Ambulatory assessment of psychophysiological stress among police officers: A proof-of-concept study

[1] Rodrigues, S., [2] Kaiseler, M., [3] Pimentel, G., [4] Rodrigues, J., [5]Aguiar, A., [6] Queirós, C., & [7]Cunha, J.P.S.

[1,6] Faculty of Psychology and Educational Sciences, University of Porto, Portugal.

[2] Institute for Sport, Physical Activity and Leisure, Leeds Beckett University, UK.

[1,3,7] Center for Biomedical Engineering Research (C-BER) of INESC TEC Porto, and Faculty of Engineering, University of Porto, Portugal.

[4,5] Institute of Telecommunications, Department of Electronic Engineering and Computers, Faculty of Engineering, University of Porto, Portugal.

Author Note:

Correspondence should be sent to: Susana Rodrigues. INESC TEC - INESC Technology and Science and FEUP - Faculty of Engineering, University of Porto, Portugal. Rua Dr. Roberto Frias s/n Edifício 1, 4200-465 Porto Portugal Telephone: 22 209 4000 Email: susanarodrigues_@hotmail.com.

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Abstract

Occupational stress has been widely recognized as a global challenge and has received increased attention by the academic community. Ambulatory Assessment methodologies, combining psychophysiological measures of stress, offer a promising avenue for future prevention and/or rehabilitation stress research. Considering that policing is well known for being a particularly stressful occupation, Emergency Responders Officers (EROs) stress levels were investigated. Particularly, this study analyzed: (i) physiological stress data obtained during shifts and compared these data with baseline levels (days off), as well as (ii) with normative values for healthy populations; (iii) stress symptoms differences from beginning to end of shift; (iv) stress events and events intensity and (v) the acceptability and feasibility of this proof-of-concept study in a highly stressful occupation. A Geo-location event system was used to help retrospective accounts of psychological stress, combined with electrocardiogram (ECG) data and mobile self-reports, that include stress symptoms, event types and event intensity. Results suggest that EROs experience high levels of stress (both on-duty and off duty) when compared to healthy populations. Stress symptoms increase from the beginning to end of the shift. However, the mean events intensity was very low. It can be concluded that stress may not always be diagnosed when using merely self-reports. These findings highlight the importance of combining both self-report and physiological stress measures in occupational health contexts. Finally, results confirm the acceptability and feasibility of the multi-method used. Key implications for policy makers and applied practitioners in the area of occupational health and future research directions are discussed.

Keywords: occupational health; ambulatory assessment; geo-location; stress; psychophysiology; Emergency Response Officers.

Introduction

The understanding of occupational stress, known as a particular form of stress that involves work (Dewe, O´Driscoll, & Cooper, 2010), should be of great concern, regarding the risks involved not only for the employee and organization, but also for national economies (Cartwright & Cooper, 1997). The experience of stress at work is one of the major problems affecting health and safety in Europe (Nakao, 2010). Accordingly, approximately one in four employees suffer from stress-related conditions, and empirical evidence suggests that between 50% and 60% of work absence days are due to stress associated problems (Maracine, 2010).

Stress can be defined as a pattern of negative physiological states and psychological responses that occur in situations that are appraised as taxing or exceeding individual's resources (Lazarus & Folkman, 1984). Stress is physiologically characterized by an onset of body alterations. Cannon (1914), described this as the "fight-or-flight" response. When a threat is perceived, the autonomic nervous system (ANS) is triggered, the parasympathetic nervous system, that controls homeostasis and the body at rest, is suppressed and the sympathetic nervous system, that controls the body's responses to a perceived threat is activated. Consequently, the secretion of stress-related hormones leads to several physiological responses, including the vasoconstriction of blood vessels, increased blood pressure and breathing rate, increased muscle tension and heart rate (HR) and a decrease in heart rate variability (HRV). Once the threat is no longer present, a sympathovagal balance is reestablished through homeostasis between the parasympathetic and sympathetic system (Taelman, Vandeput, Spaepen, & Van Huffel, 2008). These mechanisms describe the body's response to a stressful stimulus, by rapidly mobilizing energy and providing an adaptive response.

