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Validation of a Video-Based System to Determine Heart Rate for Stress Monitoring

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ABSTRACT

Studies estimate that about 50% of all lost workdays are related to occupational stress. Academic researchers have been using heart rate variability (HRV) as an indicator of stress. As a way of providing the needed heart rate data, an unobtrusive approach points to video plethysmography, being a recent method that needs further investigation and validation. Specific barriers such as room lighting conditions and face movement have been identified as the main risks for software progression. The present chapter presents a validation protocol of a video-based system to determine heart rate for stress monitoring, under different illuminance levels and position conditions. We present an in-depth protocol on how to assess the reliability of a video facial recognition software on collecting physiological data (heart rate), and our software results when compared to the gold standard, Electrocardiogram (ECG).

Keywords: Video plethysmography, Video monitoring, Stress detection, Video heart rate monitoring, Validation protocol

INTRODUCTION

Studies estimate that about 50% of all lost workdays are related to occupational stress (HSE, 2019). At a national and pan-European level, the total estimated cost of work-related stress in 2014 was observed to be considerable and ranged substantially from 195.29€ million to 165€ billion. Productivity-related losses were observed to proportionally contribute most of the total cost of work-related stress (between 70 to 90%), and that healthcare and medical costs constitute the remaining 10% to 30% (Hassard et al., 2017). Therefore, solutions to mitigate risk factors related to the working settings present an enormous potential and a clear substantial contribution. There is a tremendous need for the development of applications/software that combines multiple sources of data to gather the information that can improve employees' well-being, commitment, and performance. For more than ten years, academic researchers have been using heart rate variability (HRV) as an indicator of stress. Some systematic reviews even state that HRV provides an important window into understanding stress (Järvelin-Pasanen et al., 2018; Kim et al., 2018).

Video plethysmography comes up as a way of providing the needed heart rate data through an unobtrusive approach, being a recent method that needs further investigation and validation. Some previous laboratorial protocols have been developed to assess video-based heart rate monitoring systems; however, resting positioning and optimal solutions have been the primary focus (Kwon et al., 2012; Koenig et al., 2016; Sanyal and Nundy, 2018; Martins et al., 2021). Specific barriers such as room lighting conditions, face movement, and skin pigmentation have been identified as the main risk factors for software progression (Addison et al., 2018; Rodriguez and Castro, 2018; Chen et al., 2018). The present chapter presents a validation protocol of a video-based system to determine heart rate for stress monitoring, under different illuminance levels and face position. We present an in-depth protocol on how to assess the reliability of a video facial recognition software on collecting physiological data (heart rate), and our software results when compared to the gold standard, Electrocardiogram (ECG).

LABORATORY PILOT

Protocol Design

A laboratory pilot where we could compare our software outputs to an ECG was designed and conducted. Our pilot contained three separate experimental conditions of data collection. The participants had two separate cameras: one front-facing, and the other at 45 degrees, at all times. The main difference in the phases were scenarios with different illuminance levels, face positioning (through task vs resting), and low/high-resolution camera, and different levels of workload through Nback tasks and email writing (**Figure 1**).

Sample

The participants included in the protocol were above 18 years old, with enough cognitive skills to read, interpret and understand the details of the study, as well as signing the participants ‘consent. We did not exclude participants with cardiac pathologies to address the software's precision and sensibility. Every participant performed all the tasks in the protocol.

Environmental Conditions and Workstation

The data collection room was prepared with the ability to change between different illuminance scenarios, monitored with a luxmeter (Delta-OHM, HD 2302.0), and monitored for air temperature and relative humidity (VelociCalc Multi-Function 9565-X, TSI), as well as for noise levels (Soundmeter, Bruel & Kjaer 2250-D00). The laboratory was arranged according to the current recommendations for illuminance levels (ISO 8995:2002), air temperature and relative humidity (Portuguese legislation). Additionally, it was ensured an appropriate workplace according to each subject's anthropometric characteristics (seat height, table height, backrest, harms rest, keyboard and mouse position, and visor height and inclination). These comfortable settings were kept during the different scenarios, except for the illuminance levels, as we assessed a video monitoring system under different lightning scenarios.

