A Reasonable Officer:
Examining the Relationship between Stress, Training, and Performance in Use of Force Encounters

by

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Abstract

High-stress police encounters can evoke psychological and physiological stress reactions in officers, which can result in cognitive and perceptual deficits, as well as inferior performance. These effects can be particularly detrimental during a critical incident, when officers are expected to demonstrate sound judgement and proficient performance. However, limited research exists that objectively measures stress reactivity experienced by police officers during active-duty or the degree of police performance that can reasonably be expected under the levels of stress observed in naturalistic use of force (UoF) encounters, based on the level of experience and training officers have received. This dissertation reports on two studies, one drawing on data from officers during active-duty and the other using an experimental scenario, to examine the relationship between stress, training, and performance in UoF encounters.

Study 1 examined autonomic stress responses experienced by 64 police officers, during general duty calls for service and interactions with the public. Officer characteristics, including years of service and training profiles, were also examined to explore whether experience and training impacted cardiovascular reactivity. Study results highlight the sorts of risks that officers are routinely exposed to in the course of their duties, as well as the nature and frequency of the stress reactions experienced by officers. Results also showed that the phase of the call (e.g., encountering a subject) and incident factors (e.g., UoF) significantly increased stress reactivity. Study 2 assessed the performance of 122 officers during a realistic lethal force scenario to examine whether performance was affected by the officer's level of training, years of service, and stress reactivity. Results demonstrated that the scenario produced elevated heart rates, as well as perceptual and cognitive distortions, commensurate with those observed in naturalistic settings. The average performance rating from the scenario was 59%, with 27% of participants making at least one lethal force error. Elevated stress was a predictor of poorer performance and increased lethal force errors. Training and years of service had complex effects on both performance and lethal force errors.

The results from these two studies provide important insights into the general relationship between stress, training, and performance in UoF encounters. The findings provide LEAs with an opportunity to critically reflect on current training practices and offer a roadmap for making evidence-based improvements to training. They also provide important evidence that may inform the reasonableness standard used in courts of law by painting a realistic picture of police performance under stress given the current training available to officers. Perhaps most importantly, the research identifies a need for a concerted effort to increase police training standards and ensure the necessary infrastructure is in place to achieve them.

Keywords: police, use of force, stress, training, performance

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Dedication

To my wife, Vicky and my kids, Quinn and Bodie (who have only ever known daddy as a grad student). You are my everything. Thank you for standing with me and supporting me on this long journey.

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List of Acronyms

ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
BPM	Beats per Minute
CAD	Computer Aided Dispatch
CEW	Conducted Energy Weapon
CFS	Calls for Service
CIT	Crisis Intervention Team
DFJDM	Deadly Force Judgment and Decision-Making
ECG	Electrocardiogram
FLETC	Federal Law Enforcement Training Centre
GPS	Global Positioning System
HPA	Hypothalamic-Pituitary-Adrenal
HR	Heart Rate
HRV	Heart Rate Variability
ICC	Intraclass Correlation Coefficient
KSAs	Knowledge, Skills, and Abilities
LEA	Law Enforcement Agency
LMM	Linear Mixed Models
NDM	Naturalistic Decision-Making
OIS	Officer-Involved Shooting
PNS	Parasympathetic Nervous System
PPE	Personal Protective Equipment

RMSSD	Root mean square of successive differences between normal heartbeats
RPDM	Recognition-Primed Decision-Making
SBT	Scenario-Based Training
SET	Stress Exposure Training
SM&A	Scene Management and Aftercare
SNS	Sympathetic Nervous System
STAR	Scenario Training Assessment and Review
TSI	Tactical Social Interaction
UoF	Use of Force

Preface

This dissertation was completed under Carleton University's Integrated Thesis Policy for Psychology. Therefore, the dissertation is structured as a series of manuscripts. Both studies required significant planning, logistics, approvals, travel, and data collection, which required team efforts to successfully achieve. I affirm that I was fully involved in leading all aspects of the research for my dissertation.

The first paper, "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" was conceptualized by Dr. Craig Bennell and myself. Tori Semple, Bryce Jenkins, and I conducted the data collection in British Columbia, over a nine-day period. I performed the data analysis and interpretation with guidance from Dr. Judith Andersen and under the supervision of Dr. Bennell. I drafted the manuscript and Dr. Bennell, Dr. Andersen, Tori Semple, and Bryce Jenkins provided critical revisions. All authors approved the final version of the manuscript for submission. This article has been reproduced in full and in accordance with the copyright.[1]

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The second paper, "A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario" was conceptualized by Dr. Bennell, Dr. Brittany Blaskovits, and myself. Dr. Judith Andersen advised on stress measures during conceptualization. Dr. Blaskovits, Andrew Brown, Bryce Jenkins, Chris Lawrence, Heather McGale, Tori Semple, and myself conducted the data collection in British Columbia, over a one-month period. I performed the data analysis and interpretation with guidance from Dr. Andersen and under the supervision of Dr. Bennell. I drafted the manuscript and Dr. Bennell, Dr. Blaskovits, Andrew Brown, Bryce Jenkins, Chris Lawrence, Heather McGale, Tori Semple, and Dr. Andersen provided critical revisions. All authors approved the final version of the manuscript for submission. It is currently being considered for a special issue of Frontiers in Psychology.

In accordance with the Integrated Thesis Policy, in Appendix A each co-author, including my supervisor, has signed the co-author contribution statement, confirming their agreement to the statements in the preface. Dr. Bennell's signed statement, in support of the preface, can also be found in Appendix A.

Introduction

Policing is a highly stressful and dangerous profession (Pinizzotto et al., 2006; Violanti, 2014). In the face of a potentially violent and life-threatening critical incident, most people respond by running in fear. Police officers on the other hand are required to advance towards the threat, often encountering unpredictable, potentially uncontrollable, and novel circumstances (Alison & Crego, 2012; Fridell & Binder, 1992); hallmark characteristics of a situation that would cause a physiological stress response (Sapolsky, 2004). It is under these conditions that officers are required to make split-second decisions to preserve and protect the lives of both the public and themselves (Artwohl, 2002). Though use of force (UoF) encounters, particularly those involving lethal force, are not an overly common occurrence in Canada (Baldwin et al., 2020; Singh, 2020), they can result in tragic outcomes, including the deaths of civilians and officers. In addition to the risks of serious injury and death, these kinds of incidents can also result in strained police-community relations, as well as substantial liability for officers and law enforcement agencies (LEAs; e.g., Braidwood, 2010; Dubé, 2016; MacNeil, 2015).

High-stress police encounters can evoke psychological and physiological stress reactions in officers, which can result in cognitive and perceptual deficits, as well as inferior performance (e.g., Artwohl & Christensen, 1997; Klinger, 2006; Morrison & Vila, 1998). These effects can be particularly detrimental during a critical incident, when officers are expected to demonstrate sound judgement and proficient performance. However, very limited research exists that objectively measures the frequency and magnitude of stress reactivity experienced by police officers while responding to general duty calls for service.

Additionally, while LEAs train officers for critical incidents, the training time is often restricted due to resource and budgetary constraints (Bennell et al., 2020; Rojek et al., 2020), and training is seldom evidence-based or evaluated for intended outcomes (Sherman, 2015). While greater levels of on-the-job experience and police training should, theoretically, increase resilience to stressors and improve performance under stress (e.g., Driskell & Salas, 1996), there is little empirical understanding of the extent to which current police training achieves this and the degree of performance that can reasonably be expected under the levels of stress observed in naturalistic UoF encounters. This information is necessary to make evidence-based improvements to training, paint a realistic picture of police performance under stress, and inform the objective reasonableness standard, which is used to assess the appropriateness of force in courts of law.

Through a collaborative research partnership with a large Canadian LEA,[2] this dissertation reports on two studies, one drawing on data from officers during active-duty and the other using an experimental scenario, to examine the relationship between stress, training, and performance during UoF encounters. More specifically, the first study aimed to investigate the physiological responses experienced by police officers during general duty calls for service (CFS) and UoF encounters. This was done to develop a "profile" of physiological responses associated with various aspects of police CFS, such as the phase of the call (e.g., dispatch, enroute) and incident factors (e.g., call priority, arrest, UoF), as

[2] The LEA is the police of primary jurisdiction for approximately 8 million people (22% of the Canadian population), 75% of the geography of Canada, and represents 25% of Canadian police officers.

well as to provide novel evidence of how frequently officers experience high physiological stress responses. The study also aimed to explore whether experience and relevant operational skills training moderated cardiovascular reactivity. The second study used a highly complex and realistic lethal force scenario, aimed at replicating the level of stress observed during real-world UoF encounters, to assess performance of active-duty police officers. This study allowed for an examination of whether performance, including lethal force errors, was affected by the officer's level of operational skills training, years of police service, and stress reactivity.

This dissertation was completed under Carleton University's Integrated Thesis option, which allows one to submit a compilation of interconnected published papers, or papers awaiting publication, as opposed to the traditional monograph thesis. In my case, both papers were written with co-authors, although I led all aspects of the research (see the Preface). This approach was taken for two primary reasons. First, the studies were logistically involved, resource intensive, comprised of specialized samples (i.e., active-duty police officers), and involved complex data management and analysis techniques, which would have been prohibitive without a team of co-authors with specific expertise, such as stress physiology, policing, and police-academic partnerships. This robust team-approach leveraged existing academic partnerships with the participating LEA and a Social Sciences and Humanities Research Council (SSHRC) Insight Grant to help obtain agency support and approvals. Second, the integrated thesis approach expedited academic peer-review and the knowledge mobilization process, which both strengthened the dissertation and allowed for early dissemination and adoption of the research findings into police practice.

Because the dissertation follows the format of an Integrated Thesis, detailed literature reviews and discussions are included within each of the papers. Following the papers, a general discussion is provided that not only summarizes the findings from both studies, but also reflects on their practical implications, particularly in relation to the importance of collaboration for conducting research on police performance, as well as knowledge mobilization. The general discussion also qualifies the results, outlining overarching limitations of the research, and provides some directions for future research.

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Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters

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Data Availability Statement

The datasets for this manuscript are not publicly available because of privacy and ethical restrictions. Requests to access the datasets should be directed to SB (simonbaldwin@cmail.carleton.ca).

Ethics Statement

All procedures were approved by the Carleton University's Research Ethics Board (REB #17-106853) and the agency's Research Review Board (RRB).

Author Contributions

SB and CB conceptualized the study. SB, TS, and BJ conducted the data collection. SB performed the data analysis and interpretation with guidance from JA and under the supervision of CB, and drafted the manuscript. CB, JA, TS, and BJ provided critical revisions. All authors approved the final version of the manuscript for submission.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Abstract

Policing is a highly stressful and dangerous profession that involves a complex set of environmental, psychosocial, and health risks. The current study examined autonomic stress responses experienced by 64 police officers, during general duty calls for service (CFS) and interactions with the public. Advancing previous research, this study utilized GPS and detailed operational police records as objective evidence of specific activities throughout a CFS. These data were then used to map officers' heart rate to both the phase of a call (e.g., dispatch, enroute) and incident factors (e.g., call priority, use of force). Furthermore, physical movement (i.e., location and inertia) was tracked and assisted in differentiating whether cardiovascular reactivity was due to physical or psychological stress. Officer characteristics, including years of service and training profiles, were examined to conduct a preliminary exploration of whether experience and relevant operational skills training impacted cardiovascular reactivity. Study results provide foundational evidence that CFS factors, specifically the phase of the call (i.e., arrival on scene, encountering a subject) and incident factors (i.e., call priority, weapons, arrest, use of force), influence physiological stress responses, which may be associated with short-term performance impairments and long-term health outcomes. Implications of research findings for operational policing, police training, and health research are discussed.

Keywords: police, occupational stress, physiological reactivity, heart rate, use of force

Introduction

Policing is a highly stressful and dangerous profession that involves a complex set of environmental, psychosocial, and health risks (Andersen, Papazoglou, et al., 2016; Chopko & Schwartz, 2012; Gershon et al., 2009; Pinizzotto et al., 2006; Violanti, 2014). Against a background of less dangerous tasks, officers are required to respond to violent and life-threatening situations, often encountering novel, ambiguous, and rapidly unfolding events (Fridell & Binder, 1992). It is under these conditions that officers are required to make decisions, sometimes in a split-second, and act to protect the public and themselves (Artwohl, 2002). The current study examines physiological responses experienced by police officers, during general duty calls for service (CFS) and interactions with the public. The aim of the study is to provide novel evidence of how frequently officers experience high physiological stress responses and examine the influence of the phase of the call (e.g., dispatch, enroute) and incident factors (e.g., call priority, use of force) on physiological arousal. The study will also explore whether experience and relevant operational skills training impact cardiovascular reactivity.

When presented with a threatening stimulus (whether real or perceived) the body engages in a series of automatic physiological processes (LeDoux & Pine, 2016). Ledoux and Pine described two pathways to the threat, or "fear" response, more colloquially known as the "fight-or-flight" response. The pathways are: (1) behavioural and physiological stress responses and (2) fearful feelings in higher order cognitive processing. Under elevated levels of stress, the engagement of the first path, automatic physiological processing, happens within sub-cortical structures of the brain's limbic system. The second path engages higher order cortical cognitive processing, generating conscious feelings, such as fear or other related emotions, in response to a threat (Fenici et al., 2011; LeDoux & Pine, 2016). The fight-or-flight response is implicit (i.e., below conscious awareness) and is the default human response to threat in order to maximize survival by immediately preparing the body to fight or flee without the need for higher-order cognitive processing (LeDoux & Pine, 2016; Thayer & Sternberg, 2006).

During the fight-or-flight response, two central physiological processes are engaged to mobilize the body to meet the demands of the situation and suppress unnecessary functions (e.g., reproduction, growth; Kemeny, 2003; McEwen, 1998). As described in detail by McEwen (1998) and Lovallo (2016), the sympatho-adrenal response results in a wide-spread, powerful reaction, which includes the release of neurotransmitters and hormones. The other physiological process is the engagement of the autonomic nervous system (ANS), which is made up of two branches – the sympathetic (SNS) and parasympathetic (PNS) divisions.

Perceived threats are associated with an increase in SNS activation and, typically, the suppression of the PNS, which is associated with relaxation, focused attention, and stabilization (Berntson & Cacioppo, 2004). As reviewed by Lovallo (2016), when the SNS is activated, catecholamines such as norepinephrine and epinephrine (i.e., adrenaline) are released. Simultaneously, the hypothalamic-pituitary-adrenal (HPA) axis is activated, which results in the rapid release of epinephrine and cortisol from the adrenal glands (Lovallo, 2016). Cortisol stimulates glucose production and mobilizes fatty acids to encourage higher blood sugar and prepare for energy expenditure (Anderson et al., 2002; Sharps, 2016). The surge of these catecholamines, stress hormones, and glucose through the bloodstream stimulate increased respiration, heart rate, and blood pressure

(Chrousos, 2009; Tsigos & Chrousos, 2002). The increased blood flow, oxygenation, and energy are then directed in the highest concentration to the brain, heart, and large muscles (Tsigos & Chrousos, 2002). Conversely, blood flow to other areas (e.g., digestive system), which are not required to respond to a threat, are inhibited. Thus, activation of this stress system leads to an increase in strength, resistance, and attention to improve chances for survival in the short-term (Fenici et al., 2011; Tsigos & Chrousos, 2002). However, chronic, or maladaptive autonomic activation can be detrimental to health over the long-term (McEwen, 1998). The ways in which chronic stress may be detrimental to the health of police officers has been examined (Violanti, Burchfiel, et al., 2006; Violanti, Fekedulegn, et al., 2006). Longitudinal studies indicate that police officers experience dysregulation in HPA axis functioning associated with occupational stressors (Violanti et al., 2017). Furthermore, police officers are more likely to be diagnosed with chronic health conditions such as heart and metabolic disease than their civilian peers (Violanti, Fekedulegn, et al., 2006). However, there is a lack of studies examining the impact of acute stress on health among police officers.

Research has suggested that SNS arousal that matches situational demands (not too high or too low) is beneficial for performing optimally during threatening situations, as it can result in heightened sensory perceptions, rapid decision-making, and improved cognitive functioning (Cahill & Alkire, 2003; Hansen et al., 2009; Jamieson et al., 2010; Lambourne & Tomporowski, 2010). However, under conditions of extreme stress, such as when police officers encounter life threatening situations, performance may be impacted in various ways, some of which can be detrimental to performance (e.g., Artwohl &

Christensen, 1997; Klinger, 2006; Morrison & Vila, 1998; Westmoreland & Haddock, 1989).

When considering performance generally, maladaptive stress arousal can result in increased task errors and degradation of task accuracy (Driskell & Salas, 1996). These adverse effects primarily involve cognitive functions, such as attention, perception, and decision-making (Driskell & Salas, 1996). Attention is a limited capacity resource, in that only a certain amount of information-processing capacity exists, making it difficult to focus attention on two things at the same time (Vickers, 2007). When attending to a threat, less attention is available for cognitive processing and cognitive overload is more likely to occur, which can result in inattentional blindness (Chabris et al., 2011; Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2011a). Similarly, higher levels of arousal are associated with perceptual narrowing (e.g., tunnel vision, auditory exclusion) because the perceptual field tends to shrink under stress (Honig & Lewinski, 2008; Vickers, 2007). These attentional and perceptual deficits mean that individuals can miss relevant cues (e.g., a subject dropping their weapon; Easterbrook, 1959; Vickers, 2007) and be unable to recall aspects of a situation (Hope et al., 2016; Yuille et al., 1994). Maladaptive stress arousal is also associated with hypervigilant decision-making, which is often impulsive, disorganized, and inefficient (Johnston et al., 1997). Accordingly, Keinan et al. (1987) found that under threat of shock in a laboratory setting, participants completing a computer task tended to offer solutions prior to assessing all alternatives, abandoning their systematic approach of scanning relevant decision options. Research has also demonstrated that police decisions and behaviours, including aggression, during training were found to be associated with maladaptive heart rate (HR) arousal rather than situational factors presented in the scenario (Haller et al., 2014).

Perceptual-motor performance is also degraded by stress, although not to the same extent as cognitive performance (Nieuwenhuys & Oudejans, 2011a; Staal, 2004). For example, a study examining the execution of arrest and self-defence skills demonstrated that under stress, officers were less able to inhibit threat-related processing (e.g., perceptual narrowing) and achieve task-relevant processing (e.g., attentional control), thus leading to poorer task performance (Renden et al., 2014). In line with the default survival response, fine motor skills, such as manipulating a firearm, also tend to be at greater risk for impairment under stress than gross motor skills, such as running (Staal, 2004).

Several studies have examined officer-involved shootings (OIS) to determine how stress may have impacted performance in naturalistic settings. The findings are consistent with the broader stress and performance research. For example, hit rates in annual firearms requalification on the range are near 90% (Anderson & Plecas, 2000), but deteriorate rapidly in the real-world (i.e., hit rates ranging from 14-38%; Donner & Popovich, 2018; Morrison & Garner, 2011; Morrison & Vila, 1998). Moreover, under such conditions, officers can experience perceptual distortions, reduced motor dexterity, and impaired cognitive function (e.g., Artwohl, 2008; Honig & Sultan, 2004; Klinger & Brunson, 2009). Artwohl (2008), for example, had 157 police officers complete a survey within a few weeks of being involved in an OIS to examine perceptual and memory distortions that they may have experienced during the high stress incident. The results indicated that the majority of officers experienced perceptual narrowing (i.e., 84% experienced diminished sound and 79% experienced tunnel vision). Most participants

(74%) also reported that they responded with little or no conscious thought (i.e., automatic pilot) and many (52%) reported memory distortions or loss. Approximately 7% of the sample reported temporary paralysis, though the author indicated that this may be related to the fleeting freeze response when startled (see LeDoux, 2003), which seems prolonged in high-stress shooting conditions (i.e., 62% reported slow motion time). Similar reactions have been reported in other studies as well (e.g., Honig & Sultan, 2004; Klinger & Brunson, 2009). These effects can be particularly detrimental during a critical incident, when officers are expected to demonstrate sound judgement, proficient performance, and provide accurate recall of their actions.

Manipulating stressful real-world encounters for research purposes would be unethical (Giessing et al., 2019); thus, much of the knowledge that exists today about the physiological impact of stress on performance among police officers come from scenario-based experiments. For example, several studies have found that high stress and anxiety scenarios resulted in impairments to shooting performance (Landman et al., 2016a; Nieuwenhuys & Oudejans, 2010; Taverniers & De Boeck, 2014), quality of skill execution (Nieuwenhuys et al., 2016; Renden et al., 2014; Renden et al., 2017), proportionality of force applied (Nieuwenhuys et al., 2012; Renden et al., 2017), memory (Hope et al., 2016), and communication (Arble et al., 2019; Renden et al., 2017). However, recent studies on police officers demonstrate that the impact of acute stress on performance is complex. For example, stress appears to have differential effects on cognition and physical movement in that rehearsed and automated skills are influenced to a lesser degree (Arble et al., 2019; Renden et al., 2017; Vickers & Lewinski, 2012). Experimental research with simulations is extremely important to not only draw conclusions about what ‘might’ happen to performance in real-world stressful encounters, but also to inform police training to improve public and police safety (Giessing et al., 2019).

While there is no single “best tool” for measuring stress, real-world demands outline the choice of appropriate measures given situational and environmental constraints. Common measures of reactivity to stress capture SNS and HPA axis activation and PNS suppression. Heart rate variability (HRV) is thought to capture changes in the balance between SNS and PNS activity (Thayer et al., 2012), and salivary cortisol is used to capture HPA anticipation and reactivity to stress (Hellhammer et al., 2009). However, during real-world police encounters these measures are highly sensitive to movement (i.e., HRV) or cumbersome to collect without confounds, such as time of day (i.e., salivary cortisol), rendering these methods inappropriate for continuous monitoring throughout police active duty shifts (Dickerson & Kemeny, 2004; Smyth et al., 2013). Current research specifically discourages the collection of HRV while participants are moving because data is highly inconsistent, erroneous, and may lead to false conclusions (Heathers & Goodwin, 2017). Alternatively, HR averaged across time, while controlling for movement, is a robust, ecologically valid, objective, and easily obtainable proxy measure for stress among highly active participants (Vrijkotte et al., 2000).

Previous research supports the feasibility of measuring the stress reactions of officers using HR as they complete their operational duties. Anderson et al. (2002) fitted 76 officers with HR monitors, which were worn prior to and during shifts, and had research assistants record their actions on a minute-by-minute basis during ride-alongs.

The results provided HR profiles for various activities. For example, HR became elevated on average to 99-124 beats per minute (bpm; i.e., 40-65bpm above resting rate) when involved in a use of force (UoF) encounter (e.g., physical control, fight, hand on pistol) with a suspect, with maximum HRs reaching 112bpm above resting rate. Similarly, Andersen, Pitel, et al. (2016) monitored tactical officers during 11 active duty shifts. Researchers matched activities from the officers' shift notes with their physiological profiles. Study observations revealed that active duty tactical officers operated, on average, at 146bpm, and ranged from 160-180bpm during UoF incidents, such as pointing a firearm at suspect and warrant executions (Andersen, Pitel, et al., 2016). Taking a novel approach, Hickman et al. (2011) conducted a pilot study where one officer wore a Garmin global positioning system (GPS)-enabled wrist-watch equipped with a HR monitor. Using GPS data and information from the calls the officer responded to, HR could be visually mapped and associated to specific aspects of CFS. For example, the officer's heart rate spiked to 165bpm (69bpm higher than the officer's average HR throughout the shift) when conducting a high risk vehicle takedown (i.e., firearm drawn) of an impaired hit-and-run driver who failed to stop for police.

In the current study, continuous ambulatory cardiovascular reactivity was measured on multiple active duty shifts. This was done to develop a "profile" of physiological responses associated with various aspects of police encounters that may influence call outcome. Specifically, this novel approach mapped autonomic stress responses to both the phase of a call (e.g., dispatch, enroute) and incident factors (e.g., call priority, UoF). Advancing previous research, this study utilized GPS and detailed operational police records (e.g., police notes, dispatch records) as objective evidence of specific activities throughout a CFS to be cross-referenced with cardiovascular reactivity data. Furthermore, physical movement (i.e., location and inertia) was tracked and assisted in differentiating whether cardiovascular reactivity was due to physical or psychological stress. It has been argued that, as moderators, experience and training can serve to 'intervene' immediately following the presence of a stressor (i.e., blunting the stress response due to previous exposure) or after the stress response occurs (i.e., through the threat appraisal process; Driskell & Salas, 1996; Kavanagh, 2005; Wollert et al., 2011). Results from a UoF simulation study provided some evidence for this moderating effect, with officers on a specialized arrest unit displaying lower HR during a high-pressure scenario, compared to general duty officers (Landman et al., 2016b). Accordingly, individual variables, including an officer's years of service and training profiles, were examined to conduct a preliminary exploration of whether experience and relevant operational skills training impacted cardiovascular reactivity. Together, these data will provide foundational evidence of what CFS factors are associated with physiological stress responses and to what degree and frequency. This is an important investigation because maladaptive stress responses may be associated with short-term performance impairments (Driskell & Salas, 1996; Nieuwenhuys & Oudejans, 2011a) and long-term health outcomes (Chopko & Schwartz, 2012; Violanti, 2014).

With the use of HR as an indicator of physiological arousal, we tested whether officers' cardiovascular reactivity uniquely varied as a function of call priority, the phases of a call, incident factors, demographics, experience, and training. We hypothesized the following:

Hypothesis 1: Officers' cardiovascular reactivity would increase throughout the phases of a call (e.g., from dispatch to encounter).

Hypothesis 2: CFS dispatched with a higher priority level (i.e., very urgent), that involved an arrest/apprehension, UoF, and/or a weapon being reported or accessible, would result in officers experiencing elevated physiological arousal.