Although isolated acute stress responses do not inevitably cause chronic disease, health risks are increased when stressors, or the stress response is frequent and/or persists over long stages (Smyth, Zawadzki, & Gerin, 2013). Particularly, the continuous activation of the stress systems can lead to serious modifications on the neuro-autonomic and endocrinal balance, creating higher levels of psychological (i.e., depression, anxiety) and physiological problems (i.e., hypertension, coronary heart disease, gastrointestinal malfunctions, metabolic syndrome) (Fenici, Brisinda, & Sorbo, 2011).

Previous studies in occupational health have used a variety of biological markers of stress, such as cortisol (e.g., Collip et al., 2011), HR, HRV (e.g., Dockray et al., 2010), and blood pressure (BP) (e.g., Ewart & Johnson, 2004). However, there seems to be agreement among the academic community that HRV is the most feasible and reliable way to assess stress physiological responses (Task Force, 1996; Healey & Picard, 2005). HRV is a noninvasive measure for cardiovascular monitoring and offers the opportunity to simultaneously investigate associations between psychological processes and physiological reactions (Orsila et al., 2008). The HRV refers to cardiac rate alterations, particularly, the complex variations of both instantaneous heart rate and the series of inter-times between consecutive peaks of the R-wave of the electrocardiogram (ECG) (RR intervals). This variation is controlled by the ANS, which through the parasympathetic and the sympathetic branches, is responsible for adjusting the HR in response to external or internal physical or emotional stimulus (e.g., stress). When HRV is lower, it suggests that control mechanisms are not functioning correctly (van Ravenswaaij-Arts, Kollée, Hopman, Stoelinga, & van Geijn, 1993). Low HRV is of specific interest to psychologists, since it has been linked with poorer self-regulatory mechanisms, due to the connection of the vagal nerve (a key component that determines HRV) to the same neural network involved in emotional regulation (Appelhans & Lueken, 2006; Koval, Ogrinz, Kuppens, Van den Bergh, Tuerlinckx, & Sutterlin, 2013).

Despite advances in stress assessment research in the area of occupational health, there are still several challenges to address. First, traditional stress assessment designs are often retrospective and cross-sectional in nature, using mainly self-report measures. Consequently, data collected may be negatively influenced by memory biases or distortions associated with time delays, challenging the validity and reliability of the reports (Segerstrom & O'Connor, 2012). Second, laboratory designs are the common used solution to address the limitations presented above, since they avoid retrospective limitations and can add the rigor of an experimental design (Smith & Stone, 2003). However, laboratory experiments fail to represent real-world settings, due to the inherent artificial conditions. Finally, there seems to be a lack of reliable physiological methods that can be used to assess stress responses in applied settings, particularly among emergency professions such as policing (Hickman, Fricas, Strom, & Pope, 2011; Kusserow, Amft, & Troster, 2013).

Policing is well known for being a stressful occupation (Strahler & Ziegert, 2015), therefore the monitoring of stress among police officers working in real world scenarios seems to be a key research priority. Despite this need, such an investigation presents several challenges since stress responses can vary across individuals, situations, stressor typologies and can occur at random times, varying in duration and intensity (Kusserow et al., 2013). Although much work has been conducted to better understand police stress, most of these studies relied mainly on self-report measures. An exception is a study by Hickman et al. (2011) that aimed to investigate police stress using direct real-time and spacially anchored measurements of an officer´s response to stressors and the sample consisted of one police officer. Although the study demonstrated that continuous measurement of police officers cardiac response during a shift is possible, results were limited by the lack of self-report stress data considered. Hence, raising questions on whether observed HR increases were due to psychological stress or merely increases in physical activity.

