral psychophysiology and medicine. Springer (2012)
[9] Nõmm, S., Toomela, A.: An alternative approach to measure quantity and smoothness of the human limb motions. Estonian Journal of Engineering 19(4), 298–308 (2013)
[10] Anokhin, P.K.: Ocherki po fiziologii funktsionalnykh sistem. Medicina, Moskow (1975) (in Russian)
[11] Toomela, A.: Biological roots of foresight and mental time travel. Integrative Psychological and Behavioral Science 44(2), 97–125 (2010)
[12] Lauria, A.: Vyshije korkovyje funktsii tsheloveka i ikh narushenija pri lokal'nykh porazenijakh mozga (Higher cortical functions in man and their disturbances in local brain lesions). Moscow University Press, Moscow (1969) (in Russian)
[13] Nomm, S., Buhhalko, K.: Monitoring of the human motor functions rehabilitation by neural networks based system with kinect sensor. In: Proc. of the 12th IFAC Symposium, Analysis, Design, and Evaluation of Human-Machine Systems, Las-Vegas, Nevada, USA, pp. 249–253 (2013)