Heart Rate Variability Biofeedback as an Intervention Method for Reducing PTSD Symptoms in Police Officers Exposed to Trauma

by

Jennifer Chan

A thesis submitted in conformity with the requirements for the degree of Master of Arts
Department of Psychology
University of Toronto

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2018

Abstract

PTSD has been identified as a significant occupational hazard among first responders in Canada, associated with negative health and performance ramifications. Less is known about the accumulation of PTSD symptoms among police officers (i.e., partial PTSD [P-PTSD]) and its potential impact on performance, particularly in regards to use-of-force decisions. The current project examined levels of P-PTSD symptoms among Ontarian police officers, and its relationship with occupational performance and heart rate variability (HRV). Data was extracted from an on-going study utilizing an existing HRV biofeedback intervention to reduce lethal use-of-force decision errors. Officers’ self-reported P-PTSD symptoms did not significantly predict use-of-force decision making abilities, proxies of HRV, or significantly change from pre- to 18-months post-receiving HRV biofeedback training. While significant results were not found, this pilot study provides important insight in the potential for gathering P-PTSD symptoms from front-line police officers, as well as improving health and safety in this population.
Acknowledgments

I thank my supervisor, Judith Andersen, for mentoring and guiding me throughout this project. I also thank Evelyn Boychuck and Paula Di Nota, for support in data collection and analyses. Finally, I thank Tina Malti and Norman Farb for taking the time to review and also being a part of my committee for my Master’s thesis, and defence.
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Introduction

The Ontario Ministry of Labour has identified a significant need for research and interventions for Ontarian first responders, including police officers, which are at risk for Post-Traumatic Stress Disorder (PTSD) (Oliphant, 2016). Empirical evidence suggests that a clinical diagnosis of PTSD is associated with significant mental and physical health problems among police such as cognitive dysfunction, decreased executive function, and decreased cardiovascular health over time (Violanti et al., 2006; McKinnon et al., 2016). In Canada, the Royal Canadian Mounted Police (RCMP), report 8% of officers developing PTSD following trauma, which accounts for 80% of RCMP operational stress injuries (Freeze, 2017). Due to the culture of law enforcement, stigma and perceptions of mental health are significant barriers to help seeking; officers are less likely to seek professional help at or outside of work following trauma exposure, opting instead to seek help from family members or friends, who may not provide effective support (Heffren & Hausdorf, 2016; Amaranto, Steinberg, Castellano, & Mitchell, 2003). Police officers may be more likely to conceal their issues, due to the culture of emotional suppression required by their occupation (Amaranto, Steinberg, Castellano, & Mitchell, 2003). Given the fact that officers are likely to conceal clinical levels of PTSD, even less is known about partial PTSD (P-PTSD) and possible associations with performance. A preliminary pilot study on police in training suggests that symptoms of PTSD are associated with detriments in performance, specifically use-of-force (shoot or no shoot) decisions (Covey et al., 2013). While preliminary, the Covey et al., (2013) study indicates the need for future research in the area of P-PTSD and use-of-force decision making, given the life or death decisions that errors entail.
Post-Traumatic Stress Disorder (PTSD)

In any study examining PTSD, it is important to review the clinical criteria for diagnosis and associated symptoms. PTSD has 5 diagnostic criteria: First, the individual must have been directly or indirectly exposed to threatened or actual death, serious injury, or sexual violence. Second, the traumatic event must be persistently re-experienced. This can be through intrusive thoughts, nightmares, flashbacks, or emotional or physical reactivity following exposure to traumatic reminders. Third, the affected individual avoids trauma-related stimuli following the traumatic event, such as thoughts, feelings, or reminders. Fourth, negative thoughts or feelings begin or worsen after the traumatic event. Fifth, trauma-related arousal and reactivity begins or worsens after the trauma, such as difficulty concentrating or sleeping, hypervigilance, and a heightened startle reaction (American Psychiatric Association [APA], 2013). The occurrence of the latter four requirements for over a month qualifies the PTSD diagnosis. Furthermore, there are two additional subtypes of PTSD, Dissociative Specification, in which the individual experiences depersonalization (the experience of being an outside observer or detached from oneself), and Derealisation (experience of unreality, or distortion) (APA, 2013).

Occupational Performance and PTSD

PTSD is associated with broad psychological, physiological, and behavioural deficits (Violanti et al., 2006; McKinnon et al., 2016). Studies have shown a positive relationship between PTSD and physiological deficits, especially cardiovascular-based, such as atherosclerotic heart disease, elevated heart rate, and increased blood pressure, particularly in response to physical stressors (Cohen et al., 1997; Pitmen et al., 1987; Violanti et al., 2006). Psychological detriments include cognitive dysfunction and dissociation, such as reduced attention, executive functioning, and memory performance (McKinnon et al., 2016; Morgan III, Doran, Steffian, & Southwick, 2006).
However, previous research in PTSD and performance, especially in populations such as police, often do not measure skills that directly translate to potential occupational detriments. In a study by Morgan and colleagues (2006), special operations soldiers demonstrate significantly impaired visuo-spatial capacity and working memory during stressful events. Soldiers were randomly assigned to one of three groups: Pre-Stress, Stress, and Post-Stress. The stress condition included exercises from Military Survival School training used for training special operations personnel. During the stress condition, soldiers experienced evasion exercises (pursued by mock-enemy forces and try avoiding detection), confinement in a mock prisoners of war (POW) camp (food and sleep deprivation, and exposure to stressful interrogations). To measure working memory and visuo-spatial abilities, soldiers completed the Rey Ostereith Complex Figure (ROCF) drawing task—a standardized neuropsychological drawing task where subjects are asked to copy and later recall a complex abstract image, measuring indices of motor function, visual perception, memory, and visuo-spatial organization. Soldiers assigned to the Stress group completed the ROCF during the POW and interrogation exercises, Pre-Stress completed the ROCF prior to POW exercises, and Post-Stress completed the ROCF 6 hours after completing the POW exercises. Soldiers in the Stress condition had significantly worse recall performance on the ROCF task than soldiers that completed it pre- or post-stress conditions. While this study used scenarios that simulated far greater realistic, occupation-related stress than a traditional laboratory setting, the use of the ROCF task does not directly represent specific visuo-spatial skills used by the military population. This issue is found across research of stress influenced skill and ability assessments in law enforcement populations who may be required to use force against others during encounters, such as the military and police.
The physical and mental issues associated with clinical PTSD may be particularly concerning regarding the occupational requirements for police officers. First, officers carry weapons that can seriously injure or kill. Second, officers are routinely faced with time sensitive encounters in which they must make decisions to use or not use force against a member of the public. Unlike military personnel whose instructions in combat are to use as much force as possible to complete their mission, police must consider their legal authorities, the other, non-force options, and myriad other variables such as victims and bystanders (Morrison et al., 2011; 2006). The level of decision making efficacy that police must maintain requires excellent executive function, memory and skill based training. As seen above, clinical PTSD may interfere with the very skill set necessary for officers to make accurate decisions about the appropriateness to use force during an encounter with the public. PTSD symptoms may impact complex cognitive decisions in threatening environments, potentially resulting in less accurate use-of-force decisions, and potentially endangering lives (Covey et al., 2013).