Hypothesis 3: Officers with more experience (i.e., years of service) would experience lower cardiovascular reactivity during CFS.

Hypothesis 4: Officers with more relevant operational skills training would experience lower cardiovascular reactivity during CFS.

Methods

Participants

Over a period of nine days, 69 active duty frontline police officers from a large Canadian police agency volunteered to participate in our study. The inclusion criteria for participants were that they were considered 'fit for duty' by their police agency and currently on active duty. Screening for diseases was based on self-report. As this is not a diagnostic clinical study, we did not perform medical examinations, however we did examine self-reported diseases in relation to the data. One participant reported cardiovascular disease and another reported being on medication that affects HR, but their cardiovascular measures (i.e., HR_{rest}, $HR_{average}$, and HR_{max}) did not significantly differ from other participants and they were thus retained in the study.

A total of 125 shifts were recorded. Data from nine shifts were unusable because the HR data was corrupted (n = 3, 2.4%), the HR monitor became dislodged (n = 3, 2.4%), or the officer did not respond to any CFS (e.g., scene security; n = 3, 2.4%). This resulted in a final sample size of 64 officers over 116 shifts. Over a third of the officers (*n* = 25, 39.1%) participated during one shift, while a large number participated in two (*n* = 29, 45.3%) or three shifts (*n* = 8, 12.5%). One officer participated during four shifts and another during five. In total, approximately 1,200 hours of recording time captured HR data for 754 participant responses to 593 CFS. Accordingly, almost a quarter of the CFS (*n* = 142, 23.9%) involved a response from multiple participants.

Table 1 shows the basic sociodemographic characteristics of the sample (*n* = 64). The majority of participants were male (79.7%) and had an average age of 31 years (*SD* = 6.4). Most (87.5%) had obtained post-secondary education. All of the participants were general duty constables with between 1 month and 12 years of service (*M* = 2.06 [years], *SD* = 2.08). Over a quarter (27%) of the participants had previous experience with another law enforcement agency or the military. Training records indicated many participants had received agency training on the conducted energy weapon (CEW; 60.9%), carbine (73.4%), and responding to active threats (81.3%). There were five participants (7.9%) who reported having been involved in a lethal force encounter, as either the officer discharging their firearm, or a witness officer on scene.

Table 1

Participant Demographics

Demographic factors	*n*	%	*M*	*SD*
Sex				
Male	51	79.7%		
Female	13	20.3%		
Age	64		31	6.4
Height (in)	64		73	13.8
Weight (lb)	64		182	28.6
Highest level of formal education				
High school diploma or equivalent	8	12.5%		
Registered Apprenticeship or other trades certificate or diploma	2	3.1%		
College or other non-university certificate or diploma	18	28.1%		
University certificate or diploma below bachelors level	12	18.8%		
Bachelors degree	20	31.3%		
Post graduate degree above bachelors level	4	6.3%		
Current rank				
Constable	64	100.0%		
Current duty type				
General duty	64	100.0%		
Years of service with the agency	64		2.06	2.08
Prior service with another police agency or the military	17	27.0%		
Training experience				
Instructor experience in the area of use of force	3	4.8%		
Specialized training in the area of use of force (outside of the agency)	15	23.8%		
Martial arts	23	36.5%		
Active shooter	52	81.3%		
Conducted energy weapon	39	60.9%		
Carbine	47	73.4%		
Involved in a lethal force encounter	5	7.9%		

Materials

Demographics and Shift Questionnaires

A short demographics questionnaire was used to collect age, gender, years of service, law enforcement experience, and training. A pre-shift questionnaire was used to collect basic information on general health factors (e.g., exercise, sleep), while the UoF and level of fatigue during the shift were captured with a post-shift questionnaire.

Operational Police Records

Operational police records were obtained and reviewed to categorize officers' activities throughout their shift. Operational records included: (1) police notes, which are typically prepared during or shortly after a police occurrence and are used by officers as an aide memoire for court purposes; (2) occurrence files, which are created for the officer(s) to add reports (e.g., general, supplemental) and outline details concerning the circumstances of the call, individuals involved, actions taken, and whether charges were laid; (3) UoF reports, which an officer completes to articulate the use of an intervention and describe the officer's risk assessment; and (4) computer-aided dispatch (CAD) records, which provide time-stamped radio communications (e.g., contact with subject, arrest), officer status (e.g., dispatched, enroute, on scene), and messages to mobile workstations.

Monitoring Devices

HR, GPS, and physical movement were captured with a Polar V800 watch, H7 chest strap HR sensor, and Stride sensor, which is a foot mounted inertia sensor (Polar Electro Oy, Kempele, Finland). The H7 is paired through Bluetooth with the Polar V800 to record cardiovascular reactivity at one second intervals. Polar HR monitors are regularly used to measure HR in police research (Anderson et al., 2002; Barton et al., 2000; Hope et al., 2016; Hope et al., 2012; Hulse & Memon, 2006; Kayihan et al., 2013; Landman et al., 2016a; Meyerhoff et al., 2004; Renden et al., 2015) and the technology has been validated against electrocardiograms (ECG; Gamelin et al., 2006; Giles et al., 2016; Nunan et al., 2009; Nunan et al., 2008; Quintana et al., 2012; Rezende Barbosa et al., 2016; Wallén et al., 2012; Weippert et al., 2010). The Polar V800 is equipped with an integrated GPS that tracks speed (kilometers per hours; km/h), pace (min/km), cadence (steps/min), distance (m), location (latitude and longitude), and route. The Stride sensor automatically calibrates with the V800's GPS to capture more accurate and detailed physical movement. The battery duration of the V800 is up to 13 hours with continuous GPS recording, which covers the typical police shift.

Measures

Heart Rate

Consistent with previous research, the HR monitors attached to officers were used to collect several measures of cardiovascular reactivity: resting HR during the shift (HR_{rest}), maximum HR (HR_{peak}) reached during each phase of the call (see below for more details), and average heart rate throughout the shift ($HR_{average}$) (Andersen & Gustafsberg, 2016; Andersen, Pitel, et al., 2016; Anderson et al., 2002). HR_{rest} is best determined immediately upon waking in the morning, as HR measures taken before or during a shift may include anticipatory stress regarding the upcoming shift or potential events that might be encountered during the current shift and therefore be slightly higher than actual resting HR (Plowman & Smith, 2013). Resting HR can also be affected by body position and is reported to be higher when sitting, as opposed to when lying supine (Miles-Chan et al., 2013). However, for logistical reasons, HR_{rest} in this study was based on the lowest one-minute HR while an officer was on shift. Similar methods for determining HR_{rest} have been used in previous research (Andersen & Gustafsberg, 2016; Anderson et al., 2002). HR_{rest} during sleep was collected for a small subsample (*n* = 10) for comparative purposes. HR_{max} and HR_{min} represented the highest and lowest HR during the officer's shift. To provide a standardized measure for between-subject analysis, the difference ($HR_{peak\ above\ resting}$) between the officers' HR_{peak} during phases of the call and their HR_{rest} was calculated (Andersen, Pitel, et al., 2016; Anderson et al., 2002).

Movement

Speed (km/h), which was captured by the GPS and the inertia sensor, was collected to control for physical movement throughout an officer's shift. This assisted us in determining whether cardiovascular reactivity resulted from physical or psychological stress. For example, a large increase in HR absent of physical movement would suggest a psychological stress response. For reference purposes, average walking speed is approximately 5km/h (Bohannon, 1997). A slow or average jogging pace is 8km/h and a fast jog is 11km/h (Schnohr et al., 2015). Research on law enforcement cadets has also found that average sprint speeds are approximately 23 ½ km/h (Crawley et al., 2016; Lewinski et al., 2015).

Phase of the Call

Using GPS data and operational police records, HR_{peak} and movement were broken down temporally into four phases of the call: (1) dispatch, (2) enroute, (3) arrival on scene, and (4) encounter, UoF and/or arrest (see Figure 1). The first three phases were determined using GPS data and officer status timestamps from the CAD (e.g., dispatched, enroute, on scene). The fourth phase was established by cross-referencing GPS data, inertia sensor data, time-stamped radio communications (e.g., contact with subject, arrest), officer notes, occurrence files, and UoF reports.

Figure 1

A Disturbance CFS Provides a Graphical Representation of How Stress-Activity Mapping was Conducted Using HR, GPS, and Inertia Data in Polar Flow

Note. The left vertical axis (A) presents HR (bpm), in red on the horizontal axis. The left vertical axis (B) presents speed (km/h) from the GPS, in blue on the horizontal axis. The left vertical axis (C) presents cadence [rpm] from the Stride sensor, in green on the horizontal axis. A tracking meter (D) identifies HR and movement measures at a specific point in time, which is linked to the corresponding GPS position on the map. Physiological data can be highlighted and zoomed in for detailed examination. Imagery ©2019, CNES / Airbus, DigitalGlobe, IMTCAN, Landsat / Copernicus, McElhanney

Incident Factors

CFS were classified based on dispatch priority levels (1 through 3). To ensure CFS are dispatched in a consistent manner, dispatchers adhere to standard operating procedures to assign priority levels. Priority levels are defined as:

> Priority 1 - Very Urgent - Immediate Dispatch. A major incident or incident in progress that requires immediate police presence, assistance or service. Involves the report of a loss of life or a need for police to prevent a loss of life.
>
> Priority 2 - Urgent - Dispatch as soon as possible. There is an urgent need for police presence, assistance or service. While there is no loss of life involved, the potential for escalation of violence exists.
>
> Priority 3 - Routine - Dispatch as soon as reasonably possible. Reports that do not require immediate police presence, assistance or service.

From the post-shift questionnaires and operational records, CFS were also coded for whether weapons were reported or accessible (0 = no, 1 = yes) during any phase of a call, if there was an arrest or apprehension (0 = no, 1 = present while other officer conducted arrest, 2 = *Mental Health Act* apprehension, 3 = arrest), and whether the encounter involved UoF (0 = no, 1 = non-firearm, and 2 = firearm). UoF included the use of physical control techniques, both soft (e.g., joint locks, soft takedowns) and hard (e.g., stuns and strikes, hard takedowns), less lethal options (e.g., CEW), and firearms, with or without a subject present. For example, clearing an empty building with a firearm drawn was categorized as UoF.

Training

Officers' training records and the training information captured in the demographics form were used to identify the following six experience criteria: (1) instructor experience in the area of UoF, (2) specialized training in the area of UoF (outside of the agency), (3) martial arts, (4) active shooter, (5) CEW, and (6) carbine. All officers had taken the agency's mandatory crisis intervention and de-escalation training. To create a composite training variable, the sum of the training experience criteria for each officer was calculated. A score was assigned to each participant to indicate the number of experience criteria the officer had (0 = least and 6 = most; see Table 2). While the categorization does not take into account the recency and frequency of training experience, nor weight types of training differently, it provides a basic measure that enabled us to examine the effect of training on cardiovascular reactivity during CFS.

Table 2

Composite Training Score, Indicating the Number of Experience Criteria the Officer Possessed (0 = least and 6 = most).

Level of training	*n*	%
1	9	14.1%
2	13	20.3%
3	29	45.3%
4	9	14.1%
5	3	4.7%
6	1	1.6%
Total	64	100.0%

Procedure

To improve the likelihood of capturing physiological responses to high-stress encounters, the selection of the study location and collection period were informed by an examination of UoF trends and violent crime severity indexes in Canadian cities. The urban city that was selected had approximately 700 operational officers and five policing districts. The two districts that were targeted have a population of approximately 220,000 and an area of 86 km^2. Work shifts were 12 hours in length with staggered start times. Early morning shifts started at 0600 hours and late morning shifts started at 0930 hours. Early night shifts started at 1700 hours and late-night shifts start at 1900 hours. Participants were recruited by having the District Watch Commanders send a callout message via internal e-mail. Researchers also recruited at the pre-shift briefings.

Those interested in participating in the study completed a written informed consent form and were asked to take standard notes throughout their shift, indicating the time and call for service/activity that they were involved in. Participants were then equipped with a Polar V800 watch, H7 chest strap HR sensor, and Stride sensor. Following this, officers completed a demographics and pre-shift questionnaire. Monitoring devices were worn for the entirety of their shift. At the end of their shift, recordings were stopped, equipment removed, and the officers then completed a post-shift questionnaire. A copy of each officer's notebook notes for the shift were obtained. Each participant received a debriefing form and $50 financial compensation. A small subsample (*n* = 10) volunteered to wear a HR monitor during their normal sleep cycle so that we could obtain their resting HR while sleeping. These participants received an additional $50 in financial compensation.

After the field work was completed, the researchers accessed operational files, UoF reports, dispatch logs for the CFS, as well as training profiles for all the participants. Anonymized HR, GPS, and Stride sensor data were uploaded to the Polar Flow web application (Polar Electro Oy, 2016) where they were integrated with maps and charts for visual analysis and coding (see Figure 1). All procedures were approved by Carleton University's Research Ethics Board (REB #17-106853) and the agency’s Research Review Board (RRB).

Data Analyses

Data from the stress-activity mapping (i.e., officer HR and movement data for corresponding phases of the call), along with incident factors and demographic data, were entered into SPSS v.22 (IBM Corp, Released 2013) for quantitative analysis. All data were checked for expected ranges, presence of outliers and abnormal values. The Shapiro–Wilk test was used to assess normality (no assumptions were violated). The descriptive data are presented as frequencies, rates (%), means, and standard deviations. Paired-samples *t*-tests are used to test the mean difference between paired observations. The reported statistical tests are one-tailed, and the significance value is set to $p < 0.05$. Descriptive statistics for $HR_{peak\ above\ resting}$ across CFS are reported for each phase of the call as a function of incident factors (e.g., call priority).

To examine how the standardized measure of cardiovascular reactivity ($HR_{peak\ above\ resting}$) varied as a function of the phases of the call, demographics, incident factors, and training, linear mixed models (LMM) for repeated measures are used. LMM is a flexible approach for the analysis of repeated measures data and has several advantages over traditional methods (e.g., ANOVA). LMM can appropriately handle missing data and therefore does not exclude cases with a missing time point (Gueorguieva & Krystal, 2004). Moreover, the LMM can account for uneven spacing and correlation between repeated measurements on the same subjects and does not assume homogeneity of variance across groups and time points (Blackwell et al., 2006; Gueorguieva & Krystal, 2004). Time-varying covariates may also be included in the LMM (Blackwell et al., 2006); allowing for speed (km/h) at each phase of the call to be used as a covariate to control for movement. The LMM model will use a two-level hierarchical data structure: CFS as level-1 and participants as level-2. The model will include a random intercept to accommodate correlations in the outcome variables across CFS for each participant. All other predictors and covariates, including phase of the call, were specified as fixed effects. To compare fixed effects across models, maximum likelihood (ML) estimation was used (Zuur et al., 2009). The Bonferroni correction was used as a post-hoc test to control for type I errors.

Results

Shift HR

Table 3 presents HR data for officers across their shifts. A subsample (*n* = 10) wore a HR monitor to sleep to obtain an off-shift resting heart rate for comparative purposes. A paired-samples t-test was conducted to compare HR_{rest} at the lowest one minute while on shift and while the officer was sleeping. There was a significant difference in HR_{rest} at the lowest one minute while on shift ($M = 64.60$, $SD = 6.74$) and while the officer was sleeping ($M = 55.40$, $SD = 6.60$), $t(9) = -4.261$, $p = 0.001$, $d = 1.35$. Therefore, as expected, the resting rate in this study was slightly higher than actual resting HR during sleep. This may be attributed to factors such as anticipatory stress while on-shift or the officer's body positioning during the recording (e.g., sitting in police vehicle). As such, HR_{rest} in this study reflects the realities of an officer being at rest while on-shift and provides a context relevant baseline measure to standardize increases in HR ($HR_{peak\ above\ resting}$) between the officers.

Table 3

Descriptive Statistics for Officer HR Across Shifts

	N	*M*	*SD*	*Min*	*Max*
HR_{rest}	64	63.1	9.7	40.0	85.0
$HR_{average}$	64	82.7	10.7	54.0	102.4
HR_{min}	64	59.3	8.8	38.0	81.0
HR_{max}	64	147.6	19.6	109.0	203.0

Note: HR_{rest} is the lowest one minute on shift.

Call for Service

The types of calls responded to by participants, along with their associated dispatch priority level, are presented in Table 4. Disturbances (9.3%) and abandoned 911 calls (8.9%) were the most common calls that participants responded to. CFSs were most frequently dispatched as urgent (*n* = 524/754, 69.5%), followed by routine (*n* = 171/754, 22.7%), and very urgent (*n* = 59/754, 7.8%). Calls for weapons, shots fired, and assaults in progress were most commonly dispatched as very urgent.

Table 4

Frequency of Call Type by Priority Level

	Priority level				
	1 - Very Urgent	2 - Urgent	3 - Routine	Total	
Call type	*n*	*n*	*n*	*n*	%
Disturbance	3	65	2	70	9.3%
Abandoned 911	4	58	5	67	8.9%
Check wellbeing	0	53	1	54	7.2%
Bylaw	0	4	35	39	5.2%
Domestic in progress	7	23	0	30	4.0%
Assault report	0	26	3	29	3.8%
Assist police/fire/ambulance	0	26	2	28	3.7%
Alarm	0	27	0	27	3.6%
Unwanted person	0	14	11	25	3.3%
Suicidal person	5	19	0	24	3.2%
Fight	2	20	0	22	2.9%
Weapon	12	9	0	21	2.8%
Assist general public	0	9	12	21	2.8%
Suspicious person	0	14	4	18	2.4%
Motor vehicle incident	0	16	2	18	2.4%
Drugs	0	12	5	17	2.3%
Suspicious circumstances	1	12	3	16	2.1%
Suspicious vehicle	0	7	7	14	1.9%
Mischief	0	4	10	14	1.9%
Threats	0	5	7	12	1.6%
Shots fired	9	0	0	9	1.2%
Break and enter in progress	0	9	0	9	1.2%
Theft of vehicle	0	3	5	8	1.1%
Theft in progress	0	8	0	8	1.1%
Assault in progress	7	1	0	8	1.1%
Animal	0	6	2	8	1.1%
Other call types (<1%)	9	74	55	138	18.3%
Total	59	524	171	754	100.0%

Stress Reactivity

To examine the participant's cardiovascular reactivity during CFS, descriptive statistics for $HR_{peak\ above\ resting}$ as a function of incident factors (e.g., call priority) and phases of the call (e.g., dispatch) are displayed (see Table 5). Average $HR_{peak\ above\ resting}$ was lowest during the dispatch phase (*M* = 25.94, *SD* = 13.62), and increased while enroute (*M* = 32.50, *SD* = 13.42), and when arriving on scene (*M* = 46.37, *SD* = 16.32). Average $HR_{peak\ above\ resting}$ was highest during the encounter/UoF/arrest phase of the call (*M* = 55.30, *SD* = 20.25). Throughout all phases of the call, average $HR_{peak\ above\ resting}$ increased with the urgency of the priority level and the report or accessibility of a weapon(s) (*n* = 43/754, 5.7%). As expected, arrest (*n* = 68/754, 9%) and apprehension (*n* = 26/754, 3.4%) of a subject resulted in more pronounced increases in average $HR_{peak\ above\ resting}$ during the latter phases of the call, compared to the earlier phases. As the level of force increased from none, to non-firearm (*n* = 71/754, 9.4%), to firearm (*n* = 27/754, 3.6%), average $HR_{peak\ above\ resting}$ also increased. Interestingly, elevated average $HR_{peak\ above\ resting}$ can be observed during all phases of the call when force was used. For example, incidents where officers drew their firearm were those with the highest average $HR_{peak\ above\ resting}$ during dispatch (*M* = 38.5, *SD* = 20.4), while enroute (*M* = 44.2, *SD* = 21.1), when arriving on scene (*M* = 57.9, *SD* = 18.7), and during the encounter (*M* = 67.5, *SD* = 14.5).

Table 5

$HR_{peak\ above\ resting}$ as a Function of Incident Factors and Phases of the Call

	Dispatch HR_{peak} above resting[a] (n = 741)				Enroute HR_{peak} above resting (n = 697)				Arrival on scene HR_{peak} above resting (n = 681)				Encounter/use of force/arrest HR_{peak} above resting (n = 272)			
Incident factors	*M*	*SD*	*n*	%	*M*	*SD*	*n*	%	*M*	*SD*	*n*	%	*M*	*SD*	*n*	%
Call priority																
1 - very urgent	32.7	15.2	59	8.0%	39.5	18.5	54	7.7%	53.1	20.5	52	7.6%	56.9	25.3	22	8.1%
2 - urgent	26.0	14.0	518	69.9%	33.0	13.3	490	70.3%	46.4	15.9	475	69.8%	55.5	19.7	207	76.1%
3 - routine	23.2	10.8	164	22.1%	28.5	9.9	153	22.0%	44.1	15.4	154	22.6%	53.6	20.6	43	15.8%
Weapon(s) reported/accessible																
Yes	36.3	16.4	42	5.7%	39.9	20.4	43	6.2%	54.2	19.7	40	5.9%	55.5	24.7	26	9.6%
No	25.3	13.2	699	94.3%	32.0	12.7	654	93.8%	45.9	16.0	641	94.1%	55.3	19.8	246	90.4%
Arrest/apprehension																
Arrest	29.7	14.2	63	8.5%	38.8	16.8	66	9.5%	58.3	17.0	66	9.7%	62.9	24.5	63	23.2%
MHA apprehension	30.2	16.8	26	3.5%	32.9	14.6	25	3.6%	50.5	16.2	25	3.7%	55.0	26.3	23	8.5%
Present while other officer conducted arrest	29.0	13.1	21	2.8%	38.3	17.1	21	3.0%	51.7	12.1	21	3.1%	46.4	13.1	19	7.0%
No	25.3	13.4	631	85.2%	31.6	12.6	585	83.9%	44.6	15.8	569	83.6%	53.5	17.3	167	61.4%
Use of force																
Firearm	38.5	20.4	27	3.6%	44.2	21.1	27	3.9%	57.9	18.7	27	4.0%	67.5	14.5	25	9.2%
Non-firearm	29.0	15.4	68	9.2%	37.9	17.0	69	9.9%	55.6	16.4	70	10.3%	63.2	26.4	63	23.2%
No	25.1	12.8	646	87.2%	31.3	12.1	601	86.2%	44.7	15.6	584	85.8%	50.9	16.8	184	67.6%

Note. Sample size decreases across phases of the call, since for various reasons, not all dispatched officers travel to the scene, attend the scene, and/or come into contact with the subject of the call (e.g., officer called off, subject gone upon officer's arrival).

[a]Resting heart rate was 63 beats per minute.

To examine how cardiovascular reactivity ($HR_{peak\ above\ resting}$) varied as a function of the phases of the call, demographics, incident factors, and training, the results of the LMM for repeated measures are presented (see Table 6). Two models are displayed: one with speed (km/h) at each phase of the call as a covariate to control for movement and one without movement. Results for the model without movement will be presented and contrasted when differences appear in the model including movement. Based on this sample of officers and CFS, estimates (*B*) from the models (see Table 6) can be used to approximate average stress reactivity experienced by officers during CFS. For example, the following formula can be developed for a male officer responding to a priority 1 call with a weapon reported, where the officer clears a residence with his firearm drawn (at an average walking speed – 5km/h), resulting in the location and arrest of a subject:

146bpm (estimated HR) = HR_{rest} (63.1) + intercept (28.66) + priority 1 (5.61) + weapon reported/accessible (4.11) + average walking speed (5km/h x 2.53) + officer use of firearm (7.64) + encounter phase (18.15) + arrest (6.49)

Table 6

Linear Mixed-Effects Model for Repeated Measures with $HR_{peak\ above\ resting}$ as a Function Phases of the Call, Officer Characteristics, Incident Factors, and Training with and without Movement as a Covariate

	Without movement				With movement			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*
Fixed effects (intercept)	28.61	5.40	5.30	<.001	28.66	5.23	5.48	<.001
Phase of call[a]								
Encounter/use of force/arrest	24.39	1.04	23.52	<.001	18.15	1.02	17.72	<.001
Arrival on scene	20.28	0.65	31.36	<.001	11.58	0.67	17.32	<.001
Enroute	6.41	0.45	14.11	<.001	7.33	0.40	18.20	<.001
Dispatch	--				--			
Sex								
Female	3.39	2.21	1.54	.130	2.71	2.14	1.27	.209
Male	--				--			
Age	-0.18	0.16	-1.12	.266	-0.21	0.15	-1.35	.181
Years of service	-0.08	0.47	-0.17	.867	0.03	0.46	0.07	.942
Call priority	--							
1 - very urgent	7.00	1.55	4.52	<.001	5.61	1.39	4.04	<.001
2 - urgent	1.82	0.87	2.09	.037	1.32	0.78	1.68	.093
3 - routine	--				--			
Weapon(s) reported/accessible								
Yes	3.80	1.60	2.37	.018	4.11	1.44	2.85	.005
No	--				--			
Arrest/apprehension								
Arrest	6.48	1.74	3.72	<.001	6.49	1.57	4.14	<.001
MHA apprehension	3.65	2.02	1.80	.072	2.80	1.81	1.54	.123
Present while other officer conducted arrest	3.17	2.19	1.45	.148	1.47	1.97	0.75	.454
No	--				--			
Use of force								
Firearm	8.30	1.90	4.36	<.001	7.64	1.71	4.46	<.001
Non-firearm	0.58	1.77	0.33	.743	-0.17	1.59	-0.11	.913
No	--				--			
Level of training	-0.22	0.81	-0.28	.784	-0.19	0.78	-0.24	.807
Movement	--	--	--	--	2.53	0.11	24.04	<.001
Random effects	Var	*SD*			Var	*SD*		
Officer (intercept)	36.47	6.0			35.69	6.0		

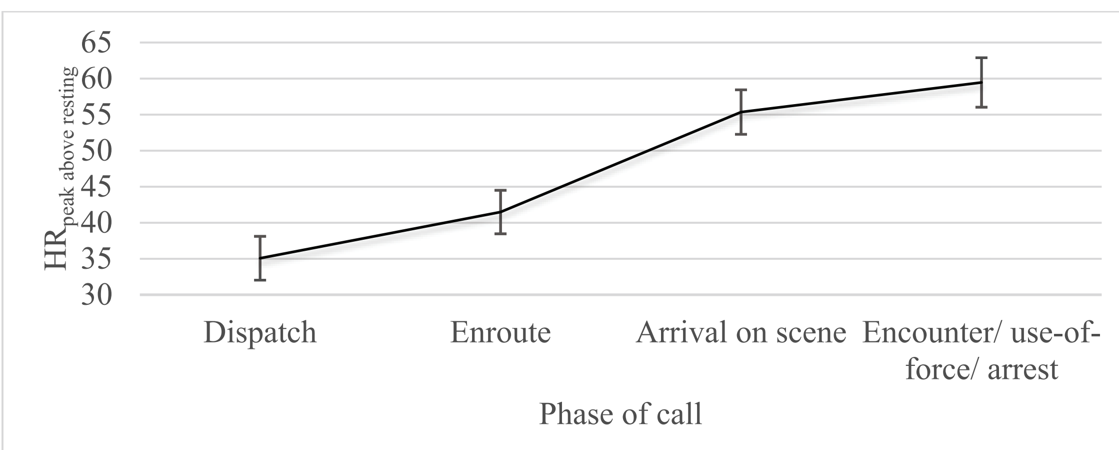
Note. Unstandardized regression coefficient (*B*), standard error (*SE*), and t value (*t*). Mean resting heart rate was 63 beats per minute.
[a]Repeated measures.