In order to overcome previous limitations in this area and considering that stress is a complex topic, Rodrigues et al. (2015) argued that work stress investigations should be multidisciplinary in nature and should employ multi-methods research approaches. In other words, studies should include accurate and reliable measurements of stress supported by both psychological and physiological data, preferably synchronized, and contain control technologies for possible confounder variables biasing physiological data. Accordingly, Trull and Ebner-Priemer (2013) proposed Ambulatory Assessment as a new research tool that covers a wide range of assessment methods combining self-report, observational, and physiological/behavioral measurements for data collection during real life settings.

The current study used a multi-method ambulatory approach to assess EROs` stress levels. Particularly, this study analyzed: physiological stress data obtained during shifts and compared these data with (i) baseline levels (days off), (ii) normative values for healthy populations, (iii) stress symptoms differences from beginning to end of shift, (iv) stress events and events intensity ratings and (v) the acceptability and feasibility of this multi-method approach within this population. This method synchronizes self-reports and physiological stress data collected in real-time during an entire workday. These data were then compared to a non-work day and all physiological data were then compared with normative values. The method included a geo-located event system with ECG data, using user-friendly, non-intrusive mobile and wearable technology. The geo-location system allowed to monitor stress information in a smartphone, using Global Positioning System (GPS) and contemplated the exact location where the event occurred. The geo-located data were used to facilitate participant´s memory retrieval of stressful events (Rodrigues, Kaiseler, Queirós & Basto-Pereira, 2017). The amount of time participants spent with the equipment, level of compliance, problems/interference reported and their engagement/satisfaction were investigated to test the acceptability and feasibility of this approach.

Method

Participants

Six male EROs from a national police force in the second largest city of Portugal were recruited from a larger study (*N*=14) assessing stress and coping (Rodrigues et al., 2017). The EROs mean age was 34.57 years (*SD*=4.32) Participants performed emergency police duties, since they were part of a rapid intervention team that was on-call 24/7 to intervene in critical situations. All participants had over five years of experience in policing. The exclusion criteria for the study were participants having a history of cardiovascular disease and/or taking prescription drugs known to affect cardiovascular function. Participants were instructed to perform no changes in their daily routine, such as sport activities, caffeine, nicotine and food consumption. The study was approved by the University of Porto ethics committee and the Portuguese National Police Force Board. Participants were instructed about the voluntary nature of participation and the confidentiality of their responses.

Design

A presentation session was organized to explain the aim and protocol of the study, including a psychoeducational component regarding the stress topic. The purpose of this component was to help participants identify stressful events or symptoms. The study instructions were explained to participants face-to-face by the first author, including a detailed demonstration of procedures. Participants were instructed about the voluntary nature of participation and the confidentiality of their responses.

Data was collected during one workday (approximately 8 hours) and one non-work day. For non-working days, participants were required to only use an ECG monitor - VitalJacket® to collect ECG baseline data. During these days, participants were instructed to rest as much as possible and avoid participating in rigorous physical activities. After data collection on non-working days, participants were asked about any stressful events experienced; however, nothing was reported. For the workdays, participants were requested to carry the VitalJacket® and a smartphone with a software application (app). EROs provided information regarding stress symptoms, event types and event intensity. A diagram illustrating the study protocol during shifts is shown in Figure 1.

FIGURE 1 ABOUT HERE

Materials and measures

Physiological data

For physiological data collection, a wearable t-shirt incorporating an ECG monitor - VitalJacket® was used (Cunha, 2010; 2012) (see Figure 2). The VitalJacket® is a wearable bio-monitoring device that provides real-time ECG at a sampling rate of 500 Hz, through one lead and a three axis Accelerometer (ACC). The ACC is an inertial sensor that measures body´s acceleration in 3-axis (x,y,z). Particularly, when a body changes its position the ACC is able to measure this change, as well as the intensity of the movement. In terms of participants' activity, the ACC gives a movement/activity intensity indication. In terms of mathematics, a simple quadratic mean (quadratic mean= $\sqrt{(acc_x^2 + acc_y^2 + acc_z^2)/3}$) is computed using all three axis

(acc_x, acc_y, acc_z), giving a global activity indicator, independent of the direction of movement.