**Accumulated Stress and PTSD**

Contrary to the belief that one specific traumatic event is required for the development of PTSD, research evidence from longitudinal, population-based studies indicate that it is possible for PTSD to develop following accumulated stress. For example, several studies show PTSD symptoms developed following the September 11th, 2001, terrorist attacks, in which millions of people internationally were indirectly exposed via mass media exposure (Silver et al., 2013). Repeated exposure to graphic media content was associated with increased PTSD symptomology and its associated health ailments (Holman et al., 2008; Schnurr & Green, 2004; Silver et al., 2013; Holmes, Creswell, & O’Connor, 2007).
Over the course their careers, police officers are exposed to numerous life-threatening situations, experiencing and accumulating a high degree of stressors in the job environment (Violanti & Aron, 1994; Karlsson & Christianson, 2003). As police officers, exposure to traumatic or violent events is inevitable, and this puts officers at a higher risk for PTSD (Carlier et al., 1997; Violanti et al., 2006; Chopko & Schwartz, 2012; Cross & Ashley, 2004). Given the above research, the accumulation of stress leading to partial or full PTSD is highly likely among police officers, considering the occupational exposures officers encounter routinely (i.e., car accidents, domestic violence, suicide) and significant fatigue (i.e., shift work and long hours) (Oliphant, 2016).

Fatigue is a particularly important, but overlooked variable. Fatigue is known to result in maladaptive autonomic arousal that leads to increases in allostatic load, defined as ‘wear and tear’ on the body’s allostatic load over time, is associated with poor health and reduced cognitive function (Thayer & Sternberg, 2006; Thayer, Hanzen, Saus-Rose, & Johnsen, 2009; Clark, Bond, & Hecker, 2007; McEwen, 2006). As relevant to policing, the risk of high allostatic load is significant, given that it increases the probability of decision-making errors during threat. Objective evidence demonstrates a physiological mechanism underlying this phenomenon, specifically, low and irregular cardiovascular arousal profiles (Schmitt et al., 2013). PTSD is associated with maladaptive autonomic arousal and cardiovascular symptoms, which will be covered below.

**Partial PTSD**

The importance of considering partial PTSD is controversial (Schnurr, 2014). Debate exists regarding the utility of identifying P-PTSD, as some believe it may not lead to functional or performance deficits and therefore has low utility to measure. Further, other researchers highlight that it is difficult to diagnosis and accurately track over time due to the problems with social
desirability issues on self-reported measures (Hoge et al., 2004; Kim et al., 2010). However, research with combat veterans indicates that P-PTSD can be identified using Weathers et al., (1993)’s well-validated self-report PTSD checklist (PCL) (Wilkins, Lang, & Norman, 2011) and may identify functional deficits (Dickstein et al., 2015). Additionally, Dickstein and colleagues compared clinically diagnosed veterans with PTSD with self-reported PCL scores, allowing them to create cut-off scores that take into account symptom concealment from officers. From this they determined two cut-off scores for the PCL, a lenient (33) and a stringent (38) P-PTSD score. These authors report significant functional deficits associated with P-PTSD among combat veterans; in comparison to veterans without PTSD. Participants that scored in the lenient P-PTSD, stringent P-PTSD, and full PTSD scored significantly higher on WHODAS-II (World Health Organization Disability Scale 2.0), suggesting significant functional impairment. Individuals with P-PTSD exhibit functional deficits similar to individuals with full PTSD. Specifically, they experience difficulties in occupational, health, and relationship domains. They are significantly more likely to self-rate worse health post-deployment than non-PTSD groups (Breslau, Lucia, & Davis, 2004). Additionally, like full PTSD, individuals with P-PTSD have significantly higher rates of general psychopathology and comorbid psychiatric diagnoses, such as Depression and Generalized Anxiety Disorder than non-PTSD groups (Lai et al., 2003). Individuals with P-PTSD also report rates of occupational impairment and higher number of work-loss days in comparison to non-PTSD individuals, as well as poorer psychosocial functioning in areas such as family and peer relationships (Breslau, Lucia, & Davis, 2004; Jeon et al., 2007).

Little research on P-PTSD has been conducted among front-line police officers. Given the cultural taboos of reporting any symptoms of PTSD, the rates of P-PTSD are conflicting, with
reported prevalence varying between 7-34% in police populations (Schnurr, 2014; Carlier et al., 1997; Marmar et al., 2005; Maia et al., 2007). In this study, we acknowledge the limitations of the PCL self-reported P-PTSD symptoms based on these cultural taboos. All officers in this study were deemed healthy by their police services and fit for active duty. The limitations of studying ‘healthy’ front-line officers constrict this study to examining any symptoms of P-PTSD and their resultant potential associations with performance. We acknowledge that this study is a pilot investigation unable to split the sample into the same lenient and stringent PCL cut off scores used by prior researchers. However, given the life or death decisions that police officers have to make (i.e. shoot/no shoot), an examination of any associations between PTSD and performance may indicate the need for future research in this novel area of investigation.

A unique aspect of the current study is the opportunity to associate P-PTSD with objective measures of performance and cardiovascular correlates known to be related to PTSD symptoms. Mechanisms of association are described below.

**PTSD and Physiology**

The diagnosis of P-PTSD using the PCL is currently dependent on the validity of the patient’s self-reported symptoms and severity (Orr & Roth, 2000). Biological indicators of physiological stress factors may bolster self-reported measures and aid in the identification of P-PTSD (Orr & Roth, 2000; Pole, 2007). PTSD is associated with maladaptive autonomic nervous system activity (ANS) as demonstrated by cardiovascular measurements (Violanti et al., 2006). The ANS has two branches, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The ANS’s vagal innervation to the heart is the most prominent factor in cardiac function. The heart is under dominant tonic inhibitory control by parasympathetic influences that favour energy conservation (Thayer & Sternberg, 2006; Jose & Collison, 1970). Often
overlooked is the role of the parasympathetic system as central in forming a flexible response to environmental demands. What is more, parasympathetic function is related to cognitive processes, such as decision-making and inhibitory control (Roos et al., 2017; Thayer et al., 2009). During threat or stressful encounters, such that police are routinely exposed to, the go-to evolutionary response is a dramatic increase in sympathetic innervation to the heart and a suppression of parasympathetic innervation (Thayer et al., 2006; 2009). In the wild, this dramatic evolutionary response is life-saving “9 out of 10 times” (Thayer, 2006). Colloquially this evolutionary threat response is called the ‘Fight, Flight or Freeze’ response (Sapolsky, 2004).

In modern society, recent research shows that maintaining parasympathetic innervation during stress or threat is possible, with training, and is associated with higher executive function, inhibitory control (less impulsive behavior), and better decision making (Laborde et al., 2014; Kinrade et al., 2010; Thayer et al., 2009).

Dysregulation of the ANS’s balance between the sympathetic and parasympathetic systems is suggested to contribute to psychophysiological symptoms observed in PTSD patients, such as hyperarousal and elevated heart rate (Brook & Julius, 2000; Thayer & Friedman, 2004; Menning, Seifert, & Maercker, 2008). Thus, indices of vagal function, such as heart rate and heart rate variability, the variation in time between heartbeat onsets (HRV), provide a measure of ANS balance and arousal. Although heart rate is not an indicator of P-PTSD, the examination of this objective variable in association with self-reported P-PTSD symptoms may be an additional source of data in which to understand the impact of P-PTSD on performance.

Indeed, researchers have explored the role of parasympathetic engagement among police officers facing potentially threatening situations during scenario based training (Saus, et al., 2006). In one study, police officers were assigned to either reality-based scenario training (experimental
condition) or static shooting training on a range (control condition). The authors demonstrate that officers who showed more parasympathetic innervation to the heart (experimental condition) made fewer errors than those who demonstrated the typical sympathetic dominance in innervation to the heart (control condition) (Saus et al., 2006). The findings contribute to the growing body of evidence showing that decision-making is enhanced when parasympathetic system innervation to the heart is not suppressed during stressful or threatening encounters.