Phase of the Call

Our first hypothesis, that officers' cardiovascular reactivity would increase throughout the phases of the call (e.g., from dispatch to encounter), was tested using a repeated measures analysis. The repeated measures analysis without speed as a covariate determined that $HR_{peak\ above\ resting}$ significantly differed across the phases of the call (F(3, 567.455) = 384.390, $p < .001$). In support of the hypothesis, the Bonferroni post-hoc correction revealed that $HR_{peak\ above\ resting}$ during the encounter (M = 59.46, SE = 1.75) was significantly higher than when being dispatched to the call (M = 35.07, SE = 1.54, $p < .001$), while enroute (M = 41.48, SE = 1.53, $p < .001$), and when arriving on scene (M = 55.35, SE = 1.57, $p < .001$). Results remained significant at the $p < .001$ level when controlling for movement. See Figure 2 for a line chart of estimated marginal means for phase of call.

Figure 2

Line Chart Displaying Estimated Marginal Means for Phase of Call, without Movement as a Covariate, from the Linear Mixed-Effects Model for Repeated Measures



Note. Results did not significantly change when movement was included as a covariate – see Table 6). HR_{rest} was 63bpm.

Incident Factors

Recall that our second hypothesis was that CFS dispatched with a higher priority level (i.e., very urgent), that involved an arrest/apprehension, UoF, and/or a weapon being reported or accessible, would result in officers experiencing elevated physiological arousal. Results for the incident factors show that $HR_{\text{peak above resting}}$ significantly differed as a function of call priority ($F(2, 713.764) = 10.221$, $p < .001$), reported/accessible weapon(s) ($F(1, 690.781) = 5.594$, $p = .018$), arrest/apprehension ($F(3, 666.173) = 4.884$, $p = .002$), and UoF ($F(2, 671.957) = 9.5$, $p < .001$). Results remained significant when controlling for movement. Specifically, results indicate that very urgent calls were associated with a 7bpm increase in heart rate compared to routine calls ($p < .001$), while the report/accessibility of a weapon(s) increased heart rate by 3.8bpm ($p = .018$). An incident involving an arrest resulted in a 6.5bpm increase in heart rate, compared to one that did not ($p < .001$). Similarly, responses involving a participant's use of their firearm elevated heart rate by 8.3bpm compared to a response that involved no UoF ($p < .001$). Incidents involving non-firearm UoF did not result in a significant increase in HR (.58bpm, $p = .784$), however this can be attributed to the collinearity between arrest/apprehension and UoF (i.e., most arrests involve some level of force, such as soft physical control techniques). In fact, when the arrest/apprehension factor was removed from the model, non-firearm UoF resulted in a 5.6bpm increase in heart rate ($p < .001$). Overall, our hypothesis was supported and, with the exception of call priority, results remained consistent when controlling for movement.

Demographics and Experience

Results for the demographic and experience characteristics show that $HR_{peak\ above\ resting}$ did not significantly differ as a function of gender ($F(1, 65.255) = 2.216$, $p = .141$), age ($F(1, 66.842) = 1.259$, $p = .266$), or years of service ($F(1, 61.406) = .028$, $p = .867$). Results remained non-significant when controlling for movement. Due to collinearity between age and years of service, models were run that retained one variable, while excluding the other. Neither age ($B = -.191$, $p = .169$) nor years of service ($B = -.344$, $p = .412$) became significant with this approach. The results did not support our third hypothesis, that officers with more experience (i.e., years of service) would experience lower cardiovascular reactivity during CFS.

Training

Our fourth hypothesis, that officers with more relevant operational skills training would experience lower cardiovascular reactivity during CFS, was also not supported. In both models, with and without movement, the composite training variable created from the sum of the training experience criteria for each officer had a non-significant effect on $HR_{peak\ above\ resting}$ ($F(1, 66.555) = .076$, $p = .\ 784$).

Movement

When speed (km/h) at each phase of the call was included as a covariate to control for movement, it had a significant effect on $HR_{peak\ above\ resting}$ ($F(1, 1664.088) = 577.717$, $p < .001$). Results indicate a 2.5bpm increase in heart rate for every 1 km/h increase in movement. The inclusion of speed (km/h) in the model did not significantly alter the results of the model, except for estimates of HR during the phase of the calls. Specifically, decreases in estimated HR were observed during the phases of the call where one would expect more movement. Thus, controlling for movement, estimates for arrival on scene and the encounter/UoF/arrest decreased by 8.7bpm and 6.2bpm, respectively.

Discussion

The current study measured continuous ambulatory cardiovascular reactivity to develop a "profile" of physiological responses associated with various aspects of police encounters. This novel approach expanded on the pilot work of Hickman and colleagues (2011), to establish the feasibility of using GPS and detailed operational police records to map general duty police officers' autonomic stress responses to the phase of a call and incident factors. Consistent with the findings of Anderson and colleagues (2002), the current study sample demonstrated that officers had an HR_{min} of 59bpm and an $HR_{average}$ of 83bpm during their shift. The striking similarity between HR measures in our study and those in the only other known study involving on-shift HR tracking of general duty officers, improves the generalizability of our results. The current research also builds on the growing body of evidence (e.g., Andersen, Pitel, et al., 2016; Anderson et al., 2002) indicating that stress arousal is a real consideration in general duty policing. For example, in our study, significant cardiovascular reactivity was observed during shifts with HR_{max} averaging 148bpm for participants and ranging up to 203bpm.

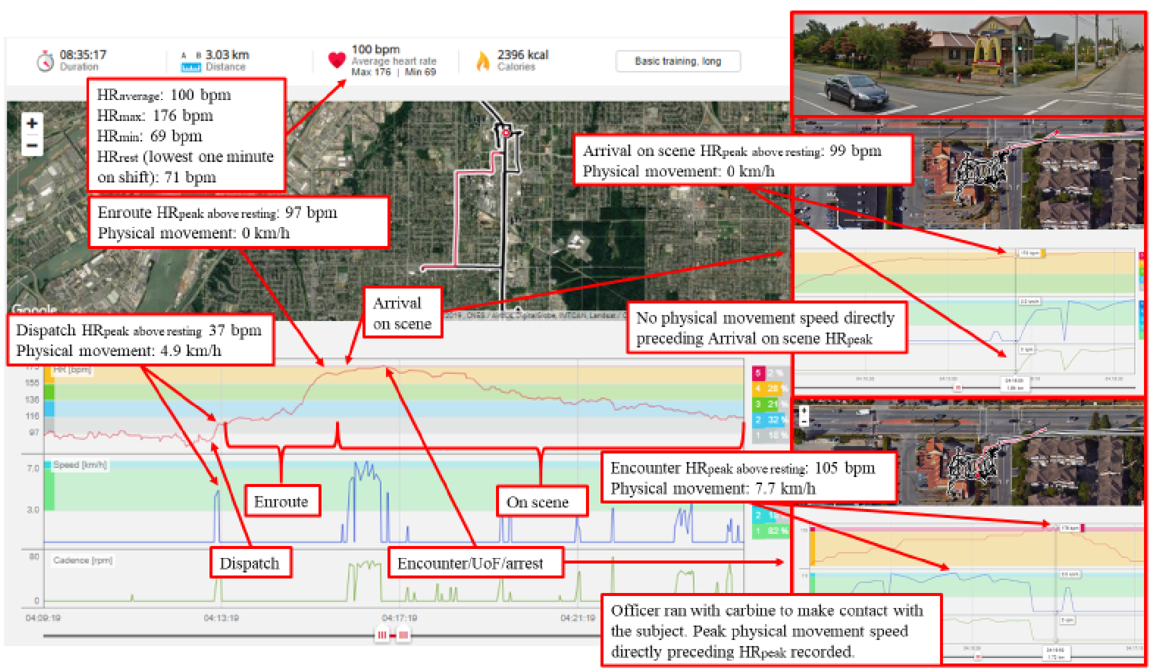
Building on the work of Anderson and colleagues (2002), our use of advanced statistical methods (i.e., LMM for repeated measures) allowed us to examine how officers' cardiovascular reactivity uniquely varied as a function of call priority, the phases of the call, incident factors, demographics, and training. Results indicate that very urgent priority 1 calls, which accounted for 8% of CFS in this study, were associated with a 7bpm increase in HR compared to routine calls ($p < .001$). As we hypothesized, independent of incident factors, average HR at dispatch (98bpm) was significantly higher than HR_{rest} and steadily elevated while enroute (105bpm), when arriving on scene (118bpm), and during the encounter/UoF/arrest phase of the call (123bpm); demonstrating increasing arousal throughout a CFS (see Figure 2). Moreover, in support of our second hypothesis, specific incident factors, such as the report/accessibility of a weapon(s), making arrests, and drawing one's firearm, increased heart rates (by 3.8bpm, 6.5bpm, and 8.3bpm, respectively) relative to calls where these factors were not present. Unfortunately, it was not possible to consistently determine the phase of a call that an officer became aware of a weapon (or potential weapon). This limits our ability to tease apart whether the influence of weapons on cardiovascular reactivity presented from a perceived (anticipatory) or real threat.

In the current study, individual variables including an officer's age, gender, years of service, and training profiles, were examined to conduct a preliminary exploration of whether demographic variables, experience, or relevant operational skills training impacted cardiovascular reactivity. None of these variables showed a significant effect, indicating that physiological arousal may not be a function of officer characteristics, nor the level of experience (i.e., years of service) or the type of training that was examined in this study, as we hypothesized. Instead, as discussed above, stress reactivity was primarily associated with higher risk incident factors. The findings related to experience and training align with studies of tactical officers, who generally respond to high risk encounters (Andersen, Papazoglou, et al., 2016; Andersen, Pitel, et al., 2016). Specifically, Andersen and colleagues (2016; 2016) found that tactical officers, despite their many years of service and elite training, typically operate at a higher level of arousal (e.g., 146bpm), ranging from 160-180bpm during UoF encounters. In both types of research (general duty and tactical officers) we see that typical police training alone does not seem to reduce physiological arousal to high risk calls. Thus, it seems likely that call risk, or perceived call risk, rather than training itself, may be determining an officer's level of physiological arousal. That being said, it is worth reiterating that although the training results of the current study align with previous research, the basic training measure used in the current study was limited. Specifically, the composite training variable did not consider the recency or frequency of training experience, nor weight types of training differently. Future research should use a more sophisticated measure of training that considers these additional factors.

Notably, this was the first known on-shift policing study to objectively measure physical movement (i.e., location and inertia) to assist in differentiating whether cardiovascular reactivity was due to physical or psychological stress. We know from medical science that movement of the body increases oxygen demands to the muscles and thus could be responsible for the increase in heart rate (via increases in respiration to meet oxygen demands). In this study we were not able to collect respiration rate. Thus, we used movement as a covariate (a proxy of increased oxygen demands) to examine if the increases in heart rate could be explained by purely physical reasons (i.e., oxygen demands to the muscles); if not, then increases in heart rate potentially stem from psychological stress. Interestingly, increases in HR resulting from physical movement appeared to be largely independent of increases in HR related to incident factors (e.g., arrest, use of a firearm). Therefore, significant increases in HR, which were observed when officers were presented with a real or perceived threatening stimulus (i.e., priority 1, reported/accessible weapon[s], arrest/apprehension, and the UoF), appear to be attributable to psychological stress and the initiation of the fight-or-flight response. The inclusion of movement as a covariate in research examining on-shift stress in general duty police encounters is a novel contribution to the field and these results support that psychological stress is a consistent and central component of operational police responses. A real-world example from the study (see Figure 3), demonstrates a case of psychological stress during a high risk CFS.

Figure 3

Case of Psychological Stress During a High-Risk Call for Service



Note. The officer was responding to an assault in progress at a McDonald’s restaurant. While enroute, dispatch advised that the subject was possibly armed with a firearm. When arriving on scene, before leaving the police vehicle, the officer’s HR had reached 170bpm (absent of movement). The officer, equipped with his carbine, made contact with the subject through the drive-thru window. The subject had a screw driver in one hand and a spatula in the other. The subject complied with commands to drop the weapons and exited from the drive-thru window. The subject was laid face-down on the ground, but then stood up and took an assaultive stance with clenched fists. The officer transitioned from his carbine and deployed his conducted energy weapon in probe mode. The subject was then taken into custody by multiple officers. Imagery ©2019, CNES / Airbus, DigitalGlobe, IMTCAN, Landsat / Copernicus, McElhanney

Overall, the general findings reported above form a foundational step for future research investigating the impact of (psychologically-related) physiological arousal. This research is likely to have implications for three important components associated with policing: performance, training, and long-term health.

Relationship Between Stress, Experience, and Performance

The relationship between arousal, experience, and performance in police encounters is complex and not fully understood. Fortunately, several policing studies have demonstrated that realistic scenarios can be developed that elicit average HR that replicate stressful real-world encounters (i.e., ~140bpm or more). These scenarios provide researchers with the opportunity to carefully study the relationship between these various factors. Within these scenarios, stress reactivity can result in perceptual distortions (e.g., tunnel vision, auditory exclusion) as well as increased performance errors and deficits in verbal communication, of the sort that are often witnessed in the field (Andersen & Gustafsberg, 2016; Andersen, Pitel, et al., 2016; Arble et al., 2019; Brisinda, Venuti, et al., 2015; Lewinski, 2008; McCraty & Atkinson, 2012; Meyerhoff et al., 2004). However, while stress can deteriorate police performance, officer experience and training has been shown to improve performance in UoF scenarios in some studies. Specifically, studies have shown that, compared to novices, experienced and elite officers often demonstrate improved decision-making processes, attentional control, shot accuracy, and cue recognition, as well as fewer decisions errors (Boulton & Cole, 2016; Landman et al., 2016b; Renden et al., 2015; Vickers & Lewinski, 2012).

Given these findings, the interaction between stress, training, and performance requires further examination. For example, it would be important to determine if there is an optimal range of physiological arousal for best performance, whether this optimal range varies as a function of experience and training, and whether this optimal range varies by call type, call priority, and/or call phase. Once these issues have been examined in scenario-based studies, confirming that the results can be replicated in field studies is important. This seems particularly important given the results of the current study, where experience factors (as measured in the current study and discussed above) were not related to stress reactivity. While performance was not examined in our study, we believe that with slight modifications the methods we used could provide the foundation for future research on the relationship between stress, experience, and performance. For example, a ride-along component could be added to assess performance as other researchers have recently done (e.g., Todak & James, 2018).

Evidence-Based Training

While the body's default response to successfully cope with a threat is to stimulate fight-or-flight physiology (LeDoux & Pine, 2016), research indicates that this threat response is malleable, with certain types of training being shown to improve performance and increase resilience to stress reactions (Andersen et al., 2018; Arnetz et al., 2009; Driskell et al., 2001; Nieuwenhuys & Oudejans, 2011b). Research suggests that initial learning (e.g., skills acquisition) occurs best under low levels of stress (Driskell & Johnston, 1998; Driskell et al., 2008). However, skilled performance is typically learned through practice in settings that mimic the environment in which the skills will be performed operationally (Schmidt & Lee, 2013). For example, traditional firearms qualification scores have high congruency with other marksmanship assessments, but low congruency with the dynamic and rapidly unfolding nature of real-world officer-involved shootings (Morrison & Vila, 1998; Wollert et al., 2011).

A well-established method for developing stress resilient skills and performance is stress exposure training (SET; Driskell & Johnston, 1998; Driskell et al., 2008; Johnston & Cannon-Bowers, 1996). SET is comprised of three carefully scaffolded phases: (1) information provision, (2) skills acquisition, and (3) application and practise, which encompass various techniques and components (Driskell & Johnston, 1998; Driskell et al., 2008; Johnston & Cannon-Bowers, 1996). The application and practise phase is typically achieved through scenario-based training (SBT), which provides officers a realistic, yet safe environment to make errors that, if made on-duty, could have severe consequences. SBT also allows officers to receive corrective feedback on their performance (Armstrong et al., 2014). The purpose of this phased approach is to increase knowledge of stress effects, reduce individuals’ anxiety and reactivity to stressors, and increase resources (e.g., skills schemas), confidence, and ability (e.g., coping) to perform under stress.

There is also growing evidence that decision-making accuracy and performance is not only related to increased sympathetic activity, but also the suppression of the stress modulating parasympathetic influence (Andersen et al., 2018; Saus et al., 2006). As such, police training that targets officers' capacity to recognize and self-regulate their responses to stressors are demonstrating promise (McCraty & Atkinson, 2012). For example, Andersen et al. (2018) demonstrated that a physiologically focused intervention that taught police officers how to modulate SNS and PNS activation during SBT with real-time cardiovascular biofeedback led to significant reductions in lethal force decision-making errors and quicker physiological recovery from stress; improvements which were maintained over the 18 month study period.

While these training methodologies provide evidence of improved performance and increased resilience to the sorts of stress reactions observed in the current study, their adoption in policing is rare; in fact, stress-based training of any type appears to be used infrequently and training is seldom evidence-based or evaluated for intended outcomes (Sherman, 2015). For example, the authors are not aware of any studies that evaluate standard in-service police training for the alignment with the principles of SET. Furthermore, we could locate only one study that objectively measured levels of stress in training (Armstrong et al., 2014).

Armstrong et al.'s (2014) study examined four scenarios that were part of an agency's mandatory UoF SBT. The results showed that, on average, HRs rose from 97bpm pre-scenario to 116bpm during physical contact. In contrast, the results of the current study found average HR between 116-142bpm during the encounter/UoF/arrest phase (dependent on the incident factors present). This discrepancy highlights the value of research, like the sort presented in this paper. Our study indicates that the SBT training evaluated by Armstrong and colleagues may not be achieving its intended level of realism (i.e., training or testing skills under realistic conditions). The results of studies like ours can help inform the development and delivery of realistic and effective operational skills training that approximates real-world stress exposure. This evidence-based training approach is likely to be particularly important for improving performance in UoF encounters, which while low frequency (Baldwin et al., 2018; Hall & Votova, 2013), can result in tragic consequences and present substantial liability for officers and agencies (Braidwood, 2010; Dubé, 2016; MacNeil, 2015). It is also important to point out that studies like ours can also inform the development of SBT content, by informing agencies as to what sort of CFS and incident factors are occurring within their jurisdiction (e.g., if weapons are often accessible in CFS, that should be an element that is built into SBT scenarios).

Arousal and Health

How occupational stress arousal impacts long-term health is also an area of avid interest and requires further investigation. Longitudinal research studies conducted with frontline officers have demonstrated elevated risks of chronic disease such as cancer, diabetes, and heart disease compared to populations of similar age (Charles et al., 2007; Violanti, 1983; Violanti, Fekedulegn, et al., 2006). Results described in this paper highlight the sorts of risks that officers are routinely exposed to in the course of their duties, while also revealing the nature of the stress reactions (and the frequency of these reactions) that may be at the root of some of these health concerns.

That being said, it is important to note that physiological arousal associated with high risk encounters (including those that involve UoF) may not necessarily be detrimental. In fact, it may be the case that higher levels of physiological arousal are appropriate (even preferred) in some encounters in order to meet the demands of the situation. What will be critical from a health risk standpoint, is not necessarily the level of arousal one experiences during the event, but *quick recovery* from the arousal (e.g., recovery within or shortly after the event). The frequency of high-risk encounters in an officer's shift, which was routinely observed in our study, may be problematic if it means that officers do not have time to recover fully during their active duty days. If this occurs, officers may experience accumulated stress that results in allostatic load, or "wear and tear" on the cardiovascular system, that is associated with long-term health outcomes (McEwen, 1998; Violanti, Fekedulegn, et al., 2006). Longitudinal research with police officers indicates that occupational stress is associated with chronic health outcomes such as cardiovascular and metabolic disease (Violanti, Fekedulegn, et al., 2006), but the study design does not allow for the distinction between the contribution of acute versus chronic stress to disease. Unfortunately, in the current study, we were unable to examine recovery rates and levels due to the varying and confounding nature of post-CFS activities (e.g., sitting, standing, reporting writing, immediately responding to another CFS) and inconsistent documentation of activities between calls (e.g., breaks, meals, interactions with officers/public). Thus, we cannot speak to health outcomes directly. Future research should certainly prioritize this so we can understand the long-term health implications of the "physiological profiles" that were generated from our study.

Limitations

While we are optimistic about the use of these research findings to improve police training and health research, we caution future researchers and lay persons to interpret and use the findings with consideration given to study limitations. For example, there is significant public interest in understanding (and being able to explain) all police actions, particularly lethal encounters. Thus, there may be a temptation to use physiological arousal, as measured in research studies such as this, to find an individual officer culpable for their actions (e.g., “that officer was likely so stressed that their performance must have been compromised”). However, it is not appropriate to do this using research of the sort reported on here. For example, it is incredibly important to remember that *group level analyses* of stress, training, and performance can only be used to understand general relationships between these variables. While this understanding may be useful to improve police training, real-world performance, or overall health, in a general way, at no time are group level research findings on physiological arousal able to be used to explain why *one particular officer* acted in the way he/she did in the field.

While HR is the most easily monitored physiological measure of stress, we must stress that this is not an absolute measure of an individual’s stress, nor does it unequivocally predict individual performance under stressful conditions (Arble et al., 2019; Brisinda, Venuti, et al., 2015; Meyerhoff et al., 2004). Research equipment used to measure ambulatory physiological arousal in police research is not as accurate as tests used for diagnostic medical purposes (i.e., hospital grade ECG testing for cardiovascular disease), and therefore this measure must be interpreted with caution. Furthermore, the collection of additional biological indicators of the stress response (e.g., HPA activity, blood markers) was not possible in this real-world study as it may have interfered with the officer’s ability to meet the challenges of the emergency situation at hand. As heart rate reactivity is only one aspect of the stress response system, future research should include as much bio sampling as is logistically and ethically possible.

Above all else, research of this type (regardless of which recording device or bio-physiological measure one uses) cannot account for all the factors that likely go into an individual officer's continuous risk assessment of a situation (which will likely include an assessment of subject behaviour, environmental features, tactical considerations, etc.) and in the moment decision-making during a real-world encounter. Therefore, the appropriateness of an individual officer's behaviour in any particular encounter must be judged based on the *reasonableness* and *necessity* of their actions, given the totality of the circumstances.

Conclusion

Very limited research exists that objectively measures stress reactivity experienced by police officers during active duty. This study provides several contributions to the field and adds to the dearth of research in this area. Of note, this study establishes the feasibility of using GPS and detailed operational police records to map general duty police officers' autonomic stress responses to the phase of a call and incident factors. The use of this innovative approach, advanced statistical methods (i.e., LMM for repeated measures), and the ability to differentiate between physical and psychological stress (by controlling for movement), provides robust estimates of (psychologically-related) physiological arousal to CFS factors (e.g., call priority, use of force). The research findings provide evidence of the extent and frequency of stress arousal in police operations, which has important implications for general duty policing, police training, and health research.

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A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario

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SB, CB, and BB conceptualized the study and JA advised on stress measures during conceptualization. SB, BB, AB, BJ, CL, HM, and TS completed the data collection. SB performed the data analysis and interpretation with guidance from JA and under the supervision of CB. SB drafted the manuscript. CB, JA, BB, AB, BJ, CL, HM, and TS provided critical revisions. All authors approved the final version of the manuscript for submission.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial relationship that could be construed as a potential conflict of interest. At the time the study was conducted, SB was employed full-time by the participating agency, and BB, AB, BJ, HM, and TS were employed as casual staff.

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Abstract

The critical incidents that police officers encounter have the hallmark characteristics of a situation that would cause a physiological stress response. Under these conditions, officers are sometimes required to make life-or-death decisions, often in a split-second, to preserve and protect the lives of both the public and themselves. Video footage of some police-public encounters highlight deficits in officer performance that have led to tragic outcomes, including serious injury or death and strained police-community relations. Using a robust methodology, the current study assessed the performance of 122 active-duty police officers during a highly complex and realistic lethal force scenario to examine whether performance was affected by the officer's level of operational skills training, years of police service, and stress reactivity. Results demonstrated that the scenario produced elevated heart rates (i.e., 150 beats per minute), as well as perceptual and cognitive distortions, such as tunnel vision, commensurate with those observed in naturalistic lethal force encounters. The average performance rating from the scenario was 59%, with 27% of participants making at least one lethal force error. Elevated stress reactivity was a predictor of poorer performance and increased lethal force errors. Level of training and years of police service had differential and complex effects on both performance and lethal force errors. Our results illustrate the need to critically reflect on police training practices and continue to make evidence-based improvements to training. The findings also highlight that while training may significantly improve outcomes, flawless performance is likely not probable, given the limits of human performance under stress. Implications for the objective reasonableness standard, which is used to assess the appropriateness of force in courts of law are discussed.

