

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

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

22 **Abstract**

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

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

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66 **Introduction**

67 The understanding of occupational stress, known as a particular form of stress that
68 involves work (Dewe, O'Driscoll, & Cooper, 2010), should be of great concern, regarding the
69 risks involved not only for the employee and organization, but also for national economies
70 (Cartwright & Cooper, 1997). The experience of stress at work is one of the major problems
71 affecting health and safety in Europe (Nakao, 2010). Accordingly, approximately one in four
72 employees suffer from stress-related conditions, and empirical evidence suggests that between
73 50% and 60% of work absence days are due to stress associated problems (Maracine, 2010).

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

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

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

111 regulation (Appelhans & Lueken, 2006; Koval, Ogrinz, Kuppens, Van den Bergh, Tuerlinckx, &
112 Sutterlin, 2013).

113 Despite advances in stress assessment research in the area of occupational health, there
114 are still several challenges to address. First, traditional stress assessment designs are often
115 retrospective and cross-sectional in nature, using mainly self-report measures. Consequently,
116 data collected may be negatively influenced by memory biases or distortions associated with
117 time delays, challenging the validity and reliability of the reports (Segerstrom & O'Connor,
118 2012). Second, laboratory designs are the common used solution to address the limitations
119 presented above, since they avoid retrospective limitations and can add the rigor of an
120 experimental design (Smith & Stone, 2003). However, laboratory experiments fail to represent
121 real-world settings, due to the inherent artificial conditions. Finally, there seems to be a lack of
122 reliable physiological methods that can be used to assess stress responses in applied settings,
123 particularly among emergency professions such as policing (Hickman, Fricas, Strom, & Pope,
124 2011; Kusserow, Amft, & Troster, 2013).

125 Policing is well known for being a stressful occupation (Strahler & Ziegert, 2015),
126 therefore the monitoring of stress among police officers working in real world scenarios seems to
127 be a key research priority. Despite this need, such an investigation presents several challenges
128 since stress responses can vary across individuals, situations, stressor typologies and can occur at
129 random times, varying in duration and intensity (Kusserow et al., 2013). Although much work
130 has been conducted to better understand police stress, most of these studies relied mainly on self-
131 report measures. An exception is a study by Hickman et al. (2011) that aimed to investigate
132 police stress using direct real-time and spacially anchored measurements of an officer's response
133 to stressors and the sample consisted of one police officer. Although the study demonstrated that

134 continuous measurement of police officers cardiac response during a shift is possible, results
135 were limited by the lack of self-report stress data considered. Hence, raising questions on
136 whether observed HR increases were due to psychological stress or merely increases in physical
137 activity.

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

147 The current study used a multi-method ambulatory approach to assess EROs` stress
148 levels. Particularly, this study analyzed: physiological stress data obtained during shifts and
149 compared these data with (i) baseline levels (days off), (ii) normative values for healthy
150 populations, (iii) stress symptoms differences from beginning to end of shift, (iv) stress events
151 and events intensity ratings and (v) the acceptability and feasibility of this multi-method
152 approach within this population. This method synchronizes self-reports and physiological stress
153 data collected in real-time during an entire workday. These data were then compared to a non-
154 work day and all physiological data were then compared with normative values. The method
155 included a geo-located event system with ECG data, using user-friendly, non-intrusive mobile
156 and wearable technology. The geo-location system allowed to monitor stress information in a

157 smartphone, using Global Positioning System (GPS) and contemplated the exact location where
158 the event occurred. The geo-located data were used to facilitate participant's memory retrieval
159 of stressful events (Rodrigues, Kaiseler, Queirós & Basto-Pereira, 2017). The amount of time
160 participants spent with the equipment, level of compliance, problems/interference reported and
161 their engagement/satisfaction were investigated to test the acceptability and feasibility of this
162 approach.

163 **Method**

164 **Participants**

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

176 **Design**

177 A presentation session was organized to explain the aim and protocol of the study,
178 including a psychoeducational component regarding the stress topic. The purpose of this
179 component was to help participants identify stressful events or symptoms. The study instructions

180 were explained to participants face-to-face by the first author, including a detailed demonstration
 181 of procedures. Participants were instructed about the voluntary nature of participation and the
 182 confidentiality of their responses.

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

192 FIGURE 1 ABOUT HERE

193 **Materials and measures**

194 **Physiological data**

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

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

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

207 **FIGURE 2 ABOUT HERE**

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

211 - AVNN - Average of (normal-to-normal) NN intervals that indicate the number of heart cycles
212 observed per temporal interval.

213 - Root Mean Square of Differences between successive NN intervals (RMSSD) - This value is
214 obtained by first calculating each successive time difference between heartbeats in
215 milliseconds. Then, each of the values is squared and the result is averaged before the square
216 root of the total is obtained. The RMSSD reflects the beat-to-beat variance in heart rate and is
217 the primary time domain measure used to estimate the vagally-mediated changes reflected in
218 HRV (Shaffer, McCraty, & Zerr, 2014).