The current study is a part of a larger, ongoing study to test the efficacy of an intervention that targets enhanced parasympathetic innervation during threatening police encounters in order to improve police decision making. The intervention is explained below.

**Targeting Parasympathetic Innervation to Improve Decision Making**

Heart rate variability (HRV)—the variation in time between the onset of heartbeats—indicates the contribution of both the sympathetic system and the parasympathetic system. The flexibility of HRV is a strong indicator of physical and emotional resilience, indicating the heart is prepared for challenge and recovers easily. The parasympathetic system is particularly important in arousal and cardiovascular regulation via the vagus nerve, contributing to cognitive processes vital for use-of-force decision making skills and inhibition (Roos et al., 2017; Thayer et al., 2009). In relation to occupational performance in police officers, the loss of influence from the parasympathetic system during threatening use-of-force encounters leads to reduced decision making accuracy, and greater errors (Saus et al., 2006).

Resting levels of HRV are considered relatively stable across a longer period of time (i.e., 1.5 years) in population based studies (Li et al., 2009). Multiple measures of resting heart rate (HR) can be used as an indicator of ANS balance. Although HRV is an ideal measure to use to assess
parasympathetic and sympathetic innervation to the heart, measures of HRV while an individual is moving presents myriad confounds with current ambulatory measurement devices. The police in the larger study engaged in high intensity movement during short scenarios and then were immediately given time to stand still and recover. A more stable measure of HRV is explained by Thayer et al., (2006). When exposed to stress, intrinsic HR rises above normal resting HR. HR can be used to measure acute ANS regulation by measuring HR recovery (relative to the officer’s own baseline HR), the decrease of HR following exercise (or intense movement) cessation; faster recovery to resting HR implies better parasympathetic control (Thayer & Sternberg, 2006).

Untreated PTSD patients demonstrate significantly lower resting HRV in comparison to controls, which is suggested to be the result of chronic ANS dysregulation, characterized by decreased parasympathetic, and increased sympathetic activity (Minassian et al., 2015; Cohen, Kotler, Kaplan, Mike, & Cassuto, 1998; Cohen et al., 1997; Tan, Dao, Farmer, Sutherland, & Gevirtz, 2010). HRV is shown to normalize in PTSD patients following SSRI treatment, suggesting that HRV manipulation has practical clinical applications in PTSD treatment (Cohen, Kotler, Matar, & Kaplan, 2000; Tan, Dao, Farmer, Sutherland, & Gevirtz, 2010). However, little is known about HRV manipulation as a treatment for P-PTSD in police officers, nor is there sufficient information in the literature regarding the use of the HRV proxy (HR recovery following stress) as a measure of HRV among officers with P-PTSD.

Reducing PTSD Symptoms with Heart Rate Variability Biofeedback

Most treatments for PTSD or P-PTSD occur post-diagnosis when major health performance deterrents are already present. Current studies have suggested that HRV biofeedback (HRV-BF), when combined with usual PTSD treatment, is effective and feasible for reducing PTSD
symptoms in clinical populations (Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011; Wahben & Oken, 2013; Zucker et al., 2009). HRV-BF consists of feeding back beat-by-beat heart rate data in conjunction with slow breathing techniques. The goal of HRV-BF is for the participant to maximize their respiratory heart rate to produce a cyclic sine-wave-like pattern (Lehrer & Gevirtz, 2013). This allows individuals to rapidly attain optimal environmental awareness and modulate autonomic arousal by evoking periods of parasympathetic activation for enhanced recovery and decision making (McCraty et al., 2012). The International Performance Resilience and Efficiency Program (iPREP), developed by Andersen and colleagues (2016), is based on empirical evidence targeting the improvement of psychological and physiological factors implicated in use-of-force errors (intervention is further elaborated in methods section). By teaching officers HRV-BF, they learn to modulate sympathetic and parasympathetic balance during stress, preventing maladaptive responses such as tunnel vision and auditory exclusion, and recover more quickly following stressful events, allowing them to continue to make accurate decisions over the course of their shift (Andersen et al., 2018; McCraty et al., 2012; Johnson, 2008). Andersen and colleagues demonstrate that teaching HRV-BF techniques during simulated use-of-force encounters enhanced psychological and physiological control during stressful situations and improved police officers’ performance during realistic emergency scenarios across 18 months (Andersen et al., 2018). The authors report that officers made more correct use-of-force decisions, and were more aware of their environments (i.e., situational awareness—accurately identifying threats from non-threats), after learning HRV-BF techniques (Andersen, Papazoglou, & Collins, 2016; Andersen, Pitel, Weerasinghe, & Papazoglou, 2016; Andersen & Gustafberg, 2016). However, the association of HRV-BF with P-PTSD symptoms, or the treatment of P-PTSD among police is a novel area of investigation. However, it was not the intention or focus of the larger iPREP study in which this current study is pulling data from.
The Current Study

The current study investigated the effect of P-PTSD symptomology on the performance of police officers during use-of-force critical incident scenarios. The purpose of the current study for my thesis was separate from the larger, on-going study testing an intervention to improve police decision making. The distinction must be made clear that this study was interested in the potential correlation between P-PTSD, performance, and cardiovascular measures (HR_Recovery), but the larger study was not designed to test these associations.

Hypothesis 1: P-PTSD symptoms are associated with performance in police officers. Officers with higher P-PTSD symptoms are more likely to make a performance error.

Hypothesis 2: Officers reporting P-PTSD at baseline will report fewer P-PTSD symptoms at 18 months following the HRV-BF intervention.

Hypothesis 3: P-PTSD symptoms are associated with slower HR recovery following stress (a proxy for low HRV).
Methods

The current study was part of a larger, on-going study to test the efficacy of iPREP to improve police decision making during threatening encounters (Andersen et al., 2018). Furthermore, methods of this study below are extracted from the Andersen et al., (2018) study.

Participants

Participants were volunteers from a pool of approximately 750 frontline officers employed by a large Canadian municipal police agency in Ontario. Fifty-seven (n=57) active duty frontline officers from this pool signed up and participated in this study. A total of twenty-seven (~47%) of participants returned and completed the 18-month follow-up evaluation. Demographic information was collected prior to the study (i.e., age, height, weight, marital status, years as a police officer) (see demographic table - Table 1). All procedures were approved by the University of Toronto Research Ethics Committee. Participants provided informed consent prior to volunteering for the study, and were informed they were eligible to withdraw from the study at any point without consequence.

Table 1. Overview of sample demographics.