Keywords: police, stress, training, use of force, objective reasonableness standard

"We don't rise to the level of our expectations – we fall to the level of our training" –

Archilochus

Introduction

Police officers encounter critical incidents that have the hallmark characteristics of a situation that would cause a physiological stress response: namely – they are unpredictable, potentially uncontrollable, novel, and often involve time pressure (Alison & Crego, 2012; Sapolsky, 2004; Violanti, 2014, p. 585). In addition, these incidents may involve witnessing or experiencing traumatic or life-threatening behaviour (Fridman et al., 2019; Pinizzotto et al., 2006; Violanti, 2014). Under these circumstances, officers are occasionally required to make life-or-death decisions, often in a split-second, to preserve and protect the lives of both the public and themselves (Artwohl, 2002). Video footage of certain police-public encounters highlight deficits in officer performance, including errors in the decision to use lethal force. Such incidents can have tragic consequences, including serious injury or death and strained police-community relations. Occasionally, such incidents can also lead to the incarceration of police officers and legal liability for law enforcement agencies (LEAs) that have not adequately prepared their officers for critical incidents (e.g., Public Prosecution Service of Canada, 2018).

LEAs train officers for critical incidents, however, training time is often restricted due to resource and budgetary constraints (Bennell et al., 2020; Rojek et al., 2020). Consequently, officers receive considerably less training relative to other professions that require high-stakes decision-making (e.g., doctors, nurses, surgeons, airline pilots; Di

Nota & Huhta, 2019).[3] Additionally, there are few studies that rigorously evaluate the efficacy of police training (Engel et al., 2020; Huey, 2018), and officers often have limited opportunity in training and the field to use various knowledge, skills, and abilities (KSAs), such as the use of force (UoF; e.g., Hall & Votova, 2013), which can impact retention (Di Nota & Huhta, 2019; O'Neill et al., 2019). Considering these factors, it is prudent to ask whether we can reasonably expect police officers to apply relevant KSAs in tense police-public interactions.

Existing research indicates that stress can adversely impact performance, but that training and experience can moderate stress reactivity and improve performance (e.g., Driskell & Salas, 1996). Thus, using a sample of Canadian police officers, the aim of the current study is to examine the level of performance that can reasonably be expected under conditions that elicit high levels of stress, based on their years of experience and the level of training they have received. Critical reflection on training practices and evidence-based improvements to training may be called for if systemic errors or deficiencies in performance are observed in realistic scenarios. Results from this study may also provide new evidence to inform the objective reasonableness standard, which is used to assess the appropriateness of force in courts of law (Cyr, 2016; Zamoff, 2020).

[3] In the United States, the average reported length of police academy training is approximately 21 weeks (i.e., 840 hours), of which around 171 hours (20%) are dedicated to the use of force (Reaves, 2016). This is typically followed by 13 weeks (i.e., 520 hours) of on-the-job learning under the supervision of a field training officer (Reaves, 2016). Once on active duty, officers receive on average less than one week (i.e., 35 hours) of training per year (Reaves, 2010). In Canada, similar training requirements exist. Additionally, the minimum education standards to apply for law enforcement in Canada are normally a high school diploma or equivalent. In contrast, registered nurses are typically required to complete a four-year university nursing program to become a generalist (National Nursing Assessment Service, 2021) and teachers generally require a minimum three-year postsecondary degree and a two-year teacher education program (Ontario College of Teachers, 2021).

For example, an empirical understanding of how on-the-job experience and level of currently available police training impact reactivity to stress and performance in threatening situations may inform judgements concerning the reasonableness of an officer's actions.

Use of Force and The Objective Reasonableness Standard

The authority for police to use force in Canada is granted under section 25 of the *Criminal Code* (1985), whereby police officers who are acting on reasonable grounds are authorized to use as much force as necessary to enforce the law. In the case of *R. v. Nasogaluak* (2010), the Supreme Court of Canada further established that the "allowable degree of force is constrained by the principles of proportionality, necessity and reasonableness" (p. 208). Where lethal force is concerned, the force must also be necessary for the purpose of self-preservation or the protection of others from death or grievous bodily harm (*Criminal Code*, 1985). For context, estimates consistently identify that approximately 0.1% of police occurrences in Canada involve UoF (Baldwin et al., 2020; Hall & Votova, 2013; Walker & Bennell, 2021). Additionally, over a five-year period (2015-2019), public databases of fatal police encounters in Canada, identified 136 individuals fatally shot by police (Singh, 2020) and 7 police officers were criminally killed in the line of duty (Memorial Ribbon Society, 2021).[4]

[4] In comparison, in the United States (US), similar UoF estimates have recently been reported (Bozeman et al., 2018), although others have estimated that 1.7% of police-public interactions in the US involve the use or threat of force (Hickman et al., 2008). Additionally, from 2015-2019 in the US, public databases recorded just over 4,900 individuals fatally shot by law enforcement officers (Tate et al., 2021) and 257 officers were criminally killed (Federal Bureau of Investigations, 2020). Based on these estimates, with a population approximately 9-times larger than Canada, the US demonstrated 36 times more individuals fatally shot by police and 37 times more officers criminally killed in the line of duty.

To assess the appropriateness of an officer's use of force, several guiding principles from international case law have become entrenched in the Canadian criminal justice system. Foremost, is the U.S. Supreme Court case of *Graham v. Connor* (1989), which established the objective reasonableness standard, instructing that the "…'reasonableness' of a particular use of force must be judged from the perspective of a reasonable officer on the scene, and its calculus must embody an allowance for the fact that police officers are often forced to make split-second decisions about the amount of force necessary in a particular situation" (p. 387). In essence, given the totality of the circumstances known at the time and without hindsight bias, would other reasonably prudent officers respond in the same or similar way (Alpert & Smith, 1994; International Association of Chiefs of Police, 2020)?

Scholars have provided research evidence of neurophysiological factors (e.g., cognitive and perceptual distortions) that might frame the perceptions and actions of a reasonable officer on the scene (e.g., Klinger & Brunson, 2009). However, the use of such research in court may be the exception rather than the rule (DuCharme, 2002). Indeed, critics argue that the objective reasonableness standard lacks an evidence-based foundation and that assessments of reasonableness focus too much on the general dangers and stressful nature of policing (Fagan & Campbell, 2020; Zamoff, 2020). To remedy this, Zamoff (2020) recently proposed that in determining the perspective of a reasonable officer, the courts should more heavily weigh the officer's experience and training, as well as the extent to which they adhered to or deviated from their training and the agency's policies. While valuable, this approach also lacks evidence of the extent that these factors are related to performance and errors, or are influenced by stress (Engel & Smith, 2009).

Psychophysiological Threat Response

When presented with a threat, whether real or perceived, the body implicitly (i.e., below conscious awareness) engages in a series of physiological processes, colloquially known as the "fight-or-flight" response (LeDoux & Pine, 2016; Thayer & Sternberg, 2006). This evolutionary adaptive response promotes survival by immediately preparing the body's physiological and cognitive capacities to meet the demands of the situation, while suppressing unnecessary functions, such as reproduction and digestion (Anderson et al., 2019; Artwohl, 2008; Kemeny, 2003). During the fight-or-flight response, the sympatho-adrenal response is triggered, which leads to a wide-spread release of catecholamines and hormones to power the survival response (Lovallo, 2016; McEwen, 1998). Specifically, the hypothalamic-pituitary-adrenal (HPA) axis is activated, which results in the rapid release of epinephrine (i.e., adrenaline) and cortisol (De Kloet et al., 1998; Lovallo, 2016). Cortisol increases blood sugar and prepares the body for energy expenditure by stimulating glucose production and mobilizing fatty acids (Lovallo, 2016; Tsigos et al., 2020). Concurrently, the autonomic nervous system (ANS) is engaged, stimulating the sympathetic nervous system (SNS) and suppressing the parasympathetic nervous system (PNS), which is associated with modifying the sympathetic response when necessary (e.g., focused attention) and performing 'rest and digest' (i.e., recovery and repair) functions (Berntson & Cacioppo, 2004; Fridman et al., 2019). When the SNS is activated, stress hormones such as norepinephrine and epinephrine are released (Lovallo, 2016).

The cascade of these catecholamines, hormones, and glucose in the bloodstream from the stress system response stimulate increased heart rate (HR), blood pressure, and respiration (Chrousos, 2009; Tsigos & Chrousos, 2002). The rapid rise in energy, oxygenation, and blood flow are directed in greatest concentration to the heart, brain, and large muscles, while they are inhibited to other areas not required to respond to a threat, such as the digestive system (Tsigos & Chrousos, 2002). Therefore, activation of this sympatho-adrenal stress response improves chances of survival in the short-term, by increasing resistance, strength, and focused attention (Artwohl, 2008; Fenici et al., 2011; Tsigos & Chrousos, 2002).

While fight-or-flight is an automatic behavioural and physiological response that is engaged without the need for higher-order cognitive processing, it can be sustained and moderated through psychological processes, such as threat appraisal, fear, and anxiety (Chan & Andersen, 2020; LeDoux & Pine, 2016; Thayer & Sternberg, 2006). The degree of SNS arousal depends primarily on the type of threat encountered and one’s perception of how severe it is (Kalisch et al., 2015; LeDoux & Pine, 2016). For example, when the threat of harm during an encounter with a subject is perceived by the officer as outweighing their ability to cope with the situation (e.g., based on experience and training), then the subject may continue to be appraised as a threat; maintaining the intensity of the emotional and physiological response (Anshel et al., 1997; Driskell & Salas, 1996; Folkman et al., 1986).

The Impact of Stress on Police Performance

Studies demonstrate that the impact of SNS arousal on performance is complex. The type of threat stimulus encountered, and the strength of the resulting threat response can improve or impair perceptual, cognitive, and motor performance depending on context (Arble et al., 2019; Bertilsson et al., 2019). Adaptive SNS arousal, which meets the demands of the situation, can be beneficial to performance (Yerkes & Dodson, 1908), such as shooting accuracy (e.g., Vickers & Williams, 2007), threat-related decision-making (e.g., Akinola & Mendes, 2012), cognitive functioning (e.g., Hansen et al., 2009), and the execution of some general policing tasks, such as situational control and communication (Regehr, 2008). However, maladaptive stress arousal (i.e., too much or too little) is considered one of the main causes of human performance failure (Vine et al., 2016) and can result in degradation of task accuracy and increased task errors (Driskell & Salas, 1996; Nieuwenhuys et al., 2012). Growing evidence also suggests that performance deficits are related to both maladaptive SNS arousal, and the suppression of the stress modulating parasympathetic influence (Andersen et al., 2018; Saus et al., 2006; Spangler et al., 2018). For example, impairments to response inhibition, resulting in more lethal force errors, can occur when the PNS is suppressed (Spangler et al., 2018).

Generally, stress-induced deficits primarily affect cognitive functions, such as perception, attention, and decision-making (Di Nota et al., 2020; Driskell & Salas, 1996). However, motor performance, in particular fine motor skills, are also affected (Anderson et al., 2019; Nieuwenhuys & Oudejans, 2011a; Staal, 2004). Since manipulating stressful real-world encounters for research purposes is unethical (Giessing et al., 2019), results from realistic scenario-based experiments form much of the existing knowledge about the impact of acute stress on performance among police officers. To date, this literature has revealed that stress inducing scenarios result in impairments to shooting performance (Landman et al., 2016a; Nieuwenhuys & Oudejans, 2010; Taverniers & De Boeck, 2014), quality of skill execution (Nieuwenhuys et al., 2016; Renden et al., 2014; Renden et al., 2017), proportionality of force applied (Nieuwenhuys et al., 2012; Renden et al., 2017), self-control (Haller et al., 2014), perceptual and attentional control (Giessing et al., 2019; Lewinski, 2008; Renden et al., 2014), memory (Hope et al., 2016), communication (Arble et al., 2019; Renden et al., 2017), and hypervigilant decision-making, which is often impulsive, inefficient, and disorganized (Johnston et al., 1997). The stress response also appears to have differential effects, whereby rehearsed and automated skills are influenced to a lesser degree (Arble et al., 2019; Renden et al., 2017; Vickers & Lewinski, 2012). These findings from experimental research with simulations are extremely important to draw conclusions about what *might* reasonably happen to performance in real-world stressful encounters (Giessing et al., 2019).

While few real-world studies exist, examinations of officer-involved shootings (OIS) have also uncovered stress-induced performance issues. For example, average hit rates ranging from 14-38% have been observed in OIS (Donner & Popovich, 2018; Morrison & Garner, 2011; Morrison & Vila, 1998), which is in stark contrast to the almost 90% hit rate reported in range-based annual firearms qualifications (Anderson & Plecas, 2000; Brown et al., 2021). In OIS incidents, officers have also reported experiencing perceptual distortions, impaired cognitive function, and reduced motor dexterity (e.g., Artwohl, 2008; Honig & Sultan, 2004; Klinger & Brunson, 2009). For example, Artwohl (2008) surveyed 157 police officers within a few weeks of being involved in an OIS. Findings demonstrated that most officers experienced perceptual narrowing, including diminished sound (84%) and tunnel vision (79%), and that the majority of officers (74%) responded on automatic pilot (i.e., with little or no conscious thought). Other studies have reported similar findings (e.g., Honig & Sultan, 2004; Klinger & Brunson, 2009).

Attentional control theory adds additional explanatory power to understanding performance impairments, above and beyond physiological processes (Eysenck et al., 2007). This theory suggests that when exposed to a threatening stimulus, attention is drawn (or distracted) away from task relevant processes (e.g., decision-making) to the threat-related stimuli via psychological and neurophysiological responses (Di Nota & Huhta, 2019; Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2017). Since attentional capacity is limited, it is difficult to attend to two things at the same time (Vickers, 2007). Therefore, when attention is focused on the threat, cognitive overload is more likely to occur, resulting in less attention available for mental and perceptual-motor processing (Driskell & Johnston, 1998; Eysenck et al., 2007; Hope, 2016).

These attentional, perceptual, and stress related deficits mean that when presented with a threat, officers may be more prone to compromised performance, decision-making errors, and perceptual challenges (e.g., missing relevant cues, such as a subject pulling out a cellphone, not a gun; Driskell & Salas, 1996; Easterbrook, 1959; Vickers, 2007). Overall, the effects of stress on performance may be particularly detrimental during a critical incident, when officers are expected to demonstrate sound judgement and proficient performance.

Impact of Training and Experience on Stress Reactivity

While the body's default response to successfully deal with a threat is to stimulate the fight-or-flight response (LeDoux & Pine, 2016), training and experience are thought to moderate stress by intervening immediately following the initial autonomic stress response (Driskell & Salas, 1996; Kavanagh, 2005; Wollert et al., 2011). This is because training and experience are said to improve one's ability to cope with a threat, subsequently affecting the appraisal process, which sustains and moderates the fight-or-flight physiology (Anshel et al., 1997; Driskell & Salas, 1996; Kelley et al., 2019).

Research provides mixed evidence for this theory (Johnson et al., 2014; Landman et al., 2016b; Rimmele et al., 2007). For example, during UoF simulation studies, officers on specialized and tactical teams displayed lower HR during a high-pressure scenario as compared to general duty officers (James et al., 2020; Landman et al., 2016b). In contrast, when Baldwin and colleagues (2019) examined officers' level of operational skills training and years of experience, neither significantly modulated stress reactivity during general duty calls for service. Instead, stress reactivity was primarily associated with situational risk factors, such as the priority of the call and whether weapons were reported, or force was used. While the evidence is mixed, greater levels of on-the-job experience and police training should, theoretically, improve coping and resilience to stressors, that is the very reason why training exists.

Impact of Training and Experience on Performance Under Stress

Research demonstrates that a wide range of training techniques can improve performance, even under stressful conditions. For example, there are many training strategies that can enhance the acquisition, retention, and application of KSAs, such as the use of spaced practice and providing appropriate feedback (Bennell, Blaskovits, et al., 2021; Di Nota, Andersen, et al., 2021; Jenkins et al., 2021). While research suggests that initial skills acquisition occurs best under low levels of stress (Driskell & Johnston, 1998; Driskell et al., 2008), once acquired, skilled performance is typically achieved through representative practice in environments that simulate the conditions under which they will be performed (Bennell, Blaskovits, et al., 2021; Pinder et al., 2011; Schmidt & Lee, 2013). Indeed, meta-analyses and systematic reviews across many domains (e.g., sport, military, medicine, policing) consistently identify the performance benefits produced by training under pressure or threat that replicates the operational environment (Gröpel & Mesagno, 2019; Kent et al., 2018; Low et al., 2021).

As a result, contemporary operational police skills training now often includes scenario-based training (SBT) that gradually exposes officers to stress-inducing simulated encounters in an attempt to develop stress-resilient skills and performance (Reaves, 2016).[5] Meta-analyses provide empirical support for this training approach as a way of improving performance (Low et al., 2021; Saunders et al., 1996). Accordingly, we expect that officers with higher levels of operational skills training will perform better than those with less training, as they will have had greater opportunity to acquire and practice their KSAs in SBT, making the KSAs more adaptive and stress resilient.

In addition to training, operational experience may also be important to performance and decision-making under stress. For example, through the acquisition and automation of schemas, which are forms of tacit knowledge gained on-the-job or during training, experienced individuals can discern subtleties in their environment that may be

[5] SBT typically involves officers being equipped with inert intervention options (e.g., rubber baton, inert OC spray, and taser), as well as a firearm loaded with non-lethal rounds (i.e., paint-based marking cartridges). The candidate is run through a scenario facilitated by an instructor. The role-player plays the role of a suspect who either escalates or de-escalates the situation based on the response of the officer. Officer performance is assessed throughout the scenario and sometimes in their post-incident articulation of their actions.

imperceptible to novices (Kahneman & Klein, 2009; Kavanagh, 2006; Klein, 2015). Using this tacit knowledge, the recognition-primed decision-making (RPDM) model suggests that under dynamic and complex circumstances, experienced decision-makers can quickly assess situations, and draw on their schemas to evaluate options and determine the first workable solution through satisficing (Klein, 1997, 1999; Ward et al., 2011). While this may not result in the selection of the best option, this process ensures that decision-makers are able to quickly respond to rapidly unfolding and nuanced situations, as opposed to being paralyzed until all plausible options are evaluated (Klein, 1999).

This type of decision-making is resilient to stress and more adaptable to complex and dynamic situations (Klein, 2015). Accordingly, studies have found that greater levels of policing experience are related to flexible rather than serial decision-making (Boulton & Cole, 2016), anticipation and cue recognition (Renden et al., 2015; Suss & Ward, 2018; Vickers & Lewinski, 2012), reduced lethal force errors (Landman et al., 2016b; Vickers & Lewinski, 2012), and increased focus on verbal de-escalation and the mitigation of force (Mangels et al., 2020). This type of experience-based decision-making is particularly salient for OIS, where officers must detect the most important cues in a dynamic environment and make decisions under strict time constraints (Vickers, 2007).

Current Study

In the current study, active-duty police officers participated in a complex, dynamic, and highly realistic lethal force scenario to examine whether performance was affected by the officer's level of operational skills training, years of police service, and stress reactivity. The findings will speak to the level of performance under stress that can reasonably be expected from officers, based on their current police training and experience. This will allow us to recommend evidence-based enhancements to training, as well as to inform the objective reasonableness standard used in courts of law.

More specifically, we hypothesized the following:

1. Officers will display elevated stress reactivity in response to the scenario, commensurate with those observed in naturalistic UoF encounters. Elevated stress reactivity is operationalized as an increase in sympathetic activity and a withdrawal of parasympathetic activity, measured by HR and HRV, as well as an increase in self-reported perceptual and cognitive distortions;
2. Stress reactivity will be moderated by level of police training and years of police service;
3. Highly elevated stress reactivity will be associated with poorer performance, as operationalized by performance scales and lethal force errors; and
4. Higher levels of training and experience will be associated with better performance.

We will also explore the types of behavioural responses that are beneficial or detrimental to officer performance. For example, determining which specific items within the metrics (e.g., de-escalation, situational awareness) were most associated with overall performance in the scenario may allow us to identify areas that training can further target to improve outcomes for public and police safety.

Methods

Participants

In June 2018, 122 active-duty police officers from a large Canadian police agency volunteered to participate in our study. The inclusion criteria for participants were that they were considered 'fit for duty'[6] by their police agency and currently on active duty. Table 7 shows the basic sociodemographic characteristics of the sample (*N* = 122). The majority of participants were male (81.1%) and had an average age of 38 years (*SD* = 8.2). Most (91.8%) had obtained some post-secondary education. Rank ranged from reserve constable (i.e., a retired police officer who fills temporary vacancies) to inspector, the majority being constables (69.7%). Participants had between 1 and 44 years of service (*M* = 11.2, *SD* = 6.6). Several participants (13.1%) had previous experience with another law enforcement agency or the military. There were 13 participants (10.7%) who reported having been involved in a lethal force encounter, as either the officer discharging their firearm, or as a witness officer on scene.

[6] Pursuant to an occupational health assessment, the individual is considered fit to perform the tasks and duties of a police officer. As this was not a diagnostic clinical study, we did not perform medical examinations of participants, however, we did examine self-reported cardiovascular disease (*n* = 4) and being on medication that affects HR (*n* = 10) in relation to the data. Several cardiovascular measures did significantly differ for the ten participants who reported being on medication that affects HR, although they did not remain significant once Bonferroni corrected ($\alpha = .05/6 = .008$). Out of an abundance of caution, all analysis involving stress reactivity was conducted with and without participants who reported being on medication that affects HR. An examination of the results did not demonstrate a difference in level of significance or effect size. Thus, all participants were retained in the study.

Table 7

Participant Demographics

	n	%	*M*	*SD*
Gender				
Female	23	18.9%		
Male	99	81.1%		
Age			38.2	8.2
Highest level of education completed				
High school diploma or equivalent	10	8.2%		
Apprenticeship/Trade school	5	4.1%		
Some College	16	13.1%		
College diploma or certificate	28	23.0%		
Some University	17	13.9%		
Bachelor's Degree	38	31.1%		
Post-Graduate Certificate	2	1.6%		
Master's Degree	5	4.1%		
Doctoral Degree	1	0.8%		
Current police rank				
Reserve Constable	1	0.8%		
Constable	85	69.7%		
Corporal	24	19.7%		
Sergeant	10	8.2%		
Staff Sergeant	1	0.8%		
Inspector	1	0.8%		
Years of police service			11.2	6.6
Previous experience with other police agency or the military				
Yes	16	13.1%		
No	106	86.9%		
Have you ever been involved in a lethal force encounter				
Subject officer	5	4.1%		
Witness officer (i.e., officer on scene)	8	6.6%		
No	109	89.3%		

Materials

Demographic Questionnaire

A demographics questionnaire was used to collect age, gender, years of service, law enforcement experience, training, self-reported cardiovascular disease, and whether they were taking medication that could affect HR. Frequency of alcohol, tobacco, and caffeine consumption, as well as frequency of exercise were also collected.

Stress Reactivity Monitoring Devices

Stress reactivity was measured using two Polar V800 Heart Rate Monitor Watches® and a Polar H7 Chest Strap Heart Rate Monitor® (Polar Electro Oy, Kempele, Finland). Together, these devices continuously record HR and R-R intervals (i.e., beat-to-beat intervals), with a sampling rate of 1000 Hz for HRV analysis. These devices have been used in prior research when officers are on-shift or participating in realistic scenarios (Baldwin et al., 2019; Hope et al., 2016; Landman et al., 2016a). They have also been validated against hospital-grade electrocardiograms (ECG; Caminal et al., 2018; Cilhoroz et al., 2020; Gilgen-Ammann et al., 2019; Hernández-Vicente et al., 2021).[7]

[7] To reduce the likelihood of lost or corrupted data, participants were also equipped with a ©FirstBeat Bodyguard 2 Heart Rate Monitor (Firstbeat Technologies Ltd., Jyväskylä, Finland), which has also been validated against ECGs (Parak and Korhonen, 2013; Bogdány et al., 2016; Hinde et al., 2021). Data from the FirstBeat Bodyguard 2 were used to supplement HR and HRV data for 9% (n = 11) of participants.

Firearms Training System

Participants were equipped with a StressVest®, which is a non-projectile system that facilitates realistic scenario-based firearms training.[8] Participants wear the StressVest® and a StressX® PRO Belt. Duty pistols are converted to fire a laser pulse that activates the StressVest® when it strikes center mass, the side, or head (with additional side panels and face sensor baseball hat). When hit, the StressX® PRO Belt delivers either a vibration or shock to the abdomen of the participant. The system has been shown to elicit stress reactivity, as measured by HR, commensurate to training with non-lethal training ammunition (i.e., Simunition® FX marking cartridges; Condon, 2015).

Video Recording Devices

In order to code participant performance, each scenario was video recorded by three ©GoPro HERO4 Silver cameras affixed in central locations around the study area (see Figure 4). All participants also wore an eye tracker (©Applied Science Laboratories Mobile Eye-5 Glasses) and certain participants wore body worn cameras (Axon Body2®) for purposes unrelated to the current study. The video footage was used to provide multiple angles to assess performance throughout the scenario.