219 - pNN50 - the percentage of the number of times per hour in which the change in consecutive
220 normal sinus (NN) intervals exceeds 50 milliseconds; this measure facilitates assessment of
221 parasympathetic (vagal) activity from 24 hour ECG recordings (Ewing, Neilson, & Travis,
222 1984).

223 - Low Frequency (LF) - is a band of power spectrum ranging between 0.04 and 0.15 Hz. and it
224 is used as an accurate reflection of sympathetic activity (Reyes del Paso, Langewitz, Mulder,
225 van Roon, & Duschek, 2013).

226 - High Frequency (HF) - is a band of power spectrum ranging between 0.15 and 0.4 Hz. This
227 represents an index of cardiac parasympathetic tone (Reyes del Paso et al., 2013).

228 - LF/HF Ratio - this is the ratio between the power of Low Frequency and High Frequency
229 bands. This measure indicates overall balance between sympathetic and parasympathetic
230 systems. Higher values reflect domination of the sympathetic system, while lower ones
231 suggest domination of the parasympathetic system.

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

235 TABLE 1 ABOUT HERE

236 **Self-report data**

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

244 FIGURE 3 ABOUT HERE

245 **Stress symptoms**

246 In order to understand the cognitive and physical symptoms of stress, a questionnaire was
247 used. This instrument included four questions related with physical ("1- Muscular tension"; "2-
248 Eye fatigue or heavy head"; "3- Nausea, abdominal discomfort and stomach pain"; "4- Difficulty

249 in maintaining the body straight”) and cognitive aspects (“5- Concentration problems”; “6-
250 Difficulty in reasoning, thinking or answering”; ”7- Affliction or nervousness”; “8- Difficulty in
251 maintaining control”). Participants were asked to rate each item on a Likert-type scale ranging
252 from 0 – “*Not felt at all*” to 4- “*Extremely felt*”. These questions were fulfilled in the software
253 app (based on Cohen & Williamson, 1988) at the beginning and end of the day, aiming to
254 evaluate whether there were alterations in stress symptoms experienced in these two moments.

255 **Event type**

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

265 **Event intensity**

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

270 **Geo-location data**

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

279 FIGURE 4 ABOUT HERE

280 **Data analysis**

281 **Physiological data analysis**

282 A software including an algorithm following Pan Tompkins's work (Pan & Tompkins,
283 1985) was used to analyze ECG data (Biodevices S.A). All HRV metrics (AVNN, RMSSD,
284 pNN50, LF, LF/HF) were computed using 5 minutes' windows, without overlapping and
285 excluding participant's movement data. HRV metrics were compared during shifts and days off
286 and were also compared to healthy individual's normative values following Voss, Schroeder,
287 Heitmann, Peters, and Siegfried (2015) study. This study included the largest population of
288 healthy individuals ($N=1,906$) and aimed to analyze age and gender related HRV differences.

289 **Self-report data analysis**

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

294 This test was used to compare participants' stress symptoms mean scores at the beginning and
295 end of shifts. A value of $p < .05$ (two tailed) was considered statistically significant. The internal
296 consistency for the 8 questions of the stress symptoms questionnaire was calculated using
297 Cronbach's alphas. This value provides a coefficient of reliability, and is used as a measure of
298 internal consistency for participants' answers. As recommended these values should be above
299 0.70 (Pallant, 2011). In the current study, the Cronbach's alphas were 0.94. Quantitative event
300 intensity levels were calculated considering the mean intensity of each event.

301 **Geo-location event-system analysis**

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

312 **Results**

313 **Physiological data**

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

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

322 FIGURE 5 ABOUT HERE

323 FIGURE 6 ABOUT HERE

324 TABLE 2 ABOUT HERE

325 **Self-report data**

326 **Stress symptoms (beginning vs end of shift)**

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

332 **Event intensity**

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

337 **Geo-located event system**

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

341 **System acceptability and feasibility**

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

349 **Discussion**

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

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

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

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

384 may not be aware of their stress and its impact on their health and may therefore be unlikely to
385 ask for help.

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

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

403 These findings should be useful for practitioners working with police officers. It is
404 recommended that police practitioners work collaboratively with officers to combat the stigma of
405 mental health problems and treatment, by normalizing help-seeking behavior (Papazoglou &
406 Andersen, 2014). Additionally, future interventions for this population could include the

407 development of peer-to-peer programs, since previous research has shown that officers seem
408 reluctant to look for clinicians (Manzella & Papazoglou, 2014; Waters & Ursury, 2007).

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

422 The current ambulatory multi method approach seems to be a promising tool to support
423 first responders’ occupational health diagnostic and interventions while also informing
424 management decisions in real time. The current method was key to understand occupational
425 stress among EROs and findings provide key practical and methodological implications.
426 Considering the contemporary increased demands on security, officers` stress monitoring during
427 real world events should be at the forefront of occupational research priorities. Furthermore, our
428 findings suggest that police practitioners should implement healthy routines (e.g., healthy eating

429 habits, exercise and lifestyle), monthly medical and physical monitoring, and group sessions for
430 stress symptoms detection, aiming to help officers cope more efficiently with daily stress.

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

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

448

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451

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