<table>
<thead>
<tr>
<th>Demographic Variable</th>
<th>n (N=57)</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>49</td>
<td>87.5</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>12.5</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
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<tr>
<td>White/Caucasian</td>
<td>41</td>
<td>73.2</td>
</tr>
<tr>
<td>African American</td>
<td>4</td>
<td>7.1</td>
</tr>
<tr>
<td>Hispanic</td>
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<td>1.8</td>
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<tr>
<td>Asian-American</td>
<td>3</td>
<td>5.3</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (Years)</td>
<td>32.80357</td>
<td>6.288</td>
</tr>
<tr>
<td>Experience (Years)</td>
<td>7.0869</td>
<td>5.6309</td>
</tr>
</tbody>
</table>

Summary of sex, ethnicity, age, and sex of sample (n=57-1=56 [1 participant did not complete demographic questionnaire]). Volunteered sample primarily consisted of male, Caucasian officers, with an average of 32 years old and 7 years of experience.
Procedure

The present study was a longitudinal repeated-measure, within-subjects quasi-experimental design (Refer to Table 2). Officers were evaluated at 3 time points: pre-intervention (Day 1), post-intervention (Day 4), and 18-month evaluation. For all training and evaluation sessions, officers were fitted with training versions of their usual police equipment (baton, conducted electrical weapon, gun, OC spray, full uniform), and a portable heart rate monitor that adhered to their skin under their clothing (Bodyguard 2, FirstBeat Technologies LTD, Jyväskylä, FI). Each day the officers began by having their baseline heart rate recorded (HR_Rest) while seated to establish their individual resting heart rate. On Day 1, officers began by completing a demographic questionnaire with an embedded PCL-C, followed by a pre-intervention evaluation. During the pre-intervention evaluation, officers completed four live-action, reality-based scenarios, one of which did not require a lethal force decision and was excluded from analyses. Therefore, pre-intervention evaluations were based on three lethal force decisions. Following the morning of pre-intervention evaluation, the training intervention began with classroom-based lessons on HRV-BF theory (see Table 2 for schedule). Day 2-3 consisted of practice sessions of HR monitoring, HRV-BF, and other training techniques (described in more detail in (Andersen & Gustafberg, 2016; Andersen et al., 2018)). During the intervention practice period, each officer was given 12 scenarios in which they made lethal force or de-escalation decisions and applied intervention techniques. Day 4 consisted of the post-intervention evaluation that was a single, intense extended scenario (active school shooter) with three stages that each officer performed along, and required three lethal force decisions. 18-month evaluations required officers to perform three scenarios requiring a single lethal force decision each.
Table 2. Experimental Design

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2 &amp; 3</th>
<th>Day 4</th>
<th>18-months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Morning</strong></td>
<td><strong>Pre Test Evaluation</strong></td>
<td><strong>iPREP HRV-BF Intervention</strong></td>
<td><strong>Post Test Evaluations</strong></td>
<td><strong>Post Test Evaluations</strong></td>
</tr>
<tr>
<td></td>
<td>3 scenarios with 1 shoot/no shoot use-of-force decision each</td>
<td>Reality based training simulations using HRV-BF</td>
<td>3-stage, extended scenario with 3 shoot/no shoot use-of-force decisions</td>
<td>3 scenarios with 1 shoot/no shoot use-of-force decision each</td>
</tr>
<tr>
<td><strong>Afternoon</strong></td>
<td><strong>Intervention Commencement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Classroom psychoeducational component</td>
<td></td>
<td>Survey measures, equipment return</td>
<td></td>
</tr>
</tbody>
</table>

Schedule of testing and intervention for participating officers throughout the study.
*Note: Officers at 18-month evaluation completed all three scenarios during a morning or afternoon block based on their availability.

**Intervention to Improve Police Decision Making**

*International Performance Resilience and Efficiency Program (iPREP)*

Of note, the intervention (iPREP) was not designed as a treatment of PTSD or P-PTSD. The sole focus of the intervention was to improve the accuracy of police use-of-force decision making.

The intervention description is taken from the methods section of Andersen et al., 2018:

“The components of the intervention include a classroom portion covering psychoeducational material (i.e., brain and physiology, acute stress, allostatic load and the impact of stress on performance, situational awareness), and active occupationally relevant scenario-based police training. The classroom portion also explains what HRV-BF is and how to use it to increase parasympathetic activation during occupational exposures. In line with Lehrer and Gevirtz’s HRV-BF protocol (Lehrer & Gevirtz, 2014), participants were provided real-time, beat-by-beat heart rate data while engaging in HRV-BF exercises that produced a characteristic sine-wave-like curve of peaks and valleys in HR, indicating parasympathetic system activation. During the intervention
period, opportunities to engage in HRV-BF are provided during times of rest and before and after each scenario as a tool to train: 1) the use of short periods of recovery to reduce allostatic load; and 2) the reduction of sympathetic dominance during psychologically threatening situations by activating parasympathetic activity (Vlemincx et al., 2013).

Autonomic recovery and modulation was taught using realistic critical incident scenarios tailored to occupational exposures experienced by police officers. Officers practiced recognizing their sympathetic system arousal, and learned physiological and psychological control techniques to improve situational awareness and decision making during scenarios (see above). Early practice scenarios were in slow motion, and designed to induce low-stress to allow officers to condition optimal physiological responses and motor techniques during higher stress scenarios. Practice scenarios gradually increased in both speed and complexity over the course of training.

Following standard police training protocol, expert police Training Officers (TO), not researchers, provided occupationally relevant feedback to students following each scenario. The intervention taught TOs to provide positive, skill focused feedback to enhance officer confidence using techniques as integrated into scenario based training (rather than traditional negative feedback following routine police training). The goal for officers by the end of the training intervention was to be able to quickly transition to an optimal mental and physiological state within seconds and recover from stressful events quickly. By inducing parasympathetic activation during recovery assists in reducing wear and tear on the body and reduces overall allostatic load (McEwen, 2006).

**Evaluations (Day 1, Day 4, 18-months)**
During pre- and post-test evaluations officers went through critical incident scenarios designed to represent real-world scenarios encountered while on-duty. Scenarios tested the participant’s
situational awareness, decision making (i.e., shoot or no shoot decisions; use of lethal force decisions), and overall performance. Experienced police officers were used as actors to enhance reality of critical incidents. Before each scenario, the participant was briefed similarly to responding to a call. Officers waited together but each completed the scenarios independently, and in the same order. After the completion of each scenario, senior officers supplied feedback to the participant and discussed the participant’s thought process and performance during the scenario. Examples of scenarios include:

*Break and Enter:* Officer receives a call to a house where a male suspect is reported kicking in the front door. Upon arrival, officer encounters the open front door and hears someone say “Call 911”. Entering the environment officer observes two men fighting over a crowbar, the homeowner and the male suspect, identifiable via verbal dialog. During the altercation, a third individual will appear.

*Active Shooter:* Officer receives a “low-stress” call to an adult learning center in regards to a threat received by a teacher from a student two days prior. Upon arrival, officer is lead to a classroom to meet with the compliant through a staged hallway where a duffle bag, duct tape, and chains are visible. Call for help is heard from the classroom, in which the teacher will be discovered stabbed. The officer must search for the suspect that is actively firing gunshots down the hallway, while protecting victims and bystanders encountered.

*Domestic Disturbance:* Officer receives a call from a homeowner a residence in regards to his two adult sons having a heated argument following drinking. Upon arrival, the homeowner runs towards the officer saying “Help, help, they’re going to kill each other!”
Within the residence the officer encounters one male on the floor visible only by his feet, a bloody knife also on the floor, and a second male covered in blood yelling and kicking a chair across the room. During the confrontation with the second male the mother of the men will appear out of a second room running and screaming.

**Measures**

*PTSD Checklist (PCL-C)*

Items from the PTSD checklist-civilian (PCL-C), a 17-item self-report measuring DSM-IV PTSD symptoms, were embedded within the demographic survey taken at the beginning of iPREP training intervention (Day 1), as well as at the 18-month follow-up evaluation. The PCL-C measures officers’ self-report of PTSD symptoms experienced in the last month on a 5-point Likert scale, with answers ranging from “Not at all” to “Extremely” (Weathers et al., 1993). Question topics include re-experiences of past stressful or traumatic events, maladaptive behaviour and thoughts, and cognitive deficits such as memory loss, or dissociation. Questions are clustered into symptom categories B (Re-Experiencing), C (Avoidance/Numbing), and D (Hyperarousal). The PCL can be scored one of three ways:

1) Determining whether an individual meets the DSM-IV symptom criteria by reporting a score of greater than 2 on at least 1 B item, 3 C items, and 2 D items.