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[8] StressVest® does not require the use of personal protective equipment (PPE) that is typically required when training with non-lethal training ammunition (aside from range certified eye protection). This allows participants to observe facial expressions, and does not restrict peripheral vision, nor does it impede communication, hearing, or movement. SecuriBlanks® are used to maintain the fidelity of the firearm (i.e., recoil and percussion). The StressVest® can be concealed under clothing, which avoids priming the participant (i.e., actor wearing bulky PPE) and improves decision-making by safely and flexibly enabling more actors to participate in the scenario.

Measures

Phase of the Scenario

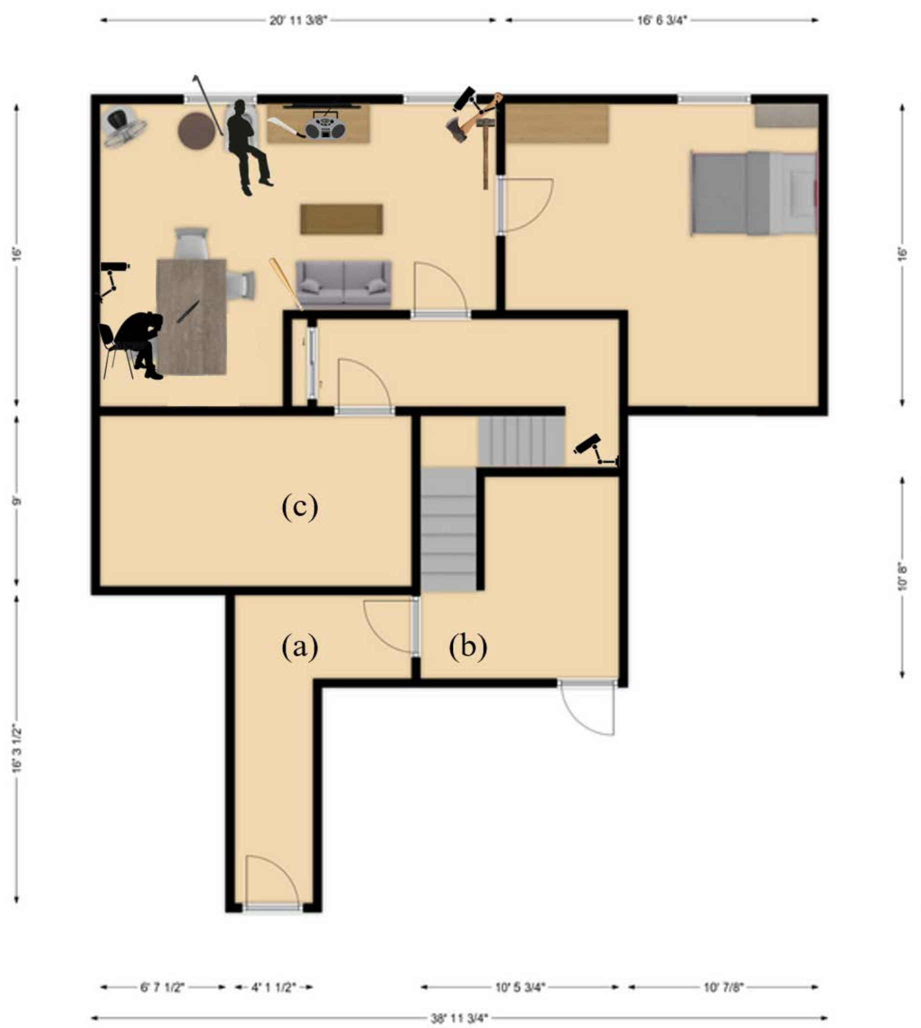
As described in more detail in the Appendix B, participants were exposed to a lethal force scenario. The scenario occurred in a building that had been designed to appear as an apartment complex (see Figure 4) in a rural setting. All participants were dispatched to a second-floor apartment for a call from a female complainant indicating that a male subject had been drinking heavily and was in breach of his probation conditions. At that point, the facilitator said, “scenario on” and participants had the opportunity to ask dispatch for additional information, if they chose to do so.

Upon arriving “on scene” and knocking on the door of the residence, the participant was greeted by a bystander, who indicated that the subject had committed an assault. The bystander remained in the scenario room and demanded the participant remove the subject, who was seated at the dining room table at the other end of the room. A partially obscured knife was on the table and the subject eventually drew it and put it to his throat, threatening to die by suicide. After some time passed, regardless of how much the officer attempted to verbally de-escalate or intervene, the subject ultimately complied and threw the knife on the ground towards the participant.

The scenario was allowed to naturally unfold a little longer until the subject spontaneously pulled a firearm, stood up, and started to shoot at the participant. This resulted in a lethal force response from the participant. Once shot at by the participant, the subject feigned a gunshot wound to the chest while the bystander contemporaneously produced and pointed a cellphone, verbally indicating that they were video recording the situation. Participants were then provided the opportunity to prioritize and perform whatever actions they deemed necessary (e.g., request resources, secure weapons, physically restrain subject and/or bystander, search subject, administer first aid). The scenario was allowed to come to a natural conclusion and was ended by the facilitator when the participant failed to demonstrate any new actions or strategies.

Figure 4

Experimental Setup of the Scenario



Note. Room measurements in feet/inches. (a) secondary safety inspection, equipping, and safety briefing area; (b) dispatch location; (c) out of bounds (bathroom).

For the purpose of analysing cardiovascular stress reactivity, the scenario (*M* = 9:25 minutes; *SD* = 2:32) was broken down temporally into five phases: (1) dispatch phase – from beginning of the simulated dispatch call to the facilitator saying "scenario on" (*M* = 1:10 minutes; *SD* = 0:53), (2) approach phase – from the facilitator saying "scenario on" to the bystander opening the apartment door (*M* = 0:46 minutes; *SD* = 0:26), (3) encounter phase – from the bystander opening the apartment door to the participant recognizing the knife on the table and/or the subject grabbing the knife on the table (*M* = 1:44 minutes; *SD* = 1:22), (4) critical phase – from the participant recognizing the knife on the table and/or the subject grabbing the knife on the table to the participant making physical contact with the subject (e.g., arrest; *M* = 3:08 minutes; *SD* = 1:40), and (5) scene management and aftercare (SM&A) phase – from the participant making physical contact with the subject to the facilitator saying "scenario over" (*M* = 2:38 minutes; *SD* = 1:04).

Stress Reactivity

Cardiovascular Stress Reactivity.

While there are strengths and limitations for all tools that measure stress reactivity (e.g., time of day confounds with salivary cortisol), theoretical knowledge and empirical research support the use of HRV as one of the most precise non-invasive measures of psychological and physiological arousal (Appelhans & Luecken, 2006; Berntson & Cacioppo, 2004; Thayer et al., 2012). For example, a meta-analysis conducted by Thayer and colleagues (2012) found HRV to be associated with neural activation of areas involved in threat perception (i.e., the amygdala and medial prefrontal cortex). As noted previously, stress reactivity is associated with an increase in sympathetic activation and suppression of parasympathetic activity (Berntson & Cacioppo, 2004; Castaldo et al., 2015; Malik et al., 1996). HRV captures the interplay between these two antagonistic systems (Appelhans & Luecken, 2006), and is regularly used as an objective physiological stress index (e.g., Giessing et al., 2019; Haller et al., 2014; James et al., 2020).

HR and HRV were captured using monitoring devices. Data were entered into ©Kubios HRV Premium Version 3.3.1. (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland), which is research software for the analysis of HRV. Samples were created for each phase of the scenario. Pre-processing of data in ©Kubios included automatic detection and correction of artifacts with interpolated beats (Lipponen & Tarvainen, 2019). Tarvainen and colleagues (2020) suggest correcting no more than 5% of beats to maintain data accuracy (e.g., avoid distortions), thus any HRV measure within a phase of the scenario that exceeded this threshold was removed. A detrending method (i.e., smoothness priors method) was used to remove very low frequency trend components for short-term HRV analysis (Tarvainen et al., 2020).

The PNS Index and SNS Index, computed in ©Kubios HRV software, were used as a measure of stress reactivity in this study (Sahoo et al., 2019). The PNS Index uses mean R-R intervals, root mean square of successive differences between normal heartbeats (RMSSD), and normalized Poincaré plot index SD1 (Kubios Oy, 2021). The SNS index is computed using mean HR interval, normalized Poincaré plot index SD2, and the Baevsky Index of Regulatory System Tension or Stress Index (Kubios Oy, 2021). These indices have been used in other research with samples of civilians (Ayuso-Moreno et al., 2020; Lundell et al., 2021), police (James et al., 2020), and special forces (Giuseppe et al., 2021). See Appendix C for further details on the measures and methods used.

Perceptual and Cognitive Distortions.

Research on officers involved in police shootings indicates that they experience various perceptual and cognitive distortions during- and post-shooting, such as tunnel vision (Artwohl, 2008; Honig & Sultan, 2004; Klinger & Brunson, 2009). To examine if the scenario resulted in perceptual and cognitive distortions – an indicator of stress reactivity – a 14-item questionnaire adapted from Artwohl (2008) was administered. Each perceptual and cognitive distortion during- (10-items) and post-scenario (4-items) were rated on a 4-point Likert-type scale ranging from 0 “not at all” to 3 “to a great extent”. Total scores could range from 0 to 42. Perceptual and cognitive distortion scores were expressed as a percentage of the total possible score (42). See Appendix D for a list of perceptual and cognitive distortions and descriptions.

Training

Participants’ training records and the training information captured in the demographics form were used to identify and assess their level of in-service operational skills training. Eight levels of training, from basic to elite, were established based on recency, frequency, and type of training experience participants received (see Table 8). See Appendix E for details on the agency’s training and methods for categorizing the level of training.

Table 8

Level of Training

Order	Training level	Amount/type of training	*n*	%
8	Elite (level 2)	Emergency response team (i.e., tactical team)	14	11.5%
7	Elite (level 1)	Use of force instructor	16	13.1%
6	Advanced	Specialized (i.e., air marshal, crisis negotiator) or firearm instructor	12	9.8%
5	Intermediate (level 3)	>5 courses	10	8.2%
4	Intermediate (level 2)	5 courses	25	20.5%
3	Intermediate (level 1)	4 courses	20	16.4%
2	Novice/basic (level 2)	3 courses	17	13.9%
1	Novice/basic (level 1)	2 courses	8	6.6%

Performance Metrics

To provide a robust assessment of performance, a combination of objective and subjective measures (Di Nota, Chan, et al., 2021) from four separate performance metrics were used: (1) the Deadly Force Judgment and Decision-Making (DFJDM), Tactical Social Interaction (TSI), and Crisis Intervention Team metrics (Vila et al., 2018), (2) the agency's performance metric, (3) the Scenario Training Assessment and Review (STAR) scale (Wollert et al., 2011), and (4) lethal force errors.

Deadly Force Judgment and Decision-Making, Tactical Social Interaction, and Crisis Intervention Team Metric.

Vila et al. (2018) developed three sets of interval-level metrics to assist in objectively assessing police officer behaviour and performance in various real-world, training, and research settings. The DFJDM metric was developed to assess performance in situations requiring the UoF, whereas the TSI and CIT metrics were developed for measuring performance during police–public interactions and encounters with people suffering from mental illness or who are in crisis, respectively. The DFJDM includes 105 performance indicators weighted from -6 (extremely negative impact on performance) to +6 (extremely positive impact on performance). The TSI has 78 performance indicators weighted from 1 (no impact on performance) to 7 (extremely positive impact on performance) and the CIT is comprised of 112 performance indicators ranging from -4 (strong negative impact on performance) to +4 (strong positive impact on performance).

In accordance with Vila and colleagues' (2018) recommendations, the authors and a group of police trainers selected performance indicators from these three metrics that were applicable to the study scenario. This resulted in a total of 39 performance indicators from the DFJDM (20), CIT (14), and TSI (5) that were then combined into a single metric (see James et al., 2019). For coding purposes, any indicators that were not completely objective (e.g., "the officer makes timely decisions regarding pre-assault indicators") were accompanied with examples (e.g., immediately drawing firearm when knife is pulled; Vila et al., 2018). See Appendix F for list of performance indicators and weightings.

When rating performance, indicators were assessed as to whether they were applicable (1 – Yes; 0 – No) for each officer in the scenario. If applicable, each indicator was rated as achieved or not (1 – Yes; 0 – No; Vila et al., 2018). Weighted performance scores were then expressed as a percentage of the potential weighted score for each officer in the scenario. Where a performance indicator was not applicable, it was removed from the potential score to avoid penalizing an officer for something they could not have done (e.g., assessing ability to reload firearm, when a reload was not necessary). For a detailed description of how the metrics were developed, applied, and scored, see Vila et al. (2018).

Agency Metric.

All items contained within the agencies' performance rubrics for scenario-based training and the basic trauma equipment course were adapted into a single metric. This contained 44-items, including: professionalism, law, and policy (3-items), skills and techniques (5-items), tactics and officer safety (28-items), and medical response (8-items). Each item was equally weighted and scored as (1 – Yes; 0 – No; Not applicable). Performance scores were expressed as a percentage of the potential applicable scores for each officer in the scenario. See Appendix G for a list of performance indicators.

Scenario Training Assessment and Review Scale.

The Federal Law Enforcement Training Centre (FLETC), the largest provider of in-service training to law enforcement in the US (FLETC, 2017), developed the STAR scale. The scale identifies eight factors considered essential to officer's operational performance, including: (1) situational awareness, (2) threat identification, (3) initial response, (4) scene control after the initial response, (5) application of force, (6) arrest/processing techniques, (7) communication, and (8) articulation/after action review (Wollert et al., 2011). Each item is rated on a four-point scale (1 – Not acceptable; 2 – Least desirable; 3 – Acceptable; 4 – Desirable; Not applicable). Performance scores were expressed as a percentage of the potential applicable scores for each officer in the scenario. See Appendix H for a list of performance indicators, ratings, descriptions, and modifications.

Lethal Force Errors.

To evaluate lethal force errors, participants were assessed for whether they: (1) shot the subject while they were armed with a knife and exhibiting a threat of self-harm (i.e., decision-making error), or (2) shot the bystander who quickly produced and pointed a cellphone after the subject was shot, while verbally indicating that they were video recording the situation (i.e., mistake of fact error).

Overall Performance.

To develop an overall performance measure, the average of the (1) DFJDM, TSI, and CIT metric, (2) agency metric, and (3) STAR scale was calculated.

Performance Coding and Reliability.

A team of eight UoF subject matter experts and trainers coded participant performance using the metrics described above. All coders had received the agencies' three-week UoF instructor course and had extensive UoF training and/or review experience. Coders received 4-hours of initial training on the use of the metrics and then completed four training assessments to confirm consistency and clarify metrics, where necessary. Coders were then randomly assigned to pairs and assigned a quarter of participants at random. Using scenario video footage, performance metrics for every participant were independently assessed by two coders to allow inter-rater reliability to be assessed.

Intraclass correlation coefficient (ICC) estimates for the total scores on each of the performance scales and their 95% confident intervals were calculated using IBM SPSS Statistics (Version 26) based on a mean-rating (k = 8), absolute-agreement, 1-way mixed-effects model (Hallgren, 2012; Koo & Li, 2016). The resulting ICCs from the

DFJDM, TSI, and CIT metric (ICC = 0.75, 95% CI [0.65-0.83], $F[121,122] = 3.89$, $p<.001$) and agency metric (ICC = 0.74, 95% CI [0.63-0.82], $F[121,122] = 4.053$, $p<.001$) were in the good-excellent (Cicchetti, 1994) or moderate-good range (Koo & Li, 2016). This indicated that coders had a relatively high degree of agreement and suggests that performance was rated similarly across coders. The STAR scale demonstrated poor-good (Cicchetti, 1994) or poor-moderate agreement (Koo & Li, 2016) (ICC = 0.52, 95% CI [0.32-0.66], $F[121,122] = 2.084$, $p<.001$).

To resolve discrepancies and achieve a single 'most correct' assessment, this study used a gold standard approach to settle disagreements. Independent third-party resolution was completed at random by another member of the coding team—neither of the original two coders (Syed & Nelson, 2015). This approach avoided using an independent coder outside the team with unknown reliability or a coercive consensus process (Bakeman & Goodman, 2020; Syed & Nelson, 2015). Once the independent third-party resolution was completed, the overall performance measure was calculated.

Procedure

The authors recruited participants from a large Canadian police agency, using e-mail, flyers, and in-person discussions. Before beginning the study, potential participants reviewed and signed an informed consent form. Participants were then equipped with the cardiovascular monitoring devices and then seated while they completed the demographics questionnaire listed above. Next, they were outfitted with other relevant equipment, including the StressVest™ system, the eye-tracker, and a BWC (if required for other aspects of the research). Participants were then exposed to the lowest level of the StressVest™ response (i.e., a localized shock to the abdomen). The shock was then increased to the highest “extreme” level, which the participants were told they would experience if shot during the scenario. Participants were then equipped with all the inert tools they carry in the field. The scenario was facilitated by an expert police trainer. The facilitator remained with the participant throughout the entirety of the scenario to act as radio dispatch and ensure the safety of the participant and role players. See Appendix B for a detailed design and description of the scenario.

After the scenario, participants were de-equipped and completed the self-reported perceptual and cognitive distortions questionnaire while sitting. A random subsample of participants were recruited to wear a HR monitor while sleeping, to establish a true resting heart rate. Participants were then debriefed by the researchers and a facilitator. All participants were provided the opportunity to withdraw their data, but none chose to withdraw. Participants were compensated with a $50.00 gift card and those who volunteered to wear the heart rate monitor while sleeping, were compensated with an additional $50.00 gift card.

The study was approved by the Carleton University Ethics Committee for Psychological Research (CUREB-B Clearance # 108733), as well as the Research Review Board (2018-04) of the agency from which the officers were recruited.

Data Analyses

All measures for the current study were entered into SPSS v.27 (IBM Corp, Released 2020) for quantitative analysis. All dependent variables were examined for expected ranges and the presence of extreme outliers. The normal distribution of dependent variables was tested using the Kolmogorov Smirnov test, as well as an examination of histograms and Q-Q plots. All performance scales, self-reported perceptual and cognitive distortions, and heart rate measures were normally distributed. SNS and PNS indexes had non-parametric distributions.

Paired-samples *t*-tests were used to test the mean difference between paired observations. Independent-samples *t*-tests and Mann–Whitney U tests were used to compare parametric and non-parametric measures between independent samples, respectively. Correlations between variables were assessed using Pearson’s correlation (r) for parametric distributions or Spearman's rank correlation (r_s) for non-parametric distributions.

For repeated measures with normal distributions, General Linear Model repeated measures were used. Greenhouse–Geisser corrected *p*-values were reported when the assumption of sphericity was violated, as indicated by the Mauchly test. Significant main effects were further analyzed with Bonferroni corrected post-hoc tests. For non-parametric repeated measures, the Friedman test was used. Significant main effects from the Friedman test were further analyzed with Bonferroni corrected Wilcoxon signed-rank tests and effect sizes calculated in accordance with Pallant (2010, p. 232). To examine the effect of training on HR, self-reported perceptual and cognitive distortions, and performance, one-way between subjects ANOVAs were conducted. Kruskal–Wallis one-way ANOVAs were conducted to examine non-parametric HRV measures.

Multiple regression analysis was used to determine the relationship between stress reactivity, experience, and training on performance. To examine the two lethal force errors with dichotomous outcomes, logistic regression was used to model the data. All assumptions were met for regression analyses.

Results

Stress Reactivity in Response to the Scenario

To measure elevated stress reactivity, we first established a true resting heart rate with a subsample (n = 29) who wore a HR monitor to sleep. A paired-samples t-test was conducted to compare HR_{rest} at the lowest one minute while completing paperwork pre-scenario to HR while the officer was sleeping. As expected, HR_{rest} (M = 77.11, SD = 10.76) was significantly higher than HR while the officer was sleeping (M = 55.80, SD = 6.53), $t(28) = 13.665$, $p < 0.001$, $d = 2.54$). HR_{rest} for the full sample was 75.17 bpm (SD = 11.13; see Table 9), which is in line with the resting rate found for officers (pre-scenario) in similar studies (Andersen et al., 2018), although it is 10-15 bpm higher than on-duty HR_{rest} (Anderson & Plecas, 2000; Baldwin et al., 2019). The slight elevation may be attributed to factors such as anticipatory stress while waiting for the scenario or the officer's body positioning during the recording (e.g., sitting upright in a chair; Miles-Chan et al., 2013).

Table 9 presents cardiovascular stress reactivity data for officers across the scenario. In support of the first hypothesis, the results indicate that participants experienced elevated stress reactivity during the scenario. $HR_{mean\_scenario}$ was 129 bpm (SD = 18.11). Elevated SNS $Index_{scenario}$ (M = 7.8, SD = 3.39) and decreased PNS $Index_{scenario}$ (M = -3.39, SD = 0.69) were also observed throughout the scenario. Average participant $HR_{max\_critical}$ was 149.81 (SD = 18.03), consistent with the HR reported during real world UoF encounters (Baldwin et al., 2019).

Table 9

Cardiovascular Stress Reactivity During Sleep, While at Rest, and During the Phases of the Scenario

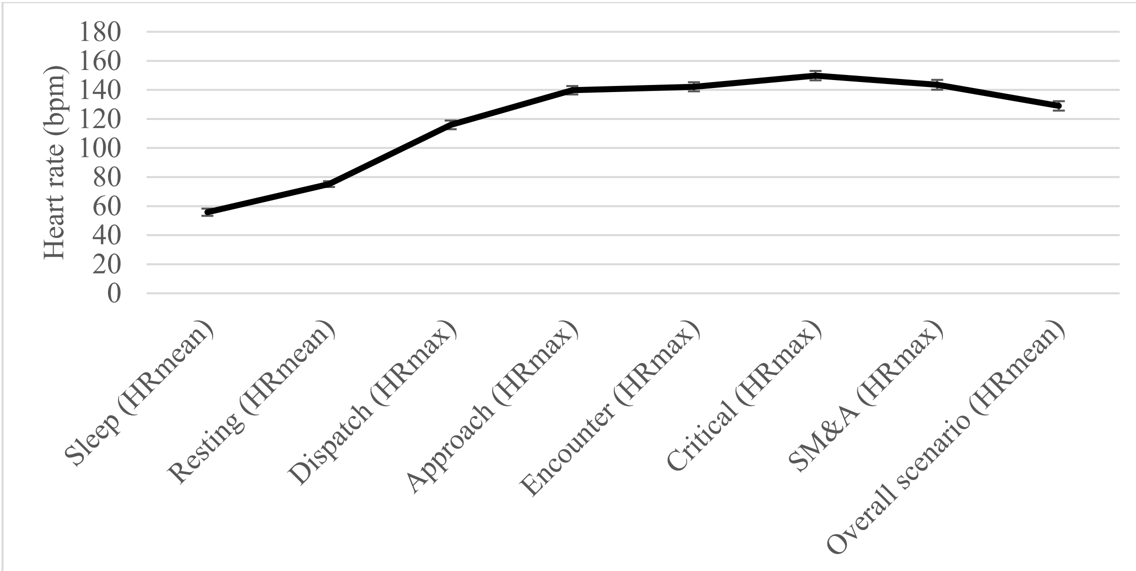
	HR_{mean} (bpm)			HR_{max} (bpm)			SNS Index			PNS Index		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Sleep	55.80	6.17	29	-	-	-	-0.76	1.26	29	1.43	1.59	29
Resting	75.17	11.13	122	-	-	-	1.46	1.67	122	-0.78	1.23	122
Phase of scenario												
Dispatch	103.95	16.39	122	115.94	16.68	122	5.05	2.94	119	-2.46	0.81	119
Approach	124.11	16.56	122	139.76	16.13	122	9.76	4.53	119	-3.30	0.67	119
Encounter	130.32	20.04	122	142.16	17.43	122	10.13	5.46	119	-3.40	0.79	119
Critical	132.38	19.57	121	149.81	18.03	122	9.55	4.68	116	-3.51	0.70	116
SM&A	128.93	18.28	117	143.52	18.47	117	9.16	4.64	118	-3.35	0.80	118
Overall Scenario	128.98	18.11	122	152.50	17.23	122	7.80	3.39	116	-3.39	0.69	116

Note. Beats per minute (bpm). Scene management and aftercare (SM&A).

Further supporting the first hypothesis, a repeated measures analysis ($n = 117$) demonstrated significant differences from at-rest HR and HR across the phases of the scenario ($F[3.251, 377.126] = 1091.954$, $p < .001$, $\eta_p^2 = .90$). After a Bonferroni post-hoc correction ($\alpha = .05/5 = .01$) was applied, it revealed that $HR_{max\_critical}$ ($M = 150.12$, $SE = 1.67$) was significantly higher than HR_{rest} ($M = 74.89$, $SE = 1.02$, $p < .001$, $d = 4.64$), as well as $HR_{max\_dispatch}$ ($M = 115.99$, $SE = 1.57$, $p < .001$, $d = 2.41$), $HR_{max\_approach}$ ($M = 139.87$, $SE = 1.51$, $p < .001$, $d = .96$), $HR_{max\_encounter}$ ($M = 142.41$, $SE = 1.67$, $p < .001$, $d = .80$), and $HR_{max\_SM\&A}$ ($M = 143.52$, $SE = 1.71$, $p < .001$, $d = .59$). See Figure 5 for a line chart of HR during sleep, while at rest, and during the phases of the scenario.