This sensor is in the VitalJacket® system and records the participant movement intensity while monitoring the ECG. Participants did not report any problems regarding the use of the equipment or any interference it may had with their daily activities.

FIGURE 2 ABOUT HERE

Physiological stress was assessed based on different components of HRV. These measures followed the guidelines presented by the Task Force (1996), that are feasible for stress assessment:

- AVNN - Average of (normal-to-normal) NN intervals that indicate the number of heart cycles observed per temporal interval.
- Root Mean Square of Differences between successive NN intervals (RMSSD) - This value is obtained by first calculating each successive time difference between heartbeats in milliseconds. Then, each of the values is squared and the result is averaged before the square root of the total is obtained. The RMSSD reflects the beat-to-beat variance in heart rate and is the primary time domain measure used to estimate the vagally-mediated changes reflected in HRV (Shaffer, McCraty, & Zerr, 2014).
- pNN50 - the percentage of the number of times per hour in which the change in consecutive normal sinus (NN) intervals exceeds 50 milliseconds; this measure facilitates assessment of parasympathetic (vagal) activity from 24 hour ECG recordings (Ewing, Neilson, & Travis, 1984).
- Low Frequency (LF) - is a band of power spectrum ranging between 0.04 and 0.15 Hz. and it is used as an accurate reflection of sympathetic activity (Reyes del Paso, Langewitz, Mulder, van Roon, & Duschek, 2013).

- High Frequency (HF) - is a band of power spectrum ranging between 0.15 and 0.4 Hz. This represents an index of cardiac parasympathetic tone (Reyes del Paso et al., 2013).
- LF/HF Ratio - this is the ratio between the power of Low Frequency and High Frequency bands. This measure indicates overall balance between sympathetic and parasympathetic systems. Higher values reflect domination of the sympathetic system, while lower ones suggest domination of the parasympathetic system.

Decreased values of AVNN, RMSSD and pNN50 are indicative of stress. Additionally, increased values of LF and LF/HF are also indicators of stress (Castaldo et al., 2015). Table 1 describes these HRV parameters and their trend under stress.

TABLE 1 ABOUT HERE

Self-report data

Demographic and medical surveys were used in order to assess participants' current health status and assure that the inclusion criteria were fulfilled. A smartphone with a software application (app), based on the SenseMyCity crowd sensing platform (Rodrigues, Aguiar, & Barros, 2014) was used. This platform consists of an app using smartphones, that includes a back office and a front office and collects real time data from embedded sensors (e.g., GPS, accelerometer, among others). This app allows participants to describe events, and rate stress levels and symptoms (see Figure 3).

FIGURE 3 ABOUT HERE

Stress symptoms

In order to understand the cognitive and physical symptoms of stress, a questionnaire was used. This instrument included four questions related with physical ("1- Muscular tension"; "2- Eye fatigue or heavy head"; "3- Nausea, abdominal discomfort and stomach pain"; "4- Difficulty in maintaining the body straight") and cognitive aspects ("5- Concentration problems"; "6- Difficulty in reasoning, thinking or answering"; "7- Affliction or nervousness"; "8- Difficulty in maintaining control"). Participants were asked to rate each item on a Likert-type scale ranging from 0 – "*Not felt at all*" to 4- "*Extremely felt*". These questions were fulfilled in the software app (based on Cohen & Williamson, 1988) at the beginning and end of the day, aiming to evaluate whether there were alterations in stress symptoms experienced in these two moments.

Event type

Type of events experienced during shifts were assessed by selecting an option from a stressor checklist (Drug traffic; Public disorder; Neighborhood intervention; Vehicles chase; Inadequate resources; Other). For the purpose of this paper, stressful situations were defined as "a situation that taxes or exceeds one´s personal resources or threatens the person wellbeing has the potential to cause stress"(Lazarus & Folkman, 1984; p.19). The stressor checklist was developed following pilot work (see Rodrigues, Kaiseler, Queirós, & Basto-Pereira, 2017). This pilot work included a study where 14 ERO´s completed daily diaries over 11 working days. Each diary entry included an open-ended question, where participants reported the most common stressors, these answers formed the stressor checklist for this study.