2) Determining whether the total severity score (summed total of 17 items) exceeds chosen threshold cut-off.

3) Combined 1 and 2 to ensure the individual both satisfies all symptom requirements and threshold cut-off.

The VA National Center for PTSD suggests a cut-off score of 36-44 for full PTSD for populations similar to VA primary care. For this study, we look at the continuous total symptom
severity scores as well as a median split, given the small sample size and relative good health of the officers. Additionally, especially in the case of P-PTSD, Franklin, Sheeran and Zimmerman (2002) found that while a majority of outpatients do not meet all symptom criterions. Furthermore, failing to meet Criterion C (Avoidance/Numbing) is the most common reason individuals who met DSM-IV criteria do not meet DSM5 criteria for full PTSD (Kilpatrick et al., 2013). However, given the small sample size it is likely that the sample will not produce enough variability to apply lenient or stringent P-PTSD cut-offs as done in Dickstein et al.’s (2015) study, and therefore both the continuous symptom counts and a median split will be used, explained in the data analyses below.

Cardiovascular Measures of HR
Officers were fitted with FirstBeat Bodyguard cardiovascular monitors (FirstBeat Technologies, LTD, Jyväskylä, FI) validated for research purposes (Teisala et al., 2014). The monitor non-invasively recorded continuous heart rate data at a rate of 1Hz, allowing physiological reactivity to be recorded in real time throughout the study. The monitor is clipped to two adhesive electrode patches applied to the officers’ skin – one below the left collarbone, and another applied on the ribcage below the heart. Timestamps were coded throughout critical incident scenarios to indicate what the officer was engaged in, for example “preparation of scenario”, “beginning and end of critical incident scenarios”, and “post-scenario feedback.” This allowed measurement of heart rate recovery time (HR_Recovery), a proxy for HRV, which indicates the time (in seconds) for the officer’s heart rate to return to their own average resting baseline HR following stressful critical incident scenarios (Andersen et al., 2018). Calculations for this measure are elaborated below in data analyses.
**Performance Ratings**

Each time point evaluated three lethal force shoot/no shoot decisions (one decision per critical incident scenario). Errors in lethal force were defined as:

1) *Error of Disinhibition*: failing to use lethal force when appropriate situational criteria have been met.

2) *Error of inhibition*: use of lethal force when appropriate situational criteria had not been met.

All criteria for correct or incorrect performance were defined, observed, and evaluated by qualified and experienced use-of-force instructors (TO’s, independent from the research study team.

**Data Analyses**

*Partial PTSD*

P-PTSD was scored in two ways. First, according to the instructions in the PCL-C (Weathers et al., 1993), continuous total symptom severity scores (range = 17-85) were obtained by summing scores from all 17 items of the PCL-C for each officer. Second, given the relatively low reporting of PTSD symptoms and only 10 individuals met the lenient P-PTSD cut-off (33), a median (23) split was conducted. For this study, low P-PTSD scores are below the median ($n_{pre}=29$; $n_{18-month}=10$), and high P-PTSD scores are above the median ($n_{pre}=26$, $n_{18-month}=17$) (Refer to Table 3 for sample PTSD symptom frequencies).

A power analysis was done on the total number of participants’ data was collected from. Using G*Power, given the sample collected, there are a sufficient number of participants and distribution of self-reported PTSD scores to conduct a median split of the participants into low P-
PTSD-scoring (below the median) and high P-PTSD-scoring (above the median) individuals, to find a medium effect size $d = 0.5$, for power $= 0.8$, and $\alpha = 0.05$ (Cohen, 1969).

**Performance**

In the larger study, performance was calculated by recording use-of-force decision-making (Andersen et al., 2018). Performance was operationalized by calculating a risk ratio (number of errors/total number of decision-making opportunities). Error rates for each officer were computed by dividing the total number of errors committed at each time point across all scenarios, by the total number of decision making opportunities at each time point (Andersen et al., 2018). However, given that the larger study followed officers across 18 months (with assessment evaluations at each 6-month period), there was a larger variability in decision making opportunities (80.7% of officers returned for at least one follow up evaluation period across 18 months, showing low overall study attrition, allowing for follow up assessment for the majority of officers. Although at 18 months only (~42% returned) was the period when PTSD was then assessed (see Andersen et al., 2018). For the purpose of this study, we are looking at individuals with P-PTSD and their individual use-of-force decisions (i.e., shoot/no shoot) at the pre-test and at 18-month follow up.

**Heart Rate Recovery Time**

In the larger study, two cardiovascular measures were analyzed: 1) an index of the peak HR (HR_Max) measured during critical incident scenarios relative to each officer’s own resting baseline HR (HR_Rest) recorded at the beginning of each evaluation day while seated, computed as ((HR_Max – HR_Rest)/HR_Rest), and 2) Heart Rate Recovery Time (HR_Recovery), which indicates the time (in seconds) for the officer’s HR_Max to return to HR_Rest (Andersen et al., 2018). Average HR recovery time was calculated for both pre- and 18-month post iPREP
intervention from the recovery times following all critical incident scenarios at each respective time point.

Heart rate recovery measures were extracted from the larger study (Andersen et al., 2018). Missing subject data for HR_Recovery pre-training (n = 7) were due to participants not returning to their average resting HR following critical incident scenarios, and having maximum HR lower than resting (n = 6). One participant at pre- and five participants at 18-months post-iPREP did not have HR_Recovery data due to technical failure and were not included in the analysis below.
Results

Demographics
A total of 57 officers, consisting primarily of Caucasian/white males participated in the study (M_{Age}=32.8; \text{Range}_{Age}=24; M_{Years\ Experience}=7.08; \text{Range}_{Years\ Experience}=27.5) (Refer to Table 2).

P-PTSD and Performance
At pre-iPREP, of the 57 officers, 55 completed the PCL-C, and 51 reported experiencing some degree of PTSD symptoms. Using Dickstein et al. (2015)’s cut-off, 10 officers (~18%) qualified for lenient P-PTSD, of which 3 qualified for both stringent P-PTSD and full PTSD (~5.5%) (M_{Pre-PCL-C}= 25.5, \text{Range}_{Pre-PCL-C}=47; M_{18-month\ PCL-C}= 26.8, \text{Range}_{18-month\ PCL-C}=42) (See Table 3 and 4 for full P-PTSD symptom summaries). As a group, officers’ had a relatively low incidence of lethal force decision errors pre-intervention, with only 9 errors from a total of 171 decision-making opportunities (~5% incorrect shooting decisions).

Table 3. P-PTSD symptom characteristics in police officers

<table>
<thead>
<tr>
<th></th>
<th>Proportion of Reported Symptoms in Each Category</th>
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<tbody>
<tr>
<td></td>
<td>Re-Experiencing (Cluster B)</td>
</tr>
<tr>
<td>Pre-Intervention</td>
<td></td>
</tr>
<tr>
<td>(N=55)</td>
<td>n(reporting symptoms) =51</td>
</tr>
<tr>
<td></td>
<td>n(reporting symptoms according to PCL-C requirements) =29</td>
</tr>
<tr>
<td>Post-Intervention</td>
<td></td>
</tr>
<tr>
<td>18 Months</td>
<td>n(reporting symptoms) =25</td>
</tr>
<tr>
<td>(N=27)</td>
<td>n(with symptoms according to PCL-C requirements) =16</td>
</tr>
</tbody>
</table>

Distribution of PTSD symptoms types by PCL-C clusters pre- and 18-months post receiving HRV-BF intervention training. Frequency rates are shown for both reporting any degree of PTSD symptoms, as well as to the PCL-C requirements (a score ≥3 for each symptom).
Table 4. P-PTSD cut-off distributions in police officers.