Figure 5

Heart Rate During Sleep, While at Rest, and During the Phases of the Scenario



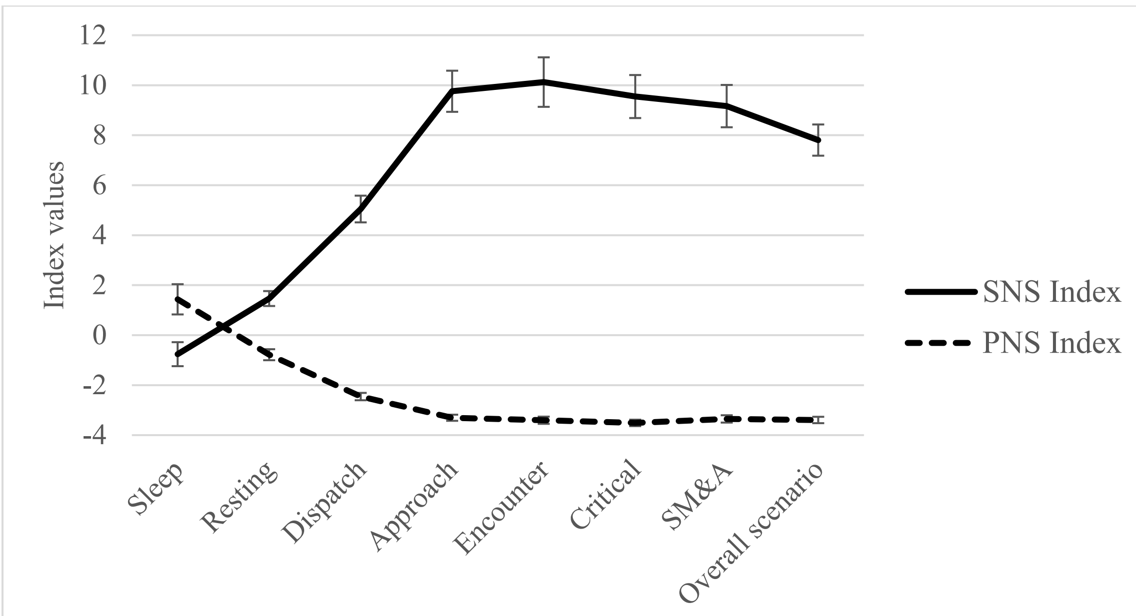
Note. Beats per minute (bpm). Scene management and aftercare (SM&A). 95% confidence interval error bars displayed.

Similarly, there was a statistically significant difference in SNS and PNS index values (n = 111) while at rest and across the phases of the scenario, $\chi^2(5)$ = 316.86, $p < .001$ and $\chi^2(5) = 370.77$, $p < .001$, respectively. A post-hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction ($\alpha = .05/5 = .01$). There were large significant increases in SNS $\text{Index}_{\text{critical}}$ compared to SNS $\text{Index}_{\text{rest}}$ (Z = 9.347, $p < .001$, $r = .61$) and SNS $\text{Index}_{\text{dispatch}}$ ($Z = 8.294$, $p < .001$, $r = .54$). However, there were no statistically significant differences between SNS $\text{Index}_{\text{critical}}$ and SNS $\text{Index}_{\text{approach}}$, SNS $\text{Index}_{\text{encounter}}$, or SNS $\text{Index}_{\text{SM\&A}}$ ($p > .01$, $r = \pm.04$-.09). There were small to large significant decreases in PNS $\text{Index}_{\text{critical}}$ compared to PNS $\text{Index}_{\text{rest}}$ (Z = -9.347, $p < .001$, $r = -.61$), PNS $\text{Index}_{\text{dispatch}}$ ($Z = -9.199$, $p < .001$, $r = -.61$), PNS $\text{Index}_{\text{approach}}$ ($Z = -9.199$, $p < .001$, $r = -.27$), and PNS $\text{Index}_{\text{SM\&A}}$ ($Z = -2.855$, $p = .004$, r

= -.19). However, once Bonferroni corrected, there was a small non-significant difference between PNS $\text{Index}_{\text{critical}}$ and PNS $\text{Index}_{\text{encounter}}$ ($Z = -2.334$, $p = .02$, $r = -.15$). Overall, these results provide support for our first hypothesis. See Figure 6 for a line chart of SNS and PNS index values during sleep, while at rest, and during the phases of the scenario.

Figure 6

SNS and PNS Index Values During Sleep, While at Rest, and During the Phases of the Scenario



Note. Scene management and aftercare (SM&A). 95% confidence interval error bars displayed.

To further assess the first hypothesis, we examined perceptual and cognitive distortions experienced by participants. The majority of participants reported experiencing the sensation of being on automatic pilot (90.9%), tunnel vision (87.6%), heightened visual clarity (82.6%), and diminished sound (70.2%) during the scenario (see Table 10). Overall, the mean perceptual and cognitive distortion score for participants was 33.6% (SD = 15.9), indicating a notable presence of distortions. These results also provide support for our first hypothesis. Perceptual and cognitive distortion scores were not significantly associated with cardiovascular stress reactivity (i.e., HR, SNS and PNS index values) during the overall scenario and during the critical phase of the scenario ($p > .05$).

Table 10

Self-Reported Perceptual and Cognitive Distortions Experienced by Participants During- and Post-Scenario

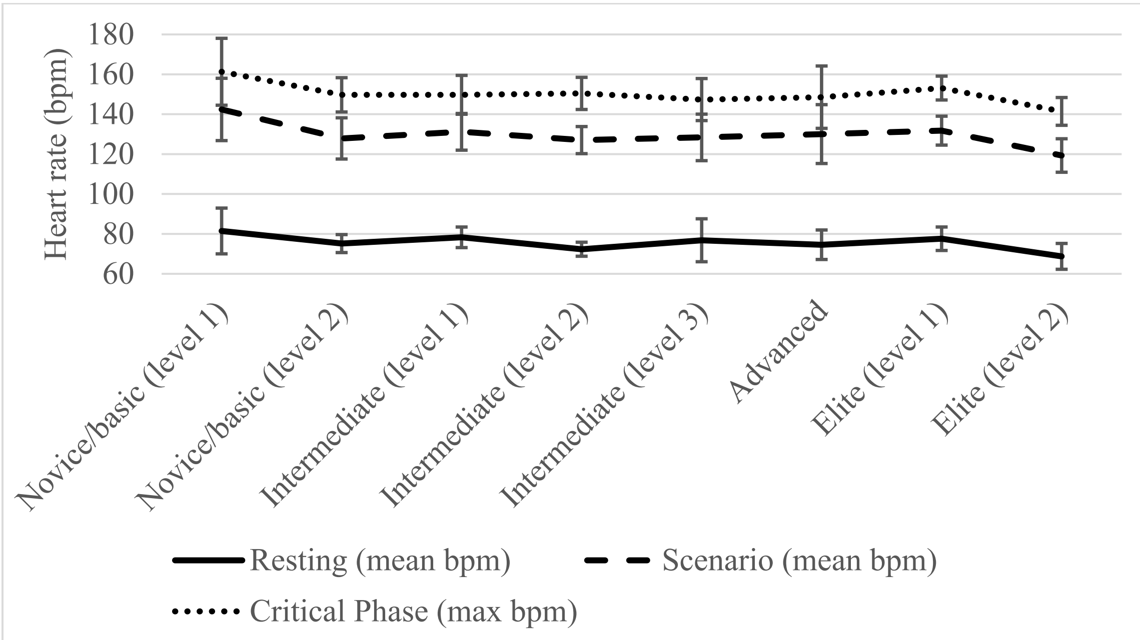
	Not at all		Very little		Somewhat		To a great extent	
	n	%	*n*	%	*n*	%	*n*	%
Diminished sound (i.e., inability to hear very loud sounds you would ordinarily hear, such as gunshots)	36	29.8%	44	36.4%	35	28.9%	6	5.0%
Intensified sounds	41	33.9%	45	37.2%	30	24.8%	5	4.1%
Heightened visual clarity	21	17.4%	44	36.4%	49	40.5%	7	5.8%
Tunnel vision (i.e., loss or narrowing of peripheral vision)	15	12.4%	30	24.8%	55	45.5%	21	17.4%
Automatic pilot (i.e., I responded with little or no conscious thought)	11	9.1%	34	28.1%	53	43.8%	23	19.0%
Slow motion time (i.e., time slowed down)	52	43.0%	41	33.9%	24	19.8%	4	3.3%
Fast motion time (i.e., time sped up)	49	40.5%	30	24.8%	29	24.0%	13	10.7%
Temporary paralysis (i.e., froze)	65	54.2%	32	26.7%	21	17.5%	2	1.7%
Dissociation (i.e., a sense of detachment or unreality)	72	60.0%	22	18.3%	25	20.8%	1	0.8%
Intrusive distracting thoughts	106	87.6%	6	5.0%	9	7.4%	0	0.0%
Memory loss for part of the event	36	30.0%	49	40.8%	33	27.5%	2	1.7%
Memory loss for some of my own behaviour	33	27.3%	51	42.1%	35	28.9%	2	1.7%
Memory distortions	65	53.7%	38	31.4%	15	12.4%	3	2.5%
"Flashbulb" memories	41	33.9%	29	24.0%	37	30.6%	14	11.6%

Stress Reactivity as a Function of Training and Experience

To test the second hypothesis, a one-way between subjects ANOVA was conducted to compare the effects of training on stress reactivity (i.e., HR_{rest}, $HR_{mean\_scenario}$, and $HR_{max\_critical}$). There were small non-significant effects of training on HR_{rest} ($F[7, 114] = 1.703$, $p = .115$, $\eta^2 = .095$), $HR_{mean\_scenario}$ ($F[7, 114] = 1.382$, $p = .22$, $\eta^2 = .078$), and $HR_{max\_critical}$ ($F[7, 114] = 1.013$, $p = .426$, $\eta^2 = .059$). Non-significant results were also observed when conducting a Kruskal–Wallis one-way analysis of variance for training on SNS $Index_{scenario}$, PNS $Index_{scenario}$, SNS $Index_{critical}$, and PNS $Index_{critical}$ ($p > .05$). These results failed to support our second hypothesis, as stress reactivity was similar across levels of training. See Figure 7 for baseline and scenario heart rate as a function of training.

Figure 7

Heart Rate as a Function of Level of Training



Note. Beats per minute (bpm). 95% confidence interval error bars displayed.

To examine whether years of police service were associated with stress reactivity, a series of non-parametric correlation tests were conducted with HR, SNS and PNS index values at rest, during the scenario, and during the critical phase of the scenario. Once Bonferroni corrected ($\alpha = .05/7 = .007$), years of service was significantly associated with $HR_{mean\_scenario}$ ($r_s = -.26$, $p = .005$), $HR_{max\_critical}$ ($r_s = -.35$, $p < .001$),[9] and PNS $Index_{critical}$ ($r_s = .26$, $p = .005$).

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[9] To confirm post-hoc that the effects of years of service on $HR_{mean\_scenario}$ and $HR_{max\_critical}$ were not confounded by age related changes to HR (see Plowman and Smith, 2013), multiple regression analysis

A one-way between subjects ANOVA revealed a small non-significant effect of training on perceptual and cognitive distortion scores ($F[7, 113] = 1.585$, $p = .147$, $\eta^2 = .089$). Years of police service was also not significantly associated with perceptual and cognitive distortion scores ($r_s = -.10$, $p = .258$). These mixed results of the effect of experience on stress reactivity provide some support for Hypothesis 2.

Performance as a Function of Stress Reactivity

All performance metrics had average scores that ranged from 50 to 66%, arguably indicating suboptimal performance under stress. Large positive correlations ($r > .60$, $p < .001$) between the three performance scales were observed (see Table 11).

Table 11

Descriptive Statistics and Correlation Matrix for Performance Metrics (N =122)

	M	*SD*	*Min*	*Max*	Agency performance metric	STAR Scale
DFJDM, TSI, and CIT metric	65.77	17.53	21.95	100.00	$.631^{***}$	$.667^{***}$
Agency performance metric	61.86	11.73	30.23	88.64		$.615^{***}$
STAR Scale	50.29	18.60	12.50	91.67		
Overall performance rating	59.31	13.96	24.99	93.43		

Note. ***indicates $p < 0.001$.

To examine our third hypothesis, a series of correlations between the performance metrics and HR, HRV, and self-reported perceptual and cognitive distortions were calculated (see Table 12). HR and perceptual and cognitive distortions were not significantly associated with performance metrics ($p > .05$). SNS Index$_{scenario}$ and SNS

was conducted controlling for participant age. Results confirmed that age was not a significant predictor of these measures and the size of the effect and level of significance for years of service remained the same.

Index$_{critical}$ demonstrated a trend suggesting that, as participants' sympathetic activity increased, their performance decreased. Specifically, small to moderate negative correlations were found between SNS Index$_{critical}$ and all performance metrics. However, once a Bonferroni correction for multiple comparisons per dependent variable was applied (α = .05/7 = .007), only the correlation with the STAR scale and the overall performance rating remained significant (p < .001). PNS Index$_{scenario}$ and PNS Index$_{critical}$, while not statistically significant, demonstrated small positive correlations with all performance metrics, suggesting that parasympathetic withdrawal may be associated with a deterioration in performance. Using *G*Power* (Faul et al., 2007), a compromise power analysis indicated that the study sample size (n = 116) was considerably underpowered (16-40% power) to detect a significant effect size of that magnitude (i.e., r = .09-.16).

Table 12

Correlations Between Stress Reactivity and Performance Metrics

	Overall Scenario			Critical Phase			Perceptual
Performance scales	HR$_{mean}$	SNS Index	PNS Index	HR$_{max}$	SNS Index	PNS Index	and cognitive distortions
DFJDM, TSI, and CIT	0.00	-0.10	0.02	0.05	-0.22*	0.09	0.034
Agency metric	-0.02	-0.09	0.05	-0.03	-0.22*	0.12	-0.065
STAR scale	-0.08	-0.21*	0.13	-0.01	-0.30***	0.16	-0.004
Overall rating	-0.04	-0.16	0.08	0.01	-0.29***	0.15	-0.006

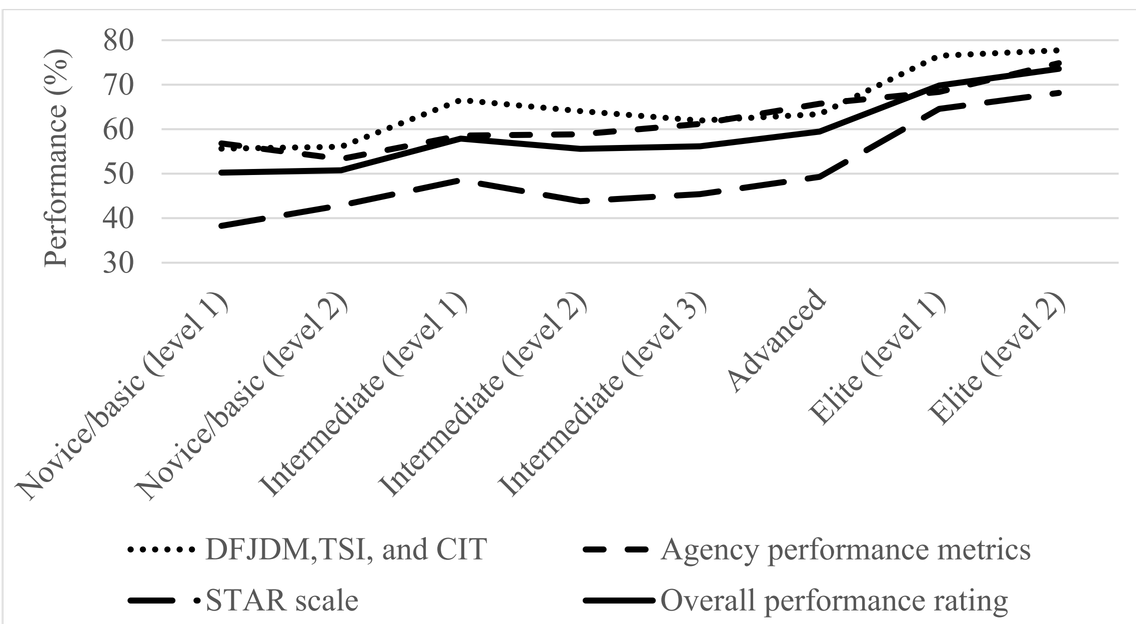
Note. Perceptual and cognitive distortions (n = 121), HR (n = 122), and HRV (n = 116). *indicates p < 0.05. ***indicates p < 0.001. An independent samples t-test was conducted to examine if there were differences in performance between participants with and without HRV data. No significant differences were found (p > .05).

Performance as a Function of Training and Experience

Our fourth hypothesis was tested with a one-way between subjects ANOVA to compare the effects of the level of training on performance metrics. There was a significant moderate to large effect of training on DFJDM, TSI, and CIT ($F[7, 114] = 3.495$, $p = .002$, $\eta^2 = .177$), agency performance metrics ($F[7, 114] = 7.225$, $p < .001$, $\eta^2 = .307$), STAR scale ($F[7, 114] = 5.928$, $p < .001$, $\eta^2 = .267$), and overall performance rating ($F[7, 114] = 6.882$, $p < .001$, $\eta^2 = .297$). Therefore, participants with higher levels of operational skills training displayed measurably better performance. See Figure 8 and Appendix I for performance scores across level of training. Years of police service was not significantly associated with any performance metrics ($r_s < .05$, $p > .05$).

Figure 8

Performance Metrics (%) as a Function of Level of Training



To examine the unique effects of training, experience, and stress reactivity on performance, multiple regression analysis was conducted. Due to high collinearity between cardiovascular measures ($r_s > \pm .80$), and the non-significant correlations between performance and both HR and the PNS Index, only SNS Index$_{critical}$ was retained in the model. In all four models (see Table 13), level of training had a significant effect on performance ($p < .001$), whereby for every increase in level of training (eight levels), there would be approximately a three unit (B = 2.87-3.36) increase in each of the performance metrics (%). Conversely, for every increase in years of police service, performance metrics (%) decreased by approximately .39 (B = .28-.50), though this effect did not reach significance for either the DFJDM, TSI, and CIT ($p = .093$), or the agency performance metrics ($p = .054$). With regards to stress reactivity, for every one-unit increase in SNS Index$_{critical}$ ($M = 9.6$, $SD = 4.7$), performance metrics (%) decreased by approximately .57 (B = .22-.99), though this effect did not reach a level of statistical significance for the DFJDM, TSI, and CIT ($p = .145$), or the agency performance metrics ($p = .304$).

Standardized β indicated that the strength of the effect from the level of training (β = .35-52) on performance was approximately double that of years of police service (β = .15-18) and stress reactivity (β = .09-25). Overall, level of training, years of police service, and stress reactivity (SNS Index$_{critical}$) explained approximately one quarter (R^2 = .17-.30) of the variance in performance in the scenario.

Table 13

Multiple Regressions for Training, Experience and Stress Reactivity on Performance

	Overall performance rating				DFJDM, TSI, and CIT				Agency performance metrics				STAR scale			
Predictors	B	SE B	β	*p*	B	SE B	β	*p*	B	SE B	β	*p*	B	SE B	β	*p*
Level of operational skills training	3.048	0.549	0.461	<.001	2.914	0.744	0.353	<.001	2.870	0.457	0.520	<.001	3.359	0.742	0.386	<.001
Years of police service	-0.393	0.175	-0.182	0.026	-0.401	0.237	-0.149	0.093	-0.282	0.145	-0.157	0.054	-0.496	0.236	-0.174	0.038
SNS $Index_{critical}$	-0.571	0.255	-0.188	0.027	-0.507	0.345	-0.134	0.145	-0.219	0.212	-0.086	0.304	-0.986	0.344	-0.246	0.005
R^2	0.30				0.17				0.30				0.26			

Lethal Force Errors.

A total of 34 (27.9%) participants made one or more lethal force errors during the scenario: 9 (7.4%) shot the subject while they were armed with a knife and exhibiting a threat of self-harm (i.e., decision-making error); 20 (16.4%) shot the bystander who quickly produced and pointed a cellphone after the subject was shot, while verbally indicating that they were video recording the situation (i.e., mistake of fact error); and 5 (4.1%) made both errors (see Figure 9).

To examine whether training, experience, and stress reactivity predicted lethal force errors, logistic regression analysis was conducted (see Table 14). All independent variables predicted ($p < .05$) the subject being shot while they were armed with a knife and exhibiting a threat of self-harm. Specifically, for each increase in level of training, the odds of shooting the subject while they were armed with a knife and exhibiting a threat of self-harm increased by 37% and the odds increased 12% for every additional year of police service. An increase in stress reactivity (i.e., one-unit increase in SNS $\text{Index}_{\text{critical}}$) also increased the odds of lethal force error on a subject armed with a knife and exhibiting a threat of self-harm by 25%. None of the variables significantly increased or decreased the odds of shooting the bystander who quickly produced and pointed a cellphone after the subject was shot. See Appendix J for a breakdown of level of training by type of lethal force error.

Table 14

Logistic Regressions for Training, Experience and Stress Reactivity on Lethal Force Errors

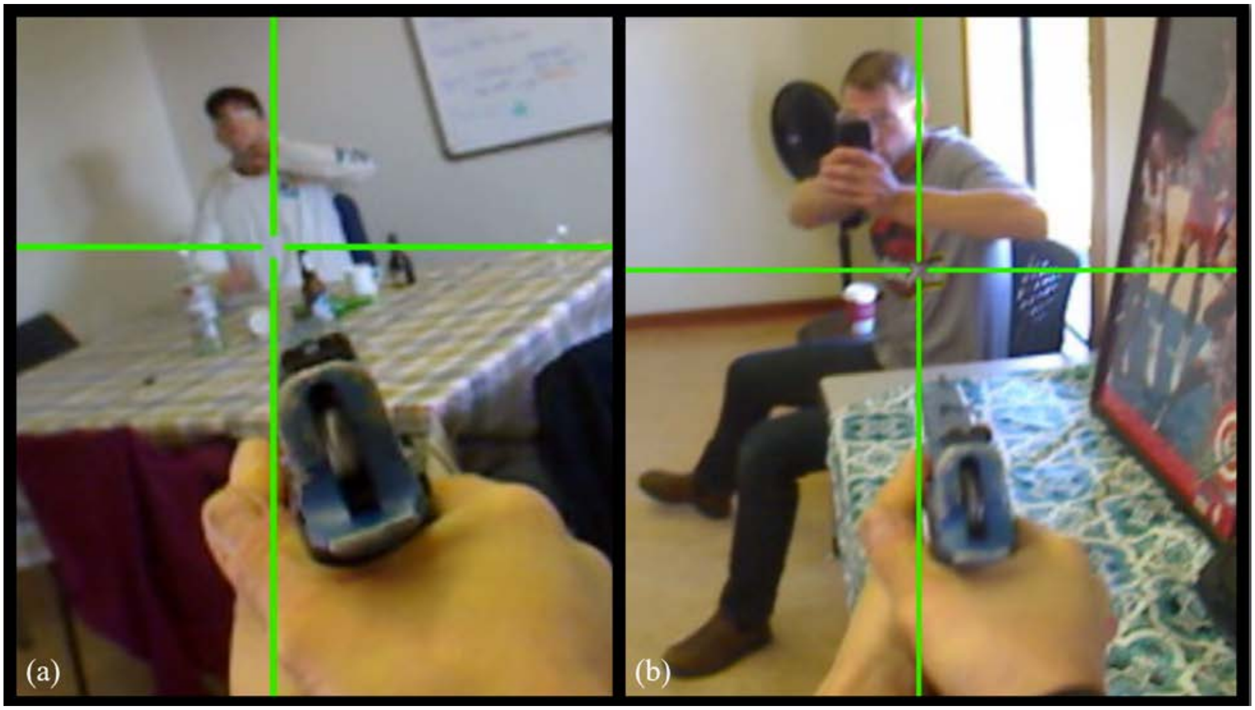
	Subject[a]				Bystander[b]			
		95% CI				95% CI		
Predictors	Exp(B)	Lower	Upper	Sig.	Exp(B)	Lower	Upper	Sig.
Level of Training	1.374	1.003	1.882	0.048	0.919	0.739	1.143	0.450
Years of police service	1.119	1.023	1.225	0.014	0.986	0.920	1.057	0.693
SNS $\text{Index}_{\text{critical}}$	1.247	1.069	1.454	0.005	1.008	0.907	1.120	0.888

[a] Shot the subject while they were armed with a knife and exhibiting a threat of self-harm (i.e., decision-making error).

[b] Shot the bystander who quickly produced and pointed a cellphone after the subject was shot, verbally indicating that they were video recording the situation (i.e., mistake of fact error).

Figure 9

Lethal Force Errors During the Scenario



Note. (a) shooting the subject while they were armed with a knife and exhibiting a threat of self-harm (i.e., decision-making error); and (b) shooting the bystander holding a cell phone (i.e., mistake of fact error). Green crosshairs represent participant gaze (from eye-tracker) at central mass while pulling the trigger.

Exploratory Analysis of Behavioural Predictors of Performance

To examine which individual behaviours were most associated with overall scores on the performance metrics, a series of non-parametric correlations were calculated. Given the exploratory nature of this analysis, Bonferroni corrections were not applied (Armstrong, 2014). Table 15 presents all behaviours with a large correlation (r_s >=.5) with at least one of the performance metrics. The table also includes correlations with level of training to assess whether these behaviours were associated with agency training.

Several trends emerged from the data, with results indicating that assessing the situation, recognizing threat cues, maintaining tactical advantage (i.e., time, distance, cover, concealment), and competence with intervention options, were all highly associated with performance in the scenario and moderately associated with level of training ($r_s > .27$). Overall verbal de-escalation and relevant de-escalation behaviours (e.g., demonstrating patience, offering help, appropriate level of aggressiveness) were also highly associated with overall performance; however, they demonstrated small ($r_s < .14$) non-significant associations with level of current police training ($p > .05$).

