

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.*

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Unobtrusive Measurement Today

Peter Hamilton



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Key Concepts in Sport and Exercise Research Methods Michael

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Table of Contents Unobtrusive Measurement Today

1. Understanding the eBook Unobtrusive Measurement Today
 - The Rise of Digital Reading Unobtrusive Measurement Today
 - Advantages of eBooks Over Traditional Books
2. Identifying Unobtrusive Measurement Today
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Unobtrusive Measurement Today
 - User-Friendly Interface
4. Exploring eBook Recommendations from Unobtrusive Measurement Today
 - Personalized Recommendations
 - Unobtrusive Measurement Today User Reviews and Ratings
 - Unobtrusive Measurement Today and Bestseller Lists
5. Accessing Unobtrusive Measurement Today Free and Paid eBooks
 - Unobtrusive Measurement Today Public Domain eBooks
 - Unobtrusive Measurement Today eBook Subscription Services
 - Unobtrusive Measurement Today Budget-Friendly Options
6. Navigating Unobtrusive Measurement Today eBook Formats
 - ePub, PDF, MOBI, and More
 - Unobtrusive Measurement Today Compatibility with Devices
 - Unobtrusive Measurement Today Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Unobtrusive Measurement Today
 - Highlighting and Note-Taking Unobtrusive Measurement Today
 - Interactive Elements Unobtrusive Measurement Today
8. Staying Engaged with Unobtrusive Measurement Today

- Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Unobtrusive Measurement Today
9. Balancing eBooks and Physical Books Unobtrusive Measurement Today
- Benefits of a Digital Library
 - Creating a Diverse Reading Collection Unobtrusive Measurement Today
10. Overcoming Reading Challenges
- Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Unobtrusive Measurement Today
- Setting Reading Goals Unobtrusive Measurement Today
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Unobtrusive Measurement Today
- Fact-Checking eBook Content of Unobtrusive Measurement Today
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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