<table>
<thead>
<tr>
<th>Median Split Cut-off</th>
<th>Pre-Intervention (n=55)</th>
<th>18 months (n=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (≤23)</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>High (&gt;23)</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>Dickstein et al., (2015)</td>
<td>Lenient (33)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Stringent (38)</td>
<td>3</td>
</tr>
</tbody>
</table>

Distribution of police officers in median (23) total symptom severity split, as well as number of officers that meet Dickstein et al. (2015)’s lenient (33) and stringent (38) PCL-C cut-offs to qualify for P-PTSD.

To compare self-reported P-PTSD symptoms and performance, a regression was calculated to predict each officer’s individual error rate based on their own total symptom severity score. A significant regression equation was not found for either pre- (F₁,₅₃=3.892; p=0.053; R²=0.068), or 18 months post-iPREP (F₁,₂₅=0.84; p=0.37; R²=0.033) (See Figure 1). A hierarchical regression was calculated and did not find adding years of occupational experience, age, sex, and ethnicity explained significantly more variance (See Table 5). A 2x2 Chi-square test of independence also compared frequency of officers’ errors (yes/no) during the critical incident scenarios, with degree of P-PTSD symptoms (high/low-based off median (23) split). No significant relationship was found pre- (X²(1, N=55)=1.90; p=0.020), or 18-months post-(X²(1, N=27)=1.77; p=0.184) receiving iPREP intervention training.
Figure 1. Comparison of self-reported PTSD symptoms and performance during critical incident scenarios.

No significant relationship was found between self-reported PTSD symptoms and performance pre- ($F_{1,53}=3.892; p=0.053; R^2=0.068$) and 18-months post receiving iPREP ($F_{1,25}=0.84; p=0.37; R^2=0.033$).
Table 5. Hierarchal regression analysis with other demographic variables pre-iPREP intervention

<table>
<thead>
<tr>
<th>Added Variable</th>
<th>ΔSS</th>
<th>R²</th>
<th>ΔR²</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTSD Score</td>
<td>12.12</td>
<td>0.051</td>
<td>------</td>
<td>3.892</td>
<td>0.054</td>
</tr>
</tbody>
</table>

Each demographic variable was added to the PTSD model and compared to PTSD-only model. No added variable to PTSD significantly explained more variance than the PTSD-only model.

P-PTSD and HRV-BF Training

A within-group paired t-test compared PTSD symptomology before and 18 months following receiving iPREP training. There was no significant difference in PTSD symptoms between start and 18 months following iPREP training (t\textsubscript{26}=-1.308; p=0.202) (Refer to Figure 2). As a group, police officers’ self-reported total symptom severity PCL-C scores did not significantly increase or decrease between initial testing, and the 18-month follow up.
Figure 2. Self-reported P-PTSD symptomology.

Self-reported PCL-C scores before receiving iPREP HRV-BF training, and 18 months following training. No significant change in self-reported scores ($t_{26}=-1.3075; p=0.2035$) was observed.

Given the small sample, we further broke down each officer’s change in self-reported P-PTSD symptoms between pre-iPREP and 18 months post-iPREP. It is suggested a 5-10 point change in PCL-C total symptom severity score is not due to chance, with 5 points as a minimum threshold for determining if an individual has responded to treatment and greater than 10 points for determining whether the improvement was clinically meaningful (Monson et al., 2008). At 18 months, we had 9 officers report fewer symptoms ($n_{(<5)}=5; n_{(5-10)}=4$), 13 officers report more symptoms ($n_{(<5)}=7; n_{(5-10)}=4; n_{(10<)}=2$), and 5 officers report no change in symptoms, in comparison to self-reported symptoms pre-iPREP.
It should be noted that although reported P-PTSD symptoms did not significantly change from Pre-iPREP intervention to post-iPREP intervention, the same is not true for overall performance. As iPREP was designed for the purpose of improving officers’ use-of-force decision making, there was significant improvement in performance found in the larger study (Andersen et al., 2018) post-iPREP and maintained through 18 months following (See Figure 3). Despite the low error at baseline (approximately 5% use of force errors), the intervention reduced subsequent post-training lethal force error rates by 67% from nine errors, to just three errors of a total 171 decision-making opportunities at immediate post intervention evaluation. This reduction in performance error relative to pre-training was maintained at 18-month (35% reduction) follow up with only 3 errors from a total of 87 decision-making opportunities.

**Figure 3. Lethal force error rates during critical incident training scenarios before and after the physiological intervention (Andersen et al., 2018).**

Performance (i.e., correct shoot/no shoot decisions) was scored by expert Use of Force Instructors, and showed a 67% decrease in errors of lethal use of force following the physiological intervention (9 errors pre-training, 3 errors post-training of 171 opportunities), which was maintained at 18-month retention evaluation (3 errors of 87 opportunities, 35% reduction relative to pre-training error rates).
**P-PTSD and Heart Rate Recovery (HRV)**

A regression was calculated to predict average HR_Recovery time (M_{Pre-Average Recovery}=679.61s, Range_{Pre-Average Recovery Time}=14837; M_{18-month Average Recovery}=226.17s, Range_{18-month Average Recovery Time}=937) based on total symptom severity scores. A significant regression equation was not found for either pre- (F_{1,45}=0.008; p=0.931; R^2=-0.02), or post-iPREP (F_{1,20}=3.692; p=0.07; R^2=0.11) (See Figure 4).
No significant relationship was found between officers’ self-reported P-PTSD symptoms and average HR_Recovery time following critical incident scenarios a) pre- (F_{1,45}=0.008; p=0.931; R^2=-0.02) and b) 18-months post (F_{1,20}=3.692; p=0.07; R^2=0.11) receiving HRV-BF training.

Figure 4. Self-reported PCL-C scores in relation to average HR_Recovery time.
**Discussion**

The objective of this study focused on the influence of P-PTSD symptomology on officers’ performance during critical incident scenarios and HR_Recovery, and the influence of HRV-BF training on these scores.

The first hypothesis predicted that as P-PTSD symptoms increased, officers’ performance during critical incident scenarios would decrease, resulting in more shoot/no shoot errors. No significant relationship was found between P-PTSD scores and performance at pre- or 18-months post receiving HRV-BF training. This result was further supported with non-significant results from a 2x2 chi square test, comparing occurrence of errors during critical incident scenarios (yes/no) and degree of P-PTSD symptomology (high/low – based of median score split). Officers’ performance during critical incident scenarios was not reliably predicted by their self-reported P-PTSD symptoms. A subsequent hierarchical regression revealed no other demographic model significantly explained more variance than a P-PTSD-only model, factoring in age, sex, years of occupational experience, and ethnicity.

The second hypothesis predicted that following receiving HRV-BF training, officers’ self-reported P-PTSD symptoms would be lower at the 18-month follow up in comparison to pre-intervention. A within sample paired t-tests comparing officers’ PCL-C at pre-intervention and 18-months post-intervention did not reveal a significant change in symptoms as a group. Officers reported a similar number of P-PTSD symptoms at pre- and 18-months post receiving HRV-BF training. However officers’ overall performance during critical incident scenarios improved following receiving HRV-BF training, which was the intended purpose of iPREP HRV-BF intervention training. Officers’ performance improved following iPREP training, making fewer
use-of-force errors during critical incident scenarios in comparison to pre-iPREP training. This increase was maintained 18 months following initial iPREP training.

