

An Unobtrusive Measurement Method for Assessing Physiological Response in Physical Human–Robot Interaction

Blaž Jakopin, Matjaž Mihelj, *Member, IEEE*, and Marko Munih, *Member, IEEE*

Abstract—The objective of this work was to develop and validate a novel unobtrusive method for measuring person’s physiological response with a low-cost integrated sensory system for use in a physical control task. Two different sensory handles were designed (cylindrical and hemispherical shape) and used in a physical human–robot control task. Twenty-three participants underwent a measurement session with both handles, performing four different tasks for each handle. Two basic task conditions were permuted: physical load (high/low) and task dynamics (high/low). Electrocardiogram, photoplethysmogram, electrodermal activity, and peripheral skin temperature signals were recorded by sensory handles and a reference high-accuracy biosignal amplifier to determine the raw signal correlation between the measurement systems. Additionally, several standardized physiological parameters were calculated and discussed for both systems. Results of raw signal correlation showed a high correlation between the reference measurement system and the sensory handles. Pearson’s correlation coefficients were above 0.8 for most of the physiological signals in all task conditions. Some effect of physical load and high task dynamics was registered. In terms of signal quality, the hemispherical design outperformed the cylindrical design. Correlation results show that the proposed system correlates well with the reference systems for all tasks. In terms of optimal design for signal quality and comfort, hemispherical handle shape is more appropriate. Unobtrusive nature and short setup time of such a method deems it appropriate for home use, monitoring, and research.

Index Terms—Affective engineering, haptic interaction, human–machine interaction, physiological sensors, unobtrusive sensors.

I. INTRODUCTION

IN THE past few decades, quantitative measurement of person’s affective state and emotion reactivity has become a major topic of research for a broad area of applications, ranging from rehabilitation robotics in human–robot interaction to user experience testing in human–computer interaction. Affective state is a representation of subject’s psychophysiological

state along two principal dimensions: valence and arousal [1]. This representation could provide valuable information on how a person is motivated, entertained, engaged, and satisfied with a certain task or product.

In human–robot interaction applications, motor rehabilitation has progressed from simple passive mechanisms for physical exercise with physical therapist present at all times to semi-autonomous robotic interfaces that can offer personalized therapy for each patient [2], [3] or objectively assess the patient’s limb mobility and biomechanical parameters [4]. These are often combined with virtual environments to make the exercise more engaging and to increase the person’s motivation [5], [6]. This type of motor rehabilitation is especially effective with post-stroke patients, where motivation and engagement in physical exercise is inherently low. In an effort to improve the success of rehabilitation, several attempts have been made to incorporate a quantitative measure of person’s affective state, that can, together with their motor performance parameters, provide different control strategies of the physical interaction task by adjusting the task difficulty [7]–[9].

Previous research has shown that estimation of person’s psychological state is possible by measuring physiological parameters, such as heart rate (HR), skin conductance, peripheral skin temperature, and respiration [10], [11], and adapting the parameters of the physical control task based on the measured physiological response [12]. Similar research was performed by Badesa *et al.* [13], [14], using multisensory data to adaptively change the complexity of the virtual reality task. Enhanced human–robot interaction experience is reported by Guerrero *et al.* [15] using a biocybernetic closed-loop controller to adapt the robot assistance. Similarly, Morales *et al.* [16] presented a new concept of a multimodal assistive robotic system to address the growing trend of patient-tailored assistance. In an effort to improve the healthcare services in the future, Swangnetr and Kaber [17] proposed an algorithm for emotional classification in patient–robot cooperation, using physiological data acquired using standard bioamplifiers. A thorough overview of the affective engineering field has recently been done by Balters and Steinert [18], where applications and physiological measurement methods were discussed. Most of the aforementioned research was based on physiological data analysis, acquired by high-tech and expensive medical equipment. Although this type of equipment is noninvasive, it is usually not user-friendly and does not enable fast setup. Previous research by Dijkers *et al.*

Manuscript received June 17, 2016; revised November 21, 2016; accepted February 24, 2017. This work was supported in part by the Slovenian Research Agency (ARRS) and research program Analysis and synthesis of movement in man and machine (P2-0228) and in part by the EU ECHORD++ project under Grant 601116 for LINem++ experiment. This paper was recommended by Associate Editor M. Swangnetr.

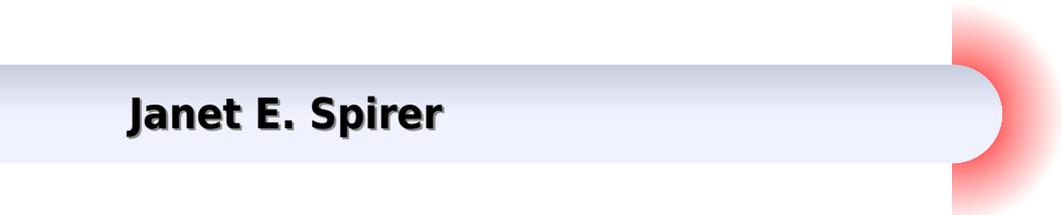
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Digital Object Identifier 10.1109/THMS.2017.2681434

Unobtrusive Measurement Today

Janet E. Spirer



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