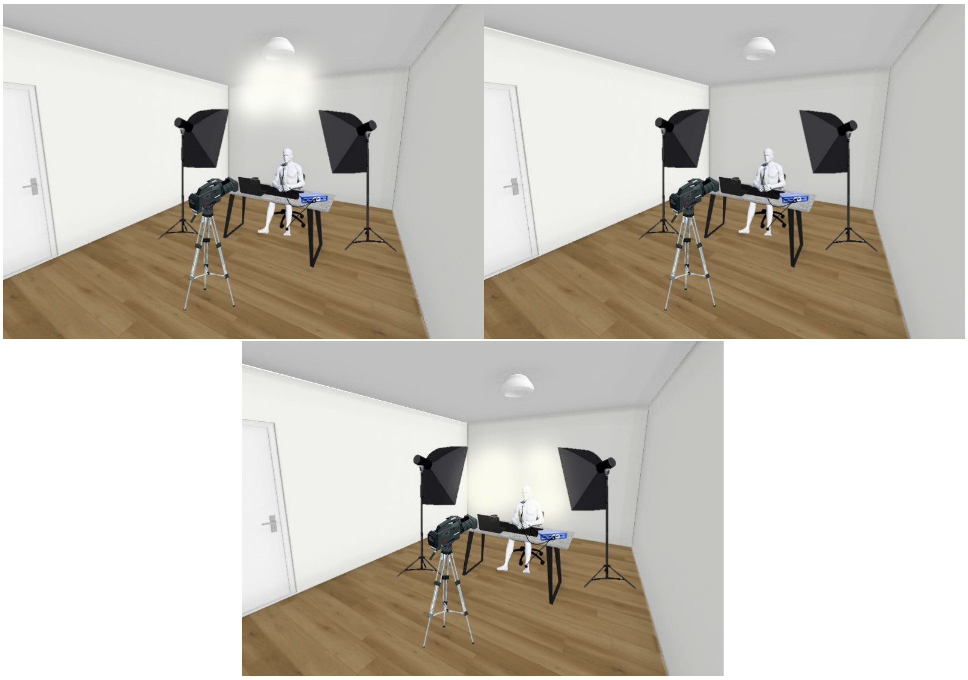

Figure 1: Lightning conditions.

Measurements

We started the protocol with three different scales for measuring stress, worry and coping strategies, being DASS-21 (Depression Anxiety and Stress Scale), PSWQ (Penn State Worry Questionnaire) and Brief Cope (Coping Orientation to Problems Experienced) (Ribeiro et al., 2004; Jiménez-Ros et al. 2019; Carver, 1997). These scales are important to address baseline measurements, specially stress and coping strategies.

The ECG was collected using the BIOPAC's MP36 Data Acquisition Unit, certified as a medical device, with a sampling rate of 500 Hz. The ECG signal was recorded using the electrode lead set SS2LB and disposable electrodes.

Having in mind different tasks for collecting heart rate, we decided to engage in two different tasks. Two N-back tasks of n-2 and n-3, and a practical email writing task. This workload was specifically selected due to its heart rate effects and cognitive workload (Vera et al., 2017; Zhou et al., 2022; Wang et al., 2022). The workload was assessed with NASA-TLX for each individual task (Hart, 2006).

Preliminary Results

The laboratory pilot report the limitations of video plethysmography software and their reliability. In **Table 1**, we can see an example for an ECG recording, and bellow our systems average results.

It is important to mention some degree of difficulty regarding skin pigmentation and difference face shapes regarding heart rate detection. A review in

Table 1. Preliminary results for ideal lighting settings.

	Ideal lighting settings (example)						
	1st Minute	2nd Minute	3rd Minute	4th Minute	5th Minute	First 3 minutes	All 5 minutes
BIOPAC HR	68.96	72.83	74.04	73.59	72.57	71.94	72.40
WEB CAM HR	71.38	71.97	72.85	74.03	74.00	72.07	72.84

2016, mentioned that future work regarding stress detection, should be carried out combining information of different modalities and creating methods for data obtention in a totally unobtrusive way, necessary for practical real-life monitoring (Alberdi et al., 2016). This software is going to integrate a recommendation system after being validated as a reliable heart rate monitor.

In 2016, a development team pointed in the right direction, mentioning that creating a real-time, multiparameter physiological measurement platform with high video resolution video was the next step (Rahman et al., 2016). With the advance in video cameras availability, almost every laptop and mobile device is provided with high resolution cameras capable of producing high quality imagery for heart rate detection.

CONCLUSION

The laboratory pilots report the limitations of video plethysmography software. This validation and its methodology contribute to the development of future stress detection applications/software. It is important to mention the importance of a well-lighted work environment, the use of a recent webcam and the integration of a multiparameter physiological measurement in order to create a prediction algorithm for stress detection.

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