The third hypothesis predicted that HR recovery time (a proxy for HRV), would be significantly slower as P-PTSD symptoms increase. No significant relationship was found between PCL-C scores and HR recovery time at pre- and 18-months post receiving HRV-BF training. Officers’ HR recovery time was not reliably predicted by their self-reported P-PTSD symptoms.

Implications

P-PTSD in Relation to Performance

This study found approximately 18% of police officers that qualified for P-PTSD, based off of Dickstein et al. (2015)’s thresholds for active military samples. This prevalence rate is slightly above P-PTSD prevalence found by Maia et al., (2007) (16%) in Brazilian police officers, but falls within the reported range of P-PTSD symptom prevalence observed in North American police officers (Arnetz et al., 2009; Chopko & Schwartz, 2012; Hartley et al., 2013). There is prior evidence of PTSD symptoms not correlating with performance in studies that compare intelligence test performance between samples with and without PTSD. In comparison to non-PTSD children, children with PTSD had significantly lower scores in the verbal subtests of the WISC-III, which measures general knowledge, language, reasoning and memory skills, but were nonsignificant in the performance scores, which measure spatial, sequencing, and problem-solving skills (Saigh, Yasik, Oberfield, Halamandaris, & Bremner, 2006; LeWinn, Stroud, Molnar, Ware, Koenen et al., 2009). Additionally, Vasterling, Brailey, Constans, Borges, & Sukter, (1997) report similar results in adult samples between war-zone exposed veterans with PTSD and war-zone exposed veterans without PTSD on the WAIS-R, displaying significantly lower verbal intelligence, but non-significant differences on performance subtests. This suggests
that deficits from PTSD may be limited to specific indices of verbal intelligence, and does not influence spatial and problem solving skills measured by the performance indices, such as those measured in the current, large study, e.g., motor and quick decision skills during critical incident scenarios.

**P-PTSD and HRV-BF Training**
P-PTSD symptoms not changing between pre- and 18-months post receiving intervention training is not surprising. PTSD symptoms are relatively stable and can take months or even years for noticeable differences (O'Donnell, Elliot, Lau, & Creamer, 2007) and given the attrition at 18-months follow up, it would be difficult to detect a significant relationship if it exists. Furthermore, the iPREP HRV-BF intervention was designed to improve decision making during use-of-force of police officers by manipulating HRV-based measures that share physiological outcomes with P-PTSD, but not by targeting P-PTSD symptoms directly. The findings of overall improvement performance improvement following iPREP training are consistent with previous studies by Andersen and Gustafson (2016), comparing the performance of groups receiving iPREP training to control groups that did not.

**P-PTSD and Heart Rate Recovery**
Prior research by Wahbeh and Oken (2013) also did not find a significant correlation between any HRV measures and continuous variables of PTSD symptoms. Although a significant difference was found between PTSD and non-PTSD in high frequency HRV peak frequency, this variable was significantly correlated with respiration rate. Wahbeh and Oken (2013) suggest that respiration may be the driving factor for the differences observed in high frequency HRV. Correspondingly, a meta-analysis found that differences in heart rate effect sizes in PTSD status or symptoms are found in the laboratory during extremely traumatic conditions, but not during
resting measures (Pole, 2007). While in this study, critical incident scenarios induce stress, it may not be stressful enough separate significant differences in heart rate indices across PTSD symptom levels, given the small sample size, and HR_Recovery may not be the ideal proxy for HRV to detect differences in P-PTSD. More research is needed to determine if the types of stress experienced by healthy police officers is enough to induce measurable cardiovascular differences.

An alternative hypothesis is that HRV and performance detriments that have been observed in previous research may only manifest in chronic, higher-level PTSD. PTSD performance detriments may require a threshold of symptoms, rather than appearing at a proportionate rate with increasing symptoms. Detriments may not manifest until physiological changes from chronic full PTSD occur, subsequently affecting performance. The hippocampus for example is thought to influence numerous cognitive functions, specifically those involving memory and spatial navigation, and contains a high density of cortisol receptors (Redish, 1999; Jadhave et al., 2012; Cheng & Ji, 2013). When exposed to chronic stress and prolonged deregulated levels of cortisol, the hippocampus atrophies (McEwen, 2002; Lovallo, 2015; Bonne et al., 2001; Smith, 2005; Gilbertson et al., 2002; Woon, Sood, & Hedges, 2010). On average PTSD patients have 6.9% smaller left hippocampal volume and 6.6% smaller right hippocampal volume compared to non-PTSD individuals who experience similar levels of trauma (Smith, 2005).

**Limitations**

One limitation of this study was the homogeneity of the sample population studied. A majority of the volunteered participants in this study were Caucasian and a near complete proportion of officers participating in this study were males, and may have shared personality traits that related to both their participation and performance in this study (i.e. a specific group with higher
motivation to improve skills and/or naturally more skilled/motivated officers). Additionally, there was relatively high homogeneity of the PTSD symptomology due to the relative good health of the collected sample. While there was a range of low to extremely high levels of self-reported P-PTSD symptoms, a majority of officers had reported moderately low levels of symptoms. Furthermore, although the PCL-C has been tested and demonstrated as a valid and reliable measure for PTSD in non-clinical samples, with good internal consistency and retest reliability (Wilkins, Lang, & Norman, 2011; Conybeare, Behar, Solomon, Newman, & Borkovec, 2012), there is still the possibility of skewed self-report, with officers underreporting their experienced symptoms due to the occupational culture of emotional suppression, and a stigma against mental health and therapy in the police force (Dickstein et al., 2015; Heffren & Hausdorf, 2016; Amaranto, Steinberg, Castellano, & Mitchell, 2003). This may have prevented a more representative assessment of P-PTSD prevalence and its influence on police performance in this study. A future study could include the use of clinically-diagnosed PTSD officers, as well as other assessments that bolster and correlate with the PCL-C, such as the Civilian Mississippi Scale, and Trauma Symptoms Checklist (Conybeare, Behar, Solomon, Newman, & Borkovec, 2012).

A limitation that must be acknowledged is that PTSD symptoms were gathered using standard self-report measures, not by clinical diagnosis. Furthermore, although the intervention (i.e., the International Performance Resilience and Efficiency Program – iPREP) was not developed for the treatment of PTSD, the mechanisms by which the intervention targets improved decision making (i.e., modulating autonomic arousal) shares physiological correlates with PTSD symptoms—specifically hyperarousal, maladaptive stress reactivity, and difficulty recovering from stressful events. The critical incident scenarios used highly ecologically valid and
accurately represented scenarios that officers encounter on-duty, visually and physiologically (Andersen, Pitel, Weerasinghe, & Papazoglou, 2016). While best-simulated physiological stress responses occur in highly realistic scenario training rather than classroom-based scenario trainings in laboratory environments, that would be a trade-off of internal validity, which was not appropriate for the larger study. For the objectives of this study, high environmental validity was higher priority for the primary objective of the Andersen et al., (2018) study. One issue that arises for the current study would be balancing the amount of stress across critical incident scenarios exposed to participating officers. A future study could combat this by including other standardized stress tests, such as the Montreal Imaging stress task, which can work in conjunction with neuroimaging.