Event intensity

Stress intensity levels were assessed for each event using a 5-point Likert-type scale ranging from 1- "*Not at all stressful*" to 5 - "*Extremely stressful*". (Kaiseler, Queirós, Passos, & Sousa, 2014). Single–item measures were used since they present several benefits, for a detailed review of these please see Fisher, Matthews, and Gibbons (2016).

Geo-location data

All data gathered with the smartphone were exported to a web server to be processed. The processed ECG data, together with the GPS information and the Google Earth platform information were used to display the location history for the full shift for each participant (see Figure 4). Each reported event and other potential stressful events were detected thorough an automated algorithm (following Rodrigues, Kaiseler, Aguiar, et al., 2015) and were imported into Google map. These events were then presented to participants at the end-of-shift interview, aiming to facilitate memory recall and help on a more accurate description of stressful events as described in Rodrigues et al. (2015) (see details in Figure 4).

FIGURE 4 ABOUT HERE

Data analysis

Physiological data analysis

A software including an algorithm following Pan Tompkins´s work (Pan & Tompkins, 1985) was used to analyze ECG data (Biodevices S.A). All HRV metrics (AVNN, RMSSD, pNN50, LF, LF/HF) were computed using 5 minutes' windows, without overlapping and excluding participant's movement data. HRV metrics were compared during shifts and days off and were also compared to healthy individual's normative values following Voss, Schroeder, Heitmann, Peters, and Siegfried (2015) study. This study included the largest population of healthy individuals (*N*=1,906) and aimed to analyze age and gender related HRV differences.

Self-report data analysis

Self-reported data collected using the smartphone and end-of-shift interviews were subject to a quantitative between-person variation analysis, centered on an event-based approach. Quantitative data from stress symptoms questionnaires were analyzed using a non-parametric hypothesis test – the Wilcoxon Signed Test - conducted using IBM SPSS AMOS (v.22) software.

This test was used to compare participants´ stress symptoms mean scores at the beginning and end of shifts. A value of $p < .05$ (two tailed) was considered statistically significant. The internal consistency for the 8 questions of the stress symptoms questionnaire was calculated using Cronbach's alphas. This value provides a coefficient of reliability, and is used as a measure of internal consistency for participants' answers. As recommended these values should be above 0.70 (Pallant, 2011). In the current study, the Cronbach's alphas were 0.94. Quantitative event intensity levels were calculated considering the mean intensity of each event.

Geo-location event-system analysis

The geo-located event system analyzed physiological data and monitored potential stressful events based on the cardiac signal retrieved from the VitalJacket®. The ECG data were divided in blocks of 100 seconds and processed using the HRV Toolkit from Physionet (Goldberger et al., 2000). This is a rigorously validated package of open source software for HRV analysis, including visualization of NN interval time series and automated outlier removal. These HRV statistics are well accepted among scholars (e.g., Castaldo et al., 2015). The system extracted HRV metrics, analyzed them and selected the places (using GPS) where a potentially stressful event occurred. These events were selected from all the moments the EROs reported an event on the app, combined with the blocks having the highest algorithms of HRV's LF power, but separated by at least 5 minutes from each other.

Results

Physiological data

A total of 47h of annotated ECG recordings during shifts and 30h of data during days off were collected and analyzed, resulting in a total of 77h of high medical grade ECG signal.

Results from AVNN, RMSSD and pNN50 mean values were lower than normative values when participants were on duty. The mean LF/HF ratio was higher than normative values for both shifts and days off (Figure 5). Additionally, two examples of this ECG signal analysis during specific events (“Driving fast”; “Gun situations” – Table 2) provided by the EROs also indicate the presence of physiological stress, considering the high values of LF/HF and low values of AVNN and pNN50 (Figure 6 a) and b).