Table 15

Individual Performance Items Associated (r_s >=.5) with Performance Metrics and Level of Training

	Overall performance rating	DFJDM, TSI, and CIT	Agency performance metrics	STAR scale	Level of training
Observe and Assess…when possible, the officer assesses the situation fully before acting.	$.739^{***}$	$.810^{***}$	$.445^{***}$	$.597^{***}$	$.290^{**}$
Recognizes subtleties in threat cues, environment and body language and responds appropriately.	$.693^{***}$	$.569^{***}$	$.559^{***}$	$.657^{***}$	$.272^{**}$
Observe and Assess…the officer overestimates their ability to read a situation.	$-.625^{***}$	$-.715^{***}$	$-.381^{***}$	$-.474^{***}$	$-.345^{***}$
Officer Behavior - Maintaining a position of tactical advantage...	$.610^{***}$	$.659^{***}$	$.433^{***}$	$.476^{***}$	$.284^{**}$
Adapt/Repair - Recognizing when their actions are not appropriate and modifying them...(*n* = 93)	$.609^{***}$	$.572^{***}$	$.426^{***}$	$.588^{***}$	0.199
Threat cues	$.573^{***}$	$.464^{***}$	$.461^{***}$	$.542^{***}$	$.275^{**}$

Cover & concealment	$.570^{***}$	$.586^{***}$	$.439^{***}$	$.452^{***}$	$.419^{***}$
Tactics…the officer manages their perceptual narrowing during a deadly encounter.	$.566^{***}$	$.538^{***}$	$.362^{***}$	$.503^{***}$	$.191^{*}$
Tactics…the officer optimizes the distance between him or herself and the identified threat.	$.565^{***}$	$.625^{***}$	$.415^{***}$	$.405^{***}$	$.382^{***}$
Time & distance	$.561^{***}$	$.621^{***}$	$.428^{***}$	$.400^{***}$	$.381^{***}$
Interacting with the Person in Crisis/Officer Behavior…demonstrating patience with the person in crisis	$.499^{***}$	$.663^{***}$	$.245^{**}$	$.337^{***}$	0.133
Officer Behavior…the officer used an appropriate level of aggressiveness.	$.499^{***}$	$.513^{***}$	$.230^{*}$	$.468^{***}$	0.112
Transitions smoothly to other techniques and/or intervention option(s). (*n* = 71)	$.464^{***}$	$.347^{**}$	$.519^{***}$	$.421^{***}$	$.349^{**}$
Tactics…the officer makes full use of available cover and concealment.	$.443^{***}$	$.516^{***}$	$.254^{**}$	$.349^{***}$	$.455^{***}$
De-escalation	$.412^{***}$	$.578^{***}$	0.158	$.252^{**}$	0.027
Precise demonstration of techniques and skills. (*n* = 121)	$.396^{***}$	$.300^{***}$	$.502^{***}$	$.316^{***}$	$.323^{***}$
Interacting with the Person in Crisis/Officer Behavior…having the ability to de-escalate a situation (calm the person in crisis down)	$.394^{**}$	$.562^{***}$	0.167	$.216^{*}$	-0.006
Officer Behavior - Offering to help the civilian…	$.352^{**}$	$.542^{**}$	0.138	0.168	0.086

Note. *indicates $p < 0.05$. **indicates $p < 0.01$. ***indicates $p < 0.001$.

Discussion

To examine whether officer performance is affected by level of current police training, experience, and stress reactivity, we developed a scenario based on extensive reviews of the agency's OIS and UoF encounters, to ensure it was realistic and reflective of the operational environment. Within the scenario, we also embedded several psychological stressors from the literature (e.g., time pressure, task load, role conflict; Wollert & Quail, 2018), and used a non-projectile firearms training system that delivered a pain penalty when shot. As a result, and in support of Hypothesis 1, officers displayed significantly elevated stress reactivity in response to the scenario, including large increases in SNS arousal and PNS withdrawal, consistent with a threat response (Castaldo et al., 2015; Laborde et al., 2017). Self-reported perceptual and cognitive distortions and large increases in HR were also observed, commensurate with those reported in naturalistic UoF encounters (e.g., Andersen, Pitel, et al., 2016; Anderson et al., 2002; Artwohl, 2008).

For example, officers' cardiovascular stress reactivity during the critical phase of our scenario reached an average of 150 bpm (75 bpm higher than their pre-scenario resting rate). In comparison, Baldwin and colleagues (2019) reported stress reactivity in the range of 146 bpm when officers drew their firearm for the purpose of arresting a subject under threatening naturalistic conditions. Andersen and colleagues (2016) also found that active duty tactical officers operated, on average, at 146 bpm during actual calls for service. Therefore, the HR produced during our scenario approximates with stress reactions to real world police encounters.

Over 70% of our participants also reported experiencing tunnel vision, heightened visual clarity, and diminished sound. These results closely correspond with the perceptual and cognitive distortions reported by others (Artwohl, 2008; Honig & Sultan, 2004; Klinger & Brunson, 2009). The high prevalence of perceptual distortions observed in this study also align with attentional control theory (Eysenck et al., 2007), which suggests that under stress, attention is directed toward the threatening stimuli, rather than task relevant processes (e.g., decision-making). These indications of perceptual narrowing are further supported by research showing that the perceptual field tends to shrink under stress (Honig & Lewinski, 2008; Vickers, 2007). Additionally, the majority of participants (91%) reported that they responded on automatic pilot. This corresponds with decision making research showing that under dynamic and complex circumstances, responses rely heavily on intuition, which occur in an automatic manner (Kahneman & Klein, 2009; Klein, 2015; Ward et al., 2011). Our cardiovascular stress reactivity measures (i.e., HR and HRV) were not associated with self-reported perceptual and cognitive distortion scores, suggesting that self-reports of these distortions may not be a good proxy measure for stress reactivity, at least under high levels of stress. This further underscores the importance of collecting both objective and subjective measures of the phenomenon under study (Di Nota, Chan, et al., 2021).

Combined, the stress reactivity data indicate that the scenario developed for this study produced adverse physiological, attentional, and perceptual conditions. Thus, this scenario arguably provides reasonably realistic conditions under which to study and draw conclusions about what *might* happen to performance in highly stressful real-world police encounters. This is important, not only for assessing the efficacy of agency training, but also for informing the courts about how officers might reasonably perform when responding to a threat, given the current police training they have received. Further, the findings indicate how this performance and stress reactivity may be moderated by an officer's level of current police training and experience.

Impact of Training and Experience on Stress Reactivity

As discussed in the literature review, while the body's immediate and subconscious response to a threat is to stimulate the fight-or-flight response (LeDoux & Pine, 2016), it is believed that training and experience can improve one's ability to cope with a threatening stimuli, subsequently affecting the threat appraisal process, which sustains and moderates the fight-or-flight physiology (Anshel et al., 1997; Driskell & Salas, 1996; Kelley et al., 2019). The current study's results provided mixed evidence for Hypothesis 2, which examined this relationship.

Specifically, in contrast to what we expected, there was no effect regarding level of training on cardiovascular stress reactivity or the extent of perceptual and cognitive distortions experienced. Current findings correspond with Baldwin and colleagues (2019) who did not find an effect of level of training on physiological arousal when officers from the same agency as the current study responded to general duty calls for service. Together, these findings may indicate that the agency's training does not include or sufficiently embed techniques that have been shown to promote adaptive coping mechanisms (e.g., mental rehearsal, reappraisal; Anshel, 2000; Colin et al., 2014). Another possible explanation is that the agency's SBT is not currently eliciting significant enough stress reactivity to replicate the naturalistic environment and result in improved coping, advanced schemas, and stress resilient KSAs. While we are not proposing that all scenarios in SBT include high levels of stress, a progressive increase in stressful scenarios, once skills have been acquired, has shown benefits for performance that generalize across novel stressors and tasks (Driskell et al., 2001).

Research also indicates that the threat response is malleable, with specific types of training being shown to increase resilience to stress reactions (Andersen et al., 2018; Arnetz et al., 2009; McCraty & Atkinson, 2012). For example, using HRV biofeedback, Andersen and colleagues (2018; 2016) taught officers to modulate autonomic arousal during threat inducing SBT by evoking parasympathetic activation. This autonomic modulation training resulted in lower maximum HR and quicker recovery from critical incident stress (i.e., the time it took to return to their average resting HR) following threat exposure (a measure of PNS activation; Thayer & Sternberg, 2006). Adopting autonomic modulation training, or embedding such techniques in already existing skills training, may be beneficial for reducing stress reactivity during real-world critical incidents, and ultimately improve officer performance under stress (Andersen et al., 2018; Bennell, Alpert, et al., 2021).

In partial support of Hypothesis 2, we did find that more years of police service reduced parasympathetic withdrawal and HR in the critical phase and overall scenario, although no effect was observed for SNS arousal or perceptual and cognitive distortion scores. This provides some evidence that on-the-job experience may be important for parasympathetic regulation, which plays a role in forming a flexible response to environmental demands (Andersen et al., 2018; Roos et al., 2017; Thayer et al., 2009). It is unclear why this mixed effect with training and experience was observed, however, research has previously found that years of police experience influenced the extent that officers believed they could cope with stressful events (Anshel et al., 1997). Further research exploring the role of training and experience is warranted.

Impact of Stress on Performance

Large positive correlations were observed between the three performance scales used, indicating general consistency across metrics. The non-perfect correlation was reflective of the different factors examined and the variable weightings within each scale. For example, many items selected from the DFJDM, TSI, and CIT metric focused on de-escalation, whereas the agency metric included more items related to officer safety and medical aftercare. Therefore, the average of the three scales was used to create an overall performance score, that captured a more comprehensive rating of KSAs essential to police work.

Under the stressful and threatening conditions produced by our scenario, average participant scores for all performance scales ranged from 50 to 66%, arguably demonstrating suboptimal performance. However, it is important to note that due to the broad scope of performance indicators used in this study, it is likely beyond the ability of any officer to perform all expected tasks on their own. For example, many officers justifiably chose to prioritize providing medical care to the subject until back-up and emergency medical services (EMS) arrived. This would have resulted in lower scores for items related to scene management, such as securing weapons and evidence, which the officer may not have assessed as a priority given the circumstances (i.e., the subject suffering from a gunshot wound to the chest).

Additionally, under stress, over a quarter of officers made one or more lethal force errors during the scenario, including decision-making errors (7%), mistake of fact errors (16%), or a combination of the two (4%).[10] Since our study did not have a control (i.e., low stress) scenario for comparison, we cannot determine the full extent to which these performance deficits and errors were stress-induced. However, our study does show that SNS arousal during the critical phase of the scenario was associated with small to moderate decreases in performance, meaning that those who had higher, more maladaptive SNS arousal during the scenario displayed poorer performance than those with lower, more adaptive SNS arousal. Additionally, while it did not reach statistical significance, small effects were observed, suggesting that parasympathetic withdrawal may also be associated with a deterioration in performance. This trend adds to the growing evidence that indicates performance deficits may not only be related to maladaptive SNS arousal, but also the suppression of the stress modulating parasympathetic influence (Andersen et al., 2018; Saus et al., 2006; Spangler et al., 2018).

Even when controlling for level of training and experience, SNS arousal was still associated with performance deficits and increased odds of lethal force decision-making errors, though not mistake of fact error. With SNS Index values that ranged from 2 (low – more adaptive) to 25 (high – more maladaptive) during the critical phase of the scenario, model estimates indicate that maladaptive stress-induced deficits could decrease performance upwards of 5-23%, depending on the performance metric. Similarly, the odds of making a lethal force decision-making error would be 5.7 times higher for those

[10] Importantly, the scenario was specifically designed to induce potential mistake of fact lethal force errors (i.e., bystander who quickly produced and pointed a cellphone after the subject was shot) to examine human error and RPDM.

with the highest SNS arousal, compared to those with the lowest SNS arousal. These findings and trends are consistent with real-world studies and scenario-based experiments, which demonstrate that maladaptive stress arousal can result in degradation of task accuracy, increased task errors, and deficits in motor skills and cognitive functions, such as perception, attention, and decision-making (e.g., Driskell & Salas, 1996; Johnston et al., 1997; Morrison & Vila, 1998). These findings provide strong evidence in support of Hypothesis 3.

Conversely, HR was not found to be associated with performance. Thus, while HR is the most easily monitored physiological proxy of stress, we must caution that this is not an absolute measure of an individual's stress reactivity, nor does it unequivocally predict individual performance under stressful conditions (Arble et al., 2019; Brisinda, Fioravanti, et al., 2015; Meyerhoff et al., 2004). Additionally, self-reported perceptual and cognitive distortion scores were not associated with performance, which may indicate that while they may be maladaptive for certain aspects of performance (e.g., situational awareness), they may also be adaptive for other aspects, such as officer safety. Therefore, caution should be used when inferring things about an individual's in-the-moment performance based on post-incident self-reported distortions, particularly given what we know about memory distortions during stress and inaccuracies in self-reports (Di Nota et al., 2020). Based on these findings, future studies examining the relationship between stress and performance should use robust measures of stress reactivity (e.g., HRV, antithrombin), which have shown predictive value (e.g., Arble et al., 2019; James et al., 2020; Taverniers & De Boeck, 2014).

Impact of Training and Experience on Performance Under Stress

In support of Hypothesis 4, there were moderate to large effects of training on all performance scales. For example, overall performance scores increased steadily from 50% for novice officers or those with basic training, to 74% for elite tactical officers. In fact, when controlling for years of police service and stress reactivity, training was the largest predictor of performance, with model estimates showing a 3% rise in performance for every increase in level of training (eight levels). This indicates that while overall performance was low, significant improvements in performance under stress can be achieved through greater levels of operational skills training.

Conversely, when controlling for training and stress reactivity, years of police service was negatively associated with performance, with model estimates showing that for every 5-year increase in years of service, performance decreased approximately 2%. This finding was somewhat unexpected as research shows that experience can improve performance, including decision-making and cue recognition (e.g., Boulton & Cole, 2016; Mangels et al., 2020; Renden et al., 2015). Since experience and training are inevitably related, our findings may be a result of using regression analysis to determine the distinct effect of on-the-job experience, while controlling for level of training. Our findings may then indicate that minimum qualifications and skills maintenance training, absent of additional or supplemental training and practice, are not sufficient to retain KSAs in the long-term (O'Neill et al., 2019). This may be particularly true for certain KSAs that are rarely used in the field, such as the UoF and medical care for a gunshot wound (Baldwin et al., 2020; Singh, 2020). Therefore, years of police service may be a crude measure of experience, as it is not necessarily indicative of exposure to critical incidents (Klein, 1999).

While greater levels of training improved global performance in the scenario, more advanced training, as well as higher years of police service, were both predictors of increased lethal force decision-making errors, even when controlling for stress reactivity. Specifically, for each increase in level of training, the odds of shooting the subject while they were armed with a knife and exhibiting a threat of self-harm increased by 37%; these errors rose 12% for every additional year of police service. In contrast, with regards to the mistake of fact errors, neither training nor years of police service predicted shooting the bystander who quickly produced and pointed a cellphone after the subject was shot. These findings do not support Hypothesis 4, nor do they align with previous research that has shown a reduction of lethal force errors with greater levels of training and experience (Landman et al., 2016b; Vickers & Lewinski, 2012).

Research related to decision-making in naturalistic environments is helpful for understanding these unexpected results. According to this body of research, both the decision-making and mistake of fact lethal force errors observed in this study would be classified as rule-based (or misdiagnosis) errors (Reason, 2000; Taylor, 2019). This type of error involves an intended behaviour (e.g., discharging a firearm at a perceived threat) that results in an unintended outcome (e.g., shooting an unarmed subject) due to a misdiagnosis of the situation and application of the wrong rule or schema (Taylor, 2019). Recall from our earlier description of RPDM that individuals rely heavily on cognitive shortcuts (e.g., satisficing) to quickly assess situations, evaluate options, and determine the first workable response (Kahneman & Klein, 2009; Klein, 1997, 1999). While this type of response is resilient to stress, requires less attentional resources, and enables a quick response to a perceived threat, it does not always result in the selection of the best response (Kahneman & Klein, 2009; Klein, 2015; Ward et al., 2011). Thus, with regards to the mistake of fact error, given the context of just being shot at by the subject, when the officers in our study saw the bystander quickly pulling an object from his pocket and raising it, this pattern was congruent with, and likely to be recognized as, a threat.

Implications for Training

Training is essential to public and police safety, particularly when dealing with high-risk encounters (Staller & Zaiser, 2015). Given the sub-optimal performance observed in this study, it is recommended that LEAs and their trainers reflect on their current training and further incorporate evidence-based best practices from recent reviews (e.g., Bennell, Blaskovits, et al., 2021; Di Nota, Andersen, et al., 2021; Jenkins et al., 2021), in hopes of achieving better performance. Importantly, this study identified several behaviours that were highly associated with positive performance, while also being related to training (i.e., they improved with additional levels of training). These behaviours included: assessing the situation, recognizing threat cues, maintaining tactical advantage (i.e., time, distance, cover, concealment), and competence with intervention options. Thus, emphasizing these behaviours in training could result in positive impacts in overall performance.

Additionally, verbal de-escalation and relevant de-escalation behaviours (e.g., demonstrating patience) were also highly associated with overall performance. However, de-escalation displayed little, if any, association with level of training. This may indicate that de-escalation skills are not adequately being trained or embedded across all types of operational skills training, and thus, should be further integrated into training. These findings also support the adoption of evidence-based de-escalation training, which if done right, has been shown to have a significant and sustained positive impact on police performance in the field, including a reduction in use of force (Engel et al., 2020; Krameddine et al., 2013).

Regarding the decision-making errors observed in this study, Andersen and colleagues (2018) cautioned against use of force models (and associated training) that may reinforce if-then contingencies, such as relating a weapon or the threat of grievous bodily harm or death to the use of lethal force. While it is certainly important for public and police safety for an officer to *draw* their firearm in response to a weapon or lethal threat in relevant instances, if use of force models do promote if-then thinking, maladaptive heuristics may be relied on that are inappropriate in certain circumstances. For instance, in our study, we observed a significant number of officers discharge their firearm at a subject who was armed with a knife but was exhibiting a threat of suicide. The odds of doing so also increased with more training and experience. Therefore, it is possible that the current UoF model and related training, are inadvertently creating and reinforcing inappropriate mental shortcuts that may be used under dynamic and highly stressful situations. Thus, LEAs should examine evidence-based training and models that target decision-making (e.g., Engel et al., 2020; Klein & Borders, 2016; Vickers, 2007) and problem-solving abilities (e.g., Belur et al., 2019; Blumberg et al., 2019; Rajakaruna et al., 2017).

Lastly, agencies need to ensure adequate amounts and frequency of training are provided to achieve mastery and retention of evidence-based KSAs (e.g., Bennell, Blaskovits, et al., 2021; Di Nota et al., 2021; O'Neill et al., 2019), as rehearsed and automated skills are influenced to a lesser degree by stress (Arble et al., 2019; Renden et al., 2017; Vickers & Lewinski, 2012). Training should also include appropriate amounts of representative practice that is commensurate with real-world settings, to allow officers the opportunity to practice and integrate a wide-range of KSAs under stressful conditions (e.g. tactics, de-escalation, decision-making, perceptual-motor movement, medical aftercare).[11] Several studies have demonstrated that training under stress can improve police performance, enhance officer safety, and reduce use of force errors (e.g., Andersen et al., 2018; Nieuwenhuys & Oudejans, 2011b; Taverniers & De Boeck, 2014).

Implications for the Objective Reasonableness Standard

Critics have argued that the objective reasonableness standard lacks an evidence-based foundation and focuses too much on the general dangers and stressful nature of policing (Fagan & Campbell, 2020; Zamoff, 2020). As the courts' interpretation of what is reasonable is not static and likely to evolve over time due to changes in equipment, training, and public opinion (Alpert & Smith, 1994; Engel & Smith, 2009; Mourtgos & Adams, 2019), this research can also advance the standard by "injecting a consistent dose of evidentiary rigor" (Zamoff, 2020, p. 585).

Performance under high levels of stress in this study was sub-optimal, with overall performance scores of 59% and over a quarter of officers making one or more lethal force errors during the scenario. While proper training may significantly improve

[11] Importantly, ending training scenarios too quickly (i.e., immediately after force is used), limits one's opportunity to practice and fully integrate these skills. This can create 'training scars,' which the authors observed in this study.

performance, threat-induced performance deficits and lethal force errors in police officers are persistent, even with training (Nieuwenhuys et al., 2015). For example, even the sample of highly trained tactical officers in this study had performance scores of 74%, and 14% made lethal force errors under stressful conditions, despite a quarter of their shift time being devoted to training (Cyr et al., 2020). These findings suggest that a reasonable officer, regardless of the amount of training and experience they have received, will likely not perform flawlessly under the unpredictable, novel, and potentially uncontrollable circumstances of a critical incident.

While this information is necessary to inform judgements concerning the reasonableness of an officer's actions, the purpose of this research is not to excuse sub-optimal performance or errors by the police. Instead, the aim is to paint a realistic picture of human performance under stress, identify the extent to which current police training and experience can improve performance, and promote police accountability. Accordingly, the results suggest that unless there is a significant investment in more frequent and evidence-based training, police officers are likely not sufficiently prepared to deliver optimal performance in critical incidents, which can impact both public and police safety.[12] Thus, absent of evidence of bias, malice, or gross incompetence on the part of an officer, responsibility for poor performance or lethal force errors lies with LEAs and governments who are responsible for setting evidence-based training standards and ensuring that they can be met. Currently, many police services identify significant

[12] While we can expect improved performance with training, it is important for LEAs and the public to be realistic and understand that, even with the best training, mistakes and performance errors will happen, as they do in every other context (e.g., elite athletes).

barriers to providing training, such as limited funding, resources, and facilities (Rojek et al., 2020). At this critical juncture in time, when trust and confidence in policing are being significantly tested (e.g., Leger, 2021), a concerted effort is required to address these challenges.

Study Limitations

There is significant public interest in understanding and being able to explain police behaviours, particularly in lethal force encounters. While we are optimistic that our research findings can improve police training and inform the courts understanding of reasonable performance under stress, we caution readers to interpret and use the findings with consideration to various study limitations presented.

While the results of this study paint a stark picture of performance under stress, which may cause some alarm, these results must be considered within the context of what is *actually* occurring in the agency's operational environment. For example, with over 16,000 officers policing approximately 8 million people, the agency's OIS are relatively rare, with an average of 21 per year; accounting for 0.0008% of their police occurrences or one OIS in approximately 130,000 occurrences. These incidents also make up less than one percent of the number of times officers from the participating agency displayed or pointed their firearm at a subject, demonstrating that the vast majority of these high-risk situations are resolved without lethal force. Additionally, from 2010 to 2019, the agency saw a 44% decline in the rate of UoF, with 2019 marking the lowest rate (0.08%) over that ten-year period, suggesting positive behavioural change over time. Importantly, Canada also has external civilian oversight bodies that assert jurisdictions to ensure arms-length and transparent investigations into incidents involving serious injury, death, or possible criminal activity (Kwon & Wortley, 2020; Stelkia, 2020). Although there have been cases where the agency's officers have been criminally charged because of their actions in lethal force encounters, these external reviews have not identified widespread or systemic officer performance issues or negligence, which could be inferred from our findings (e.g., Alberta Serious Incident Response Team, 2021; Independent Investigations Office of British Columbia, 2021; Serious Incident Response Team, 2021). Thus, while we can draw conclusions about what *might* happen to performance in highly stressful real-world police encounters, we must caution that it does not necessarily mean that it is occurring in naturalistic settings.

This study also involved only a single scenario, which was specifically designed to be complex and dynamic, and left the officer to respond on their own without backup. Such scenarios are known to elicit significant cognitive load (Hope, 2016; Mugford et al., 2013), which could inflate the sort of performance deficits we observed. While the scenario was designed to be as realistic as possible to cause high levels of stress in participants, it is also important to note that even a realistic scenario does not completely mirror the stress induced by a critical incident. For instance, in a training or research scenario, officers are aware they will not be seriously injured or killed, nor be subjected to post-OIS stressors (e.g., external civilian oversight investigations, risk of criminal liability, job loss). Therefore, we caution that no scenario-based study can truly replicate the naturalistic police environment or officer performance within it.

The current assessment of performance was also based on a single snapshot in time with one sample of officers from a specific agency. Consequently, the results may not generalize to other scenarios, other officers, or other agencies. On average, officers from the participating agency receive in-service training that aligns with other LEAs (i.e., 40 hours annually; Reaves, 2010),[13] their pre-service and supervised field training are significantly longer (i.e., six months each). Additionally, the agency arguably has high quality police training compared to other police services, as it has dedicated teams of experienced and expert learning designers (civilian and police), has standardized training and centralized oversight of instructor training, and works in collaboration with academics to embed best training practices. Therefore, the results of this study may be reflective of performance with above-average quality training.

Lastly, measurements of HRV can be influenced by respiration and physical activity, which may obscure linkages between psychological and physiological processes (Laborde et al., 2017). However, to ensure sound conclusions could be drawn, the current study used measures which are relatively free of respiratory influences, reported baseline measures, used a scenario room with confined space to restrict movement, and followed recently proposed HRV reporting guidelines (Laborde et al., 2017; Quintana et al., 2016). As cardiovascular stress reactivity is only one aspect of the stress response system, future research should include as much biological sampling (e.g., HPA activity, blood markers) as is logistically and ethically possible.

Conclusion

Based on the robust methodology and relatively large sample of active-duty police officers used in this study, the results provide important insights into the general

[13] The type, amount, and frequency of operational skills training significantly varies across police agencies; therefore, comparisons based on the *average* number of hours should be made with caution. For example, some agencies deliver less frequent mass training, while others provide more frequent spaced training.

relationship between stress, training, experience, and performance in critical police incidents. The findings provide LEAs with not only an opportunity to critically reflect on current training practices, but also offer a roadmap for making evidence-based improvements to training. They also provide important evidence which may inform the reasonableness standard used in courts of law and paint a realistic picture of police performance under stress given the current training available to officers. However, perhaps most importantly, we identify a need for a concerted effort to increase police training standards and ensure the necessary infrastructure is in place to achieve them. In this way, we should be able to enhance police performance in stressful police-citizen encounters and significantly reduce critical lethal force errors.