**Applications and Future Directions**

This project is novel as it focused on the influence of P-PTSD on cardiovascular health and direct occupational performance in police officers while on duty, as well as the effect of HRV-BF intervention training, revealing effects of iPREP’s HRV-BF training on officers with different levels of P-PTSD symptomatology as well as HRV. Based off these results, it is encouraging to see officers’ high critical incident scenario performance despite varying degrees of self-reported symptoms even towards higher reported symptom severity. These results suggest that the HRV-BF training has broad benefits for shoot/no shoot performance, despite varying degrees of P-PTSD symptomology as well as cardiovascular health.

Previous literature supports the need to address PTSD symptoms in the police force, observing international frequency rates ranging from 7-49%. (Schnurr, 2014; Carlier et al., 1997; Marmar et al., 2005; Maia et al., 2007). A number of factors may contribute to these rates including training, culture, and political atmosphere. The next step in this research is to determine what
specific functional skills are affected by P-PTSD symptoms in the policing occupation. This can be assessed by understanding in better detail the types of trauma officers are exposed to and most likely to be affected by. The BTQ (Brief trauma questionnaire) could help assess specific traumatic exposure according to the DSM-IV experienced by officers to pre-screen and determine officers most likely to develop P-PTSD, and follow their changes in cardiovascular health. Additionally, focus on specific P-PTSD symptoms police officers are likely to experience could bolster prevention and intervention training against P-PTSD development following traumatic events. In the current study, officers reported having more hyperarousal symptoms than either avoidance, or re-experiencing. Future studies could include more controlled environments to extrapolate more specific targeting factors, to help further improve the efficiency of HRV-BF and its specific benefits for officers in use-of-force decisions.

It would also be beneficial for a future study to compare the differences between clinically diagnosed P-PTSD and full PTSD in terms of occupational skills in policing. This could perhaps provide a baseline level of symptoms needed to start significantly impeding performance.

Another related research direction would be to compare sex differences. PTSD experience in female police officers and veterans differ from their male counterparts by being primarily related to sexual trauma, and are more likely to develop PTSD following traumatic events (Mota, Medved, Wang, Asmundson, Whitney, & Sareen, 2011; Gavranidou & Rosner, 2003; Breslau et al., 1999). In military populations, women are significantly the minority sex, with a sex ratio of 85:15, found to have more internalizing psychopathy, and experience pre-military stressors, such as sexual abuse and assault (Piccinelli & Wilkinson, 2000; Seedat et al., 2009; Carter-Vischer et al., 2010; Rosen & Martin, 1996). All of these can contribute to increased vulnerability to developing mental illness (Mota et al., 2011). This may contribute to differences in performance.
Given the few number of female officers in this study, we were not able to assess gender differences.

A neurological perspective could provide causal evidence of the effect of accumulated trauma in police officers. Studies using electroencephalography (EEG) have found that individuals with PTSD have increased peak alpha wave frequencies than non-clinical populations (Wahbeh & Oken, 2013). Mismatch negativity (MMN) responses are negative event related potentials elicited by unexpected sensory deviant stimuli that violate a prior stream of repeated standard stimuli (Näätänen et al., 1978). Individuals with PTSD display MMN dysfunction when presented with deviant sensory stimuli, showing both enhanced and depressed MMN waves. This is believed to reflect PTSD’s symptoms and as, as well as protective compensatory mechanisms from hyperarousal and hypervigilance (Ge, Wu, Sun, & Zhang, 2010; Morgan & Grillon, 1999; Menning, Renz, Seifert, & Maercker, 2007). EEG could be used with police officers to measure their threat detection abilities in real time, and be applied to further improving the efficiency of iPREP HRV-BF and use-of-force training.

**Conclusion**

The current study took advantage of available data on a relatively rare sample to explore possible utilization of HRV-BF training for reducing P-PTSD symptoms. Current treatments and therapy for PTSD can be expensive and time consuming. Behavioural therapy, pharmaceutical and biological treatments, even changes in physical exercise may not be feasible for all. Research on the impact of trauma on the health and functioning of police officers may provide a foundation to develop much needed accessible prevention strategies for officers at risk of PTSD. Furthermore, results from this research may contribute to the development of training strategies for other trauma-exposed populations, such as first responders and military officers. Some statistics
indicate that PTSD ranges from 10-35% of first responder, indicating a significant need for more research in this area (Freeze, 2017). PTSD accounts for the largest proportion of persistent psychological difficulties resulting from military duties in Canadian forces (Nazarov et al., 2015), and can develop in 1 in 10 of Canadian Forces personnel within their lifetime (National Defence and the Canadian Armed Forces, 2016). The potential of preventing P-PTSD and negative mental health symptoms would result in not only improved job performance, but increased safety of officers, and of the general public these forces are tasked to protect.
References


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Committee on Public Safety and National Security. House of Commons = Chambre des communes Canada.


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https://doi.org/10.1016/j.biopsycho.2017.03.004


https://doi.org/10.1207/s15327876mp1803s_2


and mental disorders in the World Health Organization world mental health surveys. 


# Appendix

**PTSD Checklist – Civilian Version (PCL-C)**

**Client’s Name: ____________________________**

Instruction to patient: Below is a list of problems and complaints that veterans sometimes have in response to stressful life experiences. Please read each one carefully, put an “X” in the box to indicate how much you have been bothered by that problem *in the last month*.

<table>
<thead>
<tr>
<th></th>
<th>Not at all (1)</th>
<th>A little bit (2)</th>
<th>Moderately (3)</th>
<th>Quite a bit (4)</th>
<th>Extremely (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Repeated, disturbing <em>memories, thoughts, or images</em> of a stressful experience from the past?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. Repeated, disturbing <em>dreams</em> of a stressful experience from the past?</td>
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<tr>
<td>3. Suddenly <em>acting or feeling</em> as if a stressful experience were <em>happening</em> again (as if you were reliving it)?</td>
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<tr>
<td>4. Feeling <em>very upset</em> when <em>something reminded</em> you of a stressful experience from the past?</td>
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<tr>
<td>5. Having <em>physical reactions</em> (e.g., heart pounding, trouble breathing, or sweating) when <em>something reminded</em> you of a stressful experience from the past?</td>
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<td></td>
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<tr>
<td>6. Avoid <em>thinking about or talking about</em> a stressful experience from the past or avoid <em>having feelings</em> related to it?</td>
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<tr>
<td>7. Avoid <em>activities or situations</em> because they <em>remind you</em> of a stressful experience from the past?</td>
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<tr>
<td>8. Trouble <em>remembering important parts</em> of a stressful experience from the past?</td>
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<tr>
<td>9. Loss of <em>interest in things that you used to enjoy</em>?</td>
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<tr>
<td>10. Feeling <em>distant</em> or <em>cut off</em> from other people?</td>
<td></td>
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<tr>
<td>11. Feeling <em>emotionally numb</em> or being unable to have loving feelings for those close to you?</td>
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<tr>
<td></td>
<td>Question</td>
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<td>--------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>12.</td>
<td>Feeling as if your <em>future</em> will somehow be <em>cut short</em>?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13.</td>
<td>Trouble <em>falling</em> or <em>staying asleep</em>?</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>14.</td>
<td>Feeling <em>irritable</em> or having <em>angry outbursts</em>?</td>
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<tr>
<td>15.</td>
<td>Having <em>difficulty concentrating</em>?</td>
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<tr>
<td>16.</td>
<td>Being “<em>super alert</em>” or watchful on guard?</td>
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<tr>
<td>17.</td>
<td>Feeling <em>jumpy</em> or easily startled?</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

**PCL-M for DSM-IV (11/1/94)** Weathers, Litz, Huska, & Keane National Center for PTSD - Behavioral Science Division
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