FIGURE 5 ABOUT HERE

FIGURE 6 ABOUT HERE

TABLE 2 ABOUT HERE

Self-report data

Stress symptoms (beginning vs end of shift)

Regarding stress symptoms, results from the Wilcoxon Signed Test showed no statistically significant change for physical and cognitive stress between the beginning and end of shift symptoms ($Z= -1.60$, $p >.05$ and $Z=.37$, $p >.05$, respectively). However, the overall mean score of stress symptoms was higher at the end of the shift (*M*=1.73; *SD*=.85) compared with the beginning of shift (*M*=1.50; *SD*=.51)

Event intensity

Stress events reported and respective stress intensity levels are presented in Table 2. Regarding quantitative stress intensity measures, the stress intensity scores ranged from 0 to 5, and the overall mean was 2.1 (*SD*=.99). “Suspect escape” was the most intense stress event reported (*M*=4.0), followed by “Public disorder (*M*=3.0) and “Gun situation” (*M*=3.0).

Geo-located event system

In total nine events were reported by all EROs using the geo-located system (Table 2). The most cited event type was “neighborhood interventions” (cited three times), followed by “Public disorder” situations (cited two times).

System acceptability and feasibility

All participants (100%) carried out the study “kit” during both a shift and a day off and did not report any problems regarding usage or interference with daily activities. Regarding the use of the software app, the majority of participants (five in six; 83%) forgot to use it after a stressful event. An exception was only one stressful event that was reported on duty by one officer. In what concerns to the use of the software app to assess stress symptoms at the beginning and end of the shift, out of the six, five EROs (83%) completed the questionnaires on both occasions.

Discussion

The current study used an ambulatory multi-method approach to assess psychophysiological stress responses in occupational health field and aimed to test the acceptability and feasibility of this method in a sample of EROs. Particularly, this study investigated: (i) physiological data obtained during shifts and compared these data with baseline levels (days off), as well as (ii) with normative values for healthy populations; (iii) stress symptoms differences from beginning to end of shift; (iv) stress events and events intensity and (v) the acceptability and feasibility of this proof-of-concept study among a highly stressful profession.

Findings provide an insight on psychophysiological stress levels of EROs when working under real world conditions and confirm the acceptability, feasibility and research potential of the method to be used in similar emergency occupational settings.

The physiological analysis suggested that EROs experienced high levels of physiological stress, when compared to baseline levels (days off) and when compared to healthy individuals based on the study conducted by Voss et al. (2015). With the exception of Voss and colleagues' paper, it is important to highlight the inexistence of studies including normative values of HRV in large healthy populations. Furthermore, to the best of our knowledge, this is the first study to provide police officers` HRV measures while working in real world conditions, highlighting the original contribution of the findings to this body of knowledge. The physiological analyses indicate stress based on the decreased values of AVNN, RMSSD and pNN50 that reflected a depressed HRV during stress (Castaldo et al., 2015). Finally, the LF/HF ratio was higher than normative values, whether the participants were on-duty or off-duty. Higher values reflect domination of the sympathetic system, while lower ones refer a higher activity from the parasympathetic system, which is compatible with stress responses (Kaur, Bhalla, Bajaj, Sanya, & Babbar, 2013).

Regarding EROs psychological stress symptoms at the beginning compared to end of the shift, findings suggest that there was a minor increase in symptoms. However, this was not statistically significant, probably due to the reduced sample size. The observed tendency supports previous work conducted among Portuguese police officers (e.g., Gomes et al., 2012) showing that physical and cognitive stress symptoms increase during the working day, probably due to experience of stress events. These findings suggest that this population may be experiencing potential cumulative stress effects along the days. Future longitudinal studies are required to confirm this assumption. Additionally, despite the fact that findings suggest the experience of higher stress symptoms at the end of the shift, five out of six EROs participating in the current study did not rate any experienced events as stressful. These findings may suggest that EROs may not be aware of their stress and its impact on their health and may therefore be unlikely to ask for help.