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General Discussion

This dissertation focused on exploring the complex relationship between stress, training, and performance in police UoF encounters. The overall goal was to inform evidence-based improvements to police training, paint a realistic picture of police performance under stress, and inform the objective reasonableness standard, which is used to assess the appropriateness of force in courts of law.

The first study, “Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters,” provided foundational evidence of stress reactivity experienced by police officers during general duty CFS, UoF encounters, and other interactions with the public. That study also included a preliminary exploration of whether experience (i.e., years of service) and relevant operational skills training impacted stress reactivity during CFS. The results indicated that physiological arousal may not be a function of police experience or current training. Instead, stress reactivity was primarily associated with higher risk incident factors, which were routinely observed in the study, such as the report of weapons, making arrests, and drawing one’s firearm.

The second study, “A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario,” assessed officer performance in a scenario to examine the extent to which it was affected by the officer’s level of training, experience, and stress reactivity. Armed with the knowledge and data from Study 1, we confirmed that the scenario produced stress reactivity commensurate with levels reported from naturalistic UoF encounters, improving the external validity and generalizability of the findings from Study 2. Results demonstrated that elevated stress reactivity was a predictor of poorer performance and increased lethal force errors. Additionally, we found that level of training and years of police service had differential and complex effects on both performance and lethal force errors.

Overall, across the two studies, the results contribute to the psychological literature and have implications for police training, courtroom decisions about police use of force, and long-term health outcomes. Regarding police training, the results demonstrated that performance under high levels of stress, of the sort that will likely be observed in UoF encounters and other critical incidents, is likely to be sub-optimal; however, with greater levels of agency training, performance under stress can be improved. These findings provide LEAs with not only an opportunity to critically reflect on their current training practices, but also provides a roadmap to make evidence-based improvements to training. That being said, making meaningful improvements to training will likely require a concerted effort on the part of police leadership and governments at all levels to develop evidence-based police training standards and ensure the necessary funding and infrastructure are in place to achieve those standards. The results presented in this dissertation can inform these discussions around standards and speaks to the need to conduct more frequent evaluations of agency training and officer performance (Huey et al., 2017).

Importantly, the results also paint a realistic picture of human performance under stress and provides important evidence to inform the reasonableness standard, which is used to assess the appropriateness of force in courts of law. For example, the first study presented objective evidence of the level of stress reactivity experienced by police officers during UoF encounters. Using a research scenario that elicited similar stress reactivity to the naturalistic environment, the second study demonstrated how officers *might* reasonably perform when responding to a threat, given the current police training they have received. The results demonstrated that while greater levels of training significantly improved performance, even highly trained officers did not display ideal performance and made lethal force errors under stressful conditions. Accordingly, the results suggest that unless there is a significant investment in more frequent and evidence-based training, police officers are likely not sufficiently prepared to deliver optimal performance in critical incidents, which can impact both public and police safety. Thus, absent of evidence of bias, malice, or gross incompetence on the part of an officer, responsibility for poor performance or lethal force errors should rest with LEAs and governments who are responsible for setting training standards and ensuring that they can be met.

Higher levels of physiological arousal associated with high-risk encounters may be appropriate (even preferred) in some circumstances in order to meet the demands of the situation; however, chronic or maladaptive autonomic activation can be detrimental to health over the long-term (McEwen, 1998). Indeed, longitudinal research studies conducted with frontline officers have demonstrated elevated risks of chronic disease such as cancer, diabetes, and heart disease compared to populations of similar age (Charles et al., 2007; Violanti, 1983; Violanti et al., 2006). The frequency of high-risk encounters in an officer's shift, which was routinely observed in Study 1, may be at the root of some of these health concerns if it means that officers do not have time to recover fully during their shifts. If this occurs, officers may experience accumulated stress that results in allostatic load, or "wear and tear" on the cardiovascular system, that is associated with long-term health outcomes (McEwen, 1998; Violanti et al., 2006).

Although I cannot speak to health outcomes directly, future research should examine the long-term health implications of the “physiological profiles” that were generated from Study 1.

Since each study had a lengthy discussion section, and key linkages between the two studies were highlighted in the discussion section of Study 2, this general discussion will focus on some of the broader implications and observations that emerged from the research process. Particularly, I will discuss lessons learned about collaborative research with LEAs and why such collaborations are critical for pragmatic and impactful police research, of the sort that was conducted for this dissertation. I will also speak to the importance of knowledge mobilization for incorporating research findings into police practice. Finally, I will discuss the general limitations of the studies and present areas for future research.

The Importance of Collaboration for Conducting Research on Police Performance

While it is said that “it takes a village to raise a child,” it takes a large research team with strong support and open-mindedness from police officers, trainers, and leadership to conduct robust and meaningful applied police research. Studies suggest that police agencies are typically resistant to research and change, particularly due to a lack of leadership and support from middle management (Duxbury et al., 2018; Koziarski & Kalyal, 2021; Sherman, 2015). However, throughout the research process, the studies reported on here had strong support at all levels. This may be attributed to the organization’s adoption of many best practices for evidence-based policing, including: progressive leadership and champions who actively advocate for evidence-based policing; internal policies for conducting research, including a research review board that coordinates and approves academic research involving agency officers; support for employees completing graduate studies; and internal research units with ‘embedded’ PhD researchers (Blaskovits et al., 2020; Koziarski & Kalyal, 2021; Sherman, 2015). This level of agency support may also have been enabled by the external research grant that was obtained for the studies, which the agency sponsored at the application phase.

In my experience with this research, officers and trainers were all too eager to participate in the research process, because of their interest in knowledge, evidence, and improving outcomes, such as public and police safety. The police collaborators also expressed a real interest in gaining insights into how stress can impact human performance, and what this means for their daily work and lives. Between both studies we collected data from almost 200 police participants and were assisted by countless instructors. This ‘professional development’ opportunity for participants and facilitators served not only to educate them on aspects of psychology and physiology, but also allowed them to reflect on and apply these insights to their policing duties. For example, throughout the research, it was observed that while officers understood that their work is stressful, they were generally unaware of the internal physiological processes at play and were quite surprised when they saw evidence of their own stress reactivity while on duty or during the scenario. This type of knowledge is critical for officers to understand and it is important that they reflect on the psychophysiological changes that occur throughout their shift, their implications for performance, and the importance of resilience strategies, such as visualization, automation of skills, and breathing techniques (Andersen et al., 2018; Di Nota et al., 2021; Di Nota & Huhta, 2019).

Importantly, involving the agency's UoF experts and trainers in the research process (e.g., scenario design, study facilitation, performance assessment) ensured the studies and interpretation of the findings were grounded in a true understanding of the realities of operational policing, which civilian academics can never fully possess. Their involvement and validation of the research has facilitated early adoption of the findings. For example, the agency has adopted the evidence-based methods I used for scenario development, including the incorporation of psychological stressors (e.g., task load, time pressure, noise) into scenarios. The agency is also now drawing on comprehensive reviews of use of force reports to ensure training scenarios are realistic and operationally relevant. Additionally, the agency has recently included a module on critical incident stress in its annual mandatory training (required for 17,000 Canadian police officers), which prominently includes walk-throughs of case studies from Study 1 (see Appendix K). Including case studies from agency officers (i.e., peers) in training enables a relatable understanding of the internal stress response likely to be experienced in critical incidents and provides important insights for supervisors to be aware of when supporting these officers. The training further presents officers with mitigation strategies to help prepare for and reduce stress reactivity in-the-moment, such as visualization and breathing techniques to stimulate parasympathetic activation (e.g., Andersen et al., 2018). This demonstrates some initial, but broad reaching impacts that this research has already had, due in part to the strong collaborative research partnership with the LEA. Again, such impacts would be difficult, if not impossible to achieve by academic researchers working alone.

Lastly, this collaborative partnership improved the ecological validity of the studies in several ways. For example, it allowed for both studies to include the target sample of *active-duty* police officers, a specialized sample which is difficult to recruit (Nix et al., 2019; Reiner, 2000). Additionally, Study 1, which established evidence of the extent of stress arousal during real-world CFS and UoF encounters, would have been prohibited without agency support and approvals. The research partnership also facilitated necessary security clearances and approvals under the *Privacy Act* (Department of Justice, 1985), which are required to grant access to training and operational records for the analyses, as well as critical incident and UoF data for the design of a realistic and representative scenario for Study 2. Use of training facilities and prohibited equipment, such as conducted energy weapons and firearms, were also supplied by the agency as in-kind contributions to the research. This ensured a realistic, yet safe environment for Study 2. As previously discussed, the collaborative partnership also facilitated the engagement of police trainers, which ensured the studies were underpinned by operational police expertise. For example, performance assessments in Study 2 were completed by UoF experts and trainers, the likes of which would provide expert testimony on officer performance and compliance with policy and training, in courts of law. The ecological validity achieved through these steps was critical for painting a realistic picture of police performance under stress, thus providing robust evidence to inform the courts on the level of performance that can reasonably be expected from police officers based on their experience and training.

The Importance of Knowledge Mobilization

As discussed above, the collaborative partnership with the participating LEA has facilitated the early adoption of the research and findings; however, the aim of this research is to inform academics, LEAs, and the courts more broadly. Particularly, because the results have implications for the objective reasonableness standard, which is used to assess the appropriateness of force in courts of law across North America, and because the findings illustrate the general need to critically reflect on and improve current training practices. However, police research that has policy implications and seeks to influence practice is often confined to expensive subscription-based journals, which limits their usefulness (Ashby, 2021; Bennell & Blaskovits, 2018; Danner, 2012). For examples, studies have found that the police rarely read closed access publications (Blaskovits et al., 2020; Rojek et al., 2012; Telep & Lum, 2014). Therefore, there has been a call for more open access to police and legal research (Bennell & Blaskovits, 2018; Carroll, 2006).

In line with this recommendation for broader and easier access to research for officers, academics, legal practitioners, and the public, both studies were published (or submitted for publication) in an open access psychology journal with special topics related to policing (i.e., “De-escalating Threat: The Psychophysiology of Police Decision Making” and “Training Revisited: Drawbacks and Advances”). These decisions to publish in special issues surround the studies with similar research, which likely helps ensure the studies are accessed by a broader and targeted audience. For example, since the first study, “Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters” was published in October 2019, it has reached over 12,000 views, been cited in the academic literature over 20 times, and has more views than over 90% of all Frontiers[14] articles (as of July 2021). Importantly, many of these early steps for knowledge mobilization were facilitated by Carleton University's Integrated Thesis Policy for Psychology, which allowed for the studies to be academically peer-reviewed and published, as part of the dissertation.

Since research suggests that police officers and professionals are more likely to access professional journals and other sources, as opposed to academic journals (Blaskovits et al., 2020; Rojek et al., 2012; Telep & Lum, 2014), I have also worked with my police-research network to disseminate lay summaries of the research (see Appendix L). This includes the Force Science Institute in the United States, who deliver police training on behavioral science and human dynamics. They produce monthly news articles that are published online and disseminated to their mailing list of approximately 60,000, as well as being re-distributed by other practitioner publications such as Police1 (Lexipol), as well as the Federal Law Enforcement Training Center. Through these broader networks, they estimate that on average their articles are distributed to approximately 100,000-250,000 academics and practitioners worldwide. Use of these knowledge mobilization strategies has helped ensure that this research gets into the hands of those that can influence practice; however, future steps will be taken to disseminate this research even further through other professional journals (e.g., The Police Chief) to maximize mobilization (Blaskovits et al., 2020; Rojek et al., 2012; Telep & Lum, 2014).

[14] Study 1 was published in Frontiers in Psychology and Study 2 is also under review by this journal. Frontiers is the 3rd most-cited publisher and Frontiers in Psychology had an impact factor of 2.99 in 2020.

Limitations

The limitations of the studies were discussed in each manuscript, respectively. This included cautions around the use of this research to try to explain all police actions, particularly lethal force encounters, as opposed to using it to draw general conclusions about what *might* happen to performance in highly stressful real-world police encounters. An additional limitation across both studies was that the measures of cardiovascular stress reactivity, such as HR and HRV used in the studies, represent only one aspect of the stress response system. While steps were taken to ensure validity and interpretability of these proxy measures for stress (e.g., controlling for physical movement, adhering to HRV reporting guidelines), future research should include as much biological sampling, such as HPA activity and blood markers, as is logistically and ethically possible.

In addition to the specific limitations of the studies that were already discussed, the key general limitation that requires consideration is the risk of potential research bias that might occur when collaborating with and conducting research from within a LEA. Indeed, as an employee of an LEA, the knowledge and experience that I have gained from this position affects my own interpretation of the data and could bias the research (Flyvbjerg, 2001; Onwuegbuzie & Leech, 2005). To help mitigate this risk, I was cognizant of my personal preconceptions and remained reflexive in my position and interpretation throughout the research process. This self-awareness was facilitated by my study of epistemology during my masters degree in Sociology (Baldwin, 2014). Additionally, the integrated thesis approach facilitated important checks and balances, such as co-authors that are external to policing and the blinded peer-reviewed publication process. Lastly, the agency was supportive of research process and never influenced the findings or their interpretation, as exemplified by the findings in Study 2, which are not overly favorable to the agency or policing generally. Fortunately, the participating agency has strong leadership that supports evidence-based decision-making and understands that robust evaluation and critical reflection is essential to self-improvement.

Future Directions

Study limitations were also discussed in each of the papers separately, but there are some additional future lines of research that warrant consideration. The proposal for this dissertation originally had a third study that would examine stress reactivity experienced by officers during the agency's operational skills training and qualifications. Unfortunately, due to the scope and complexities of the other two studies, this study had to be abandoned. As a result, future research should examine the extent to which agency training elicits stress commensurate with the naturalistic setting. This will be important because skilled performance is typically learned through practice in settings that mimic the environment in which the skills will be performed operationally (Jenkins et al., 2021; Schmidt & Lee, 2013).

Based on the results of the research reported in the two papers, more frequent and robust evaluations of police training should also be conducted to assess whether training incorporates evidence-based best practices from recent reviews (e.g., Bennell et al., 2021; Di Nota et al., 2021; Jenkins et al., 2021). It will also be important to validate whether training is resulting in intended behavioural outcomes, as there is little research evidence available to suggest that it is (Bennell et al., 2021; Engel et al., 2020; Huey, 2018). Specifically, based on the research findings, focus of future research should target de-escalation strategies and related behaviours, as this appears to be a significant gap in current police training (Engel et al., 2020).

Lastly, while this study predominantly focused on physiological indices of stress, future research should examine whether psychological constructs, such as memory systems and personality traits, are associated with performance under stress (Giessing et al., 2019; Landman et al., 2016), as well as the threat appraisal process (Anshel et al., 1997; Peacock & Wong, 1990). Candidate systems and traits include working memory functioning, ego-depletion, and impulsivity as these have all been shown to relate to various aspects of police decision-making (Condon, 2015; Donner et al., 2017; Staller et al., 2019). A greater understanding of the psychological processes related to resilience under stress can potentially help promote coping strategies and improved performance in critical incidents.

Conclusion

Very limited research exists that objectively measures stress reactivity experienced by police officers during active-duty or the degree of police performance that can reasonably be expected under the levels of stress observed in naturalistic UoF encounters. Through a collaborative and team-based research partnership with a large Canadian LEA that champions evidence-based policing practices, this dissertation reported on two studies, one drawing on data from officers during active-duty and the other using an experimental scenario. Across the two studies, the results provide important insights into the general relationship between stress, training, experience, and performance in critical police incidents.

The findings provide LEAs with an opportunity to reflect on their training; indeed, the research identifies a need for a concerted effort to increase police training standards, develop best training practices, and ensure the necessary training infrastructure is in place to achieve optimal results. The findings also provide important evidence that may inform the reasonableness standard used in courts of law given that they paint a realistic picture of how police officers may perform under stress given their current training. Using various knowledge mobilization strategies, I hope to facilitate easy and widespread access to this research by police officers, academic researchers, legal practitioners, and the general public. This will hopefully result in the broader incorporation of the research findings into police and legal practice, and make the public more informed about police decision-making and the factors that influence it. Ultimately, this will help accomplish the primary goal of this research, which is to improve public and police safety.

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Appendix A **Co-Authored Papers Contributions**

Co-Author	Statement of Contribution	Signature	Date
Craig Bennell	I, Dr. Craig Bennell, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscripts titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" and "A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario" of which I am a co-author.		Aug 15, 2021
Judith Andersen	I, Dr. Judith Andersen, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscripts titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" and "A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario" of which I am a co-author.	Judith Andersen	25 August 2
Tori Semple	I, Tori Semple, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscripts titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" and "A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario" of which I am a co-author.	Tori Semple	August 14, 2021
Bryce Jenkins	I, Bryce Jenkins, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscripts titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" and "A Reasonable Officer: Examining the Relationship between Stress, Training, and Performance in a Highly Realistic Lethal Force Scenario" of which I am a co-author.	Bryce Jenkins	Aug 15 2021
Brittany Blaskovits	I, Dr. Brittany Blaskovits, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscript titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" of which I am a co-author.		Aug 16 2021
Andrew Brown	I, Andrew Brown, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscript titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" of which I am a co-author.		Aug 15, 2021

Chris Lawrence	I, Chris Lawrence, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscript titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" of which I am a co-author.		Aug 15, 2021
Heather McGale	I, Heather McGale, affirm that I have read and agree to the preface in Simon Baldwin's dissertation, and acknowledge that Simon took the lead role in the manuscript titled "Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters" of which I am a co-author.		August 16th 2021

Appendix B **Scenario Design**

The scenario was developed by the authors, based on extensive reviews of the agency's officer-involved shootings and UoF encounters. This ensured the scenario was realistic and reflective of the operational environment. In order to increase the stress of the scenario, several psychological stressors from the literature were embedded in the scenario (Driskell & Salas, 1996; Jenkins et al., 2020; Wollert & Quail, 2018). These stressors included time pressure (i.e., a countdown in which the subject had a knife to their throat and indicated they would kill themselves), task load (e.g., multiple subjects), threat (e.g., a localized shock to the abdomen, if shot), ambiguity (e.g., situation inconsistent with dispatch information), novelty (e.g., the subject drawing a firearm after a knife had been discarded), role conflict (e.g., protecting bystander vs. de-escalating armed threat), noise (e.g., loud music playing, constant distractions from the bystander), performance pressure (e.g., instructor observing and video recording), distance (e.g., confined space), role ambiguity (e.g., providing medical attention immediately vs. waiting for emergency medical services [EMS]), and coordination demands (e.g. requesting backup, EMS).

Prior to the study, the scenario was pilot tested on a small sample of officers (N = 12) and then revised to ensure that it remained standardized despite there being multiple ways a participant could initially react.[15] The same two actors were present in every

[15] Since the pilot was conducted in a different location than the study and the scenario was refined after the pilot, participants from the pilot were not included in the study sample.

scenario. They followed a script that was flexible enough to ensure they could adapt to whatever decisions a participant made.

The scenario occurred in a building that had been designed to appear as an apartment complex in a rural setting. The facilitator told the participant to communicate with them through their radio and respond to the call as they would in real-life. All participants were then dispatched to a second-floor apartment for a call from a female complainant indicating that her son (the subject) had been drinking heavily and was in breach of his probation conditions. The son refused to turn down the stereo and dispatch had difficulty hearing the complainant over the music. Information about the location and residence were provided to the participant. The nature of the call made it appropriate for a single officer to respond. At that point, the facilitator said, “scenario on” and, if they chose to do so, participants had the opportunity to ask dispatch for additional information. Given the rural environment, if backup was requested, the participant was advised that their only backup was currently on another call and unavailable. Responses for questions to dispatch were scripted for the facilitators to ensure consistency.

During the approach to the second-floor apartment, the participants walked up 14 steps. Upon arriving “on scene” and knocking on the door of the residence, the participant was greeted by a white male (the bystander), who was the boyfriend of the subject (also white) and the actual son of the female (mother) complainant. The music from a radio remained at a high volume. The disgruntled bystander agitatedly explained that the subject assaulted his mother (who had now left the residence) and wanted the subject removed from the residence. This changed the scenario from a breach of probation conditions to a domestic assault, providing the participant necessary grounds for arrest. Upon entering the apartment, there was a living/dining room (with a couch, coffee table, television, dining table, and other miscellaneous items) and a separate bedroom (complete with a bed, wardrobe, and clothes). There were several weapons (i.e., baseball bat, axe, sledgehammer, crowbar, machete) in plain sight throughout the apartment and a scent training system (AirAware®) released a marijuana-like smell.

The bystander immediately sat on a chair, offset between the entry and subject. The bystander refused to comply with any demands from the participant and continued to demand the participant to remove the subject, who was seated at the dining room table at the other end of the room. A partially obscured knife, within arms reach of the subject, was present on the dining room table among several empty bottles of alcohol. The confrontational subject remained seated at the table and refused to comply with directions from the participant. The subject eventually drew a knife and put it to his throat threatening to die by suicide. This provided the officers with the opportunity to attempt to de-escalate the situation and/or use intervention options. Any less-lethal intervention employed by the participant were feigned as being ineffective by the subject (e.g., swiping away conducted energy weapon probes, wiping away OC spray).

After some time passed, regardless of how much the officer attempted to verbally de-escalate or intervene, the subject complied and threw the knife on the ground towards the participant. The scenario was allowed to naturally unfold a little longer until the subject spontaneously pulled a firearm, stood up, and started to shoot at the participant, activating the StressVest™ response (i.e., a localized shock to the abdomen).[16] This resulted in a lethal force response from the participant. Once shot at by the participant, the subject feigned a gunshot wound to the chest while the bystander contemporaneously produced and pointed a cellphone, verbally indicating that they were video recording the situation. From that point forward, the subject and the bystander were both compliant and followed any subsequent commands from the participant.

Participants were then provided the opportunity to prioritize and perform whatever actions they deemed necessary (e.g., request resources, secure weapons, physically restrain subject and/or bystander, search subject, administer first aid). To indicate some imminent action was required from the participant, both the subject and bystander referenced the subject's deteriorating condition from the gunshot wound and, if requested, dispatch relayed that back-up and EMS were 20 minutes away. The scenario was allowed to come to a natural conclusion and was ended by the facilitator when the participant failed to demonstrate any new actions or strategies. The scenario did not result in a fatal outcome. After the scenario, the scenario room was re-adjusted so that it appeared the same for each new participant.

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[16] If the participant maintained a position of concealment (i.e., doorway at back for room) during the scenario, the bystander would walk over to the subject, who would then start choking the bystander. This behaviour would force the officer to move from their position of cover at which point, the subject would draw and shoot at the participant.

Appendix C **Cardiovascular Reactivity Technical Specification**

While there are strengths and limitations for all tools that measure stress reactivity (e.g., logistics and invasiveness of biological samples, time of day confounds with salivary cortisol), theoretical knowledge and empirical research support the use of heart rate variability (HRV) as one of the most precise non-invasive measure of psychological and physiological arousal (Appelhans & Luecken, 2006; Berntson & Cacioppo, 2004; Thayer et al., 2012). For example, a meta-analysis conducted by Thayer and colleagues (2012) found HRV to be associated with neural activation of areas involved in threat perception (i.e., the amygdala and medial prefrontal cortex). Stress reactivity is associated with an increase in sympathetic activation and suppression of parasympathetic activity (Berntson & Cacioppo, 2004; Castaldo et al., 2015; Malik et al., 1996). HRV captures the interplay between these two antagonistic systems (Appelhans & Luecken, 2006), and is regularly used as an objective physiological stress index (e.g., Giessing et al., 2019; Haller et al., 2014; James et al., 2020).

Heart rate (HR) and HRV were captured using monitoring devices. For logistical reasons, cardiovascular stress reactivity measures at rest in this study were based on the lowest one-minute HR, while sitting and completing pre-scenario paperwork for the study. Similar methods for determining cardiovascular reactivity at rest have been used in previous research (Andersen & Gustafsberg, 2016; Anderson et al., 2002; Baldwin et al., 2019). For comparative purposes, true resting cardiovascular reactivity during sleep was collected for a quarter of the sample (n = 29). HR_{mean} (bpm) and HR_{max} (bpm) represent the average and highest HR during each phase of the scenario, respectively.

Unlike analysis of absolute HR, HRV analysis is generally interested in how intervals change from beat to beat and by how much (Fenici et al., 2011; Tarvainen et al., 2016). The R wave is the most prominent and easily detectable peak in the cardiac rhythm and as a result, is typically used to calculate the inter-beat-interval or "R-R interval" (Tarvainen et al., 2016). From R-R intervals, various time-domain measures can then be calculated that summarize a series of successive R-R interval values and thus the variability in HR (Tarvainen et al., 2016).

To examine HR and HRV, data were entered into ©Kubios HRV Premium Version 3.3.1. (Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland), which is research software for the analysis of HRV. Samples were created for each phase of the scenario (e.g., dispatch, critical). Pre-processing of data in ©Kubios included automatic detection and correction of artifacts with interpolated beats (Lipponen & Tarvainen, 2019). Tarvainen and colleagues (2020) suggests correcting no more than 5% of beats to maintain data accuracy (e.g., avoid distortions), thus any HRV measure within a phase of the scenario that exceeded this threshold was removed. A detrending method (i.e., smoothness priors method) was used to remove very low frequency trend components for short-term HRV analysis (Tarvainen et al., 2020). The correlation between gold-standard five-minute recording length and the very-short-term intervals (i.e., 30s) used in this study has recently been reported and shown promise for police research, particularly during realistic police training (Brisinda, Venuti, et al., 2015; Munoz et al., 2015; Smith et al., 2013).

Reflective of factors indicative of PNS and SNS activity outlined in the literature (Berntson et al., 1997; Malik et al., 1996; Rajendra et al., 2006), the PNS Index