Accordingly, the results of the ECG analysis (using AVNN, pNN50 and LF/HF metrics) performed during specific events showed that, particularly for “Gun situations”, physiological stress was evident in the ECG signal, but this event was not rated as stressful. It is crucial to highlight the importance of the current multi-method approach to understand these compiling findings. Particularly, if only self-report measures were used, one could potentially reach the premature conclusion that EROs do not experience stress events. Hence, combining psychophysiological measures of stress seems to be key to fully understand these professional’s occupational health while working under real world conditions.

A possible explanation for the fact that EROs do not rate events as stressful could be due to the fact that those events are regularly experienced by them during their shifts, therefore they do not perceive them as stressful, but rather as a routine part of their daily work. An alternative explanation for these findings could be related to the police culture. As stated by Turvey (1995) an officer is expected, by his culture to endure, not to talk about problems or concerns with others. Officers are expected to maintain a surface immunity to their own humanness. When a police officer expresses psychosocial stress, this could be viewed as a weakness, therefore they do normally avoid reporting it (Anshel, 2000). Further qualitative research designs are required to fully understand EROs appraisal of stress events in real world.

These findings should be useful for practitioners working with police officers. It is recommended that police practitioners work collaboratively with officers to combat the stigma of mental health problems and treatment, by normalizing help-seeking behavior (Papazoglou & Andersen, 2014). Additionally, future interventions for this population could include the development of peer-to-peer programs, since previous research has shown that officers seem reluctant to look for clinicians (Manzella & Papazoglou, 2014; Waters & Ursury, 2007).

Regarding the acceptability of this study, this was assessed considering the use of the equipment and the engagement with the methodology. All officers carried the study “kit” all day, without reporting any disturbance with the equipment, demonstrating the high acceptability and feasibility of this method. In regards to the use of the geo-located system, in agreement with Rodrigues et al. (2015) findings among bus drivers, this method seems to facilitate memory retrieval among EROs when identifying stressful events. Other possible future advantage in GPS location tagging could be the chance to have this data available in real time allowing for police commanders to have a better control of their teams and it would be easier to identify stressful hotspots (e.g., dangerous neighborhoods, roads). Additionally, from an implementation perspective this system may be a tool to provide citywide “stress maps”, spotting areas in need for an emergency response or a local authority intervention. It is recommended that future studies should test the functionality of the system with different professionals working in urban mobile environments.

The current ambulatory multi method approach seems to be a promising tool to support first responders’ occupational health diagnostic and interventions while also informing management decisions in real time. The current method was key to understand occupational stress among EROs and findings provide key practical and methodological implications. Considering the contemporary increased demands on security, officers` stress monitoring during real world events should be at the forefront of occupational research priorities. Furthermore, our findings suggest that police practitioners should implement healthy routines (e.g., healthy eating habits, exercise and lifestyle), monthly medical and physical monitoring, and group sessions for stress symptoms detection, aiming to help officers cope more efficiently with daily stress.

The current study is not without limitations. First, is the low level of compliance for specific kinds of data, such as the little use of the software app following events. This could be due to the fact that EROs do not perceive events as stressful. Alternatively, they could be too involved in daily events, restricting their capacity for study compliance. A possible solution to overcome this challenge is to have an audible/vibrating alert system in the smartphone, capable of detecting changes in HRV parameters after a stressful event, and warning EROs to fulfill a quick stress survey. Alternatively, participants could report events only at the end of the shift using the geo-located event system. Second, the small sample size, and short time duration of data collection should also be acknowledged as limitations. Finally, it is also important to acknowledge that this type of methodology is resource intensive in terms of software, technology and expertise (i.e., psychology, biomedical and informatics).

Despite these limitations, we believe that our 77h of geo-located data is one of the largest datasets obtained with police officers, and our results point to some promising avenues for future research and practice that can be used with larger samples and different occupational groups. Hence, findings from the current study extend the body of knowledge of occupational stress assessment and provide a feasible and accurate methodology allowing a holistic approach to stress assessment among highly stressful professions working under real world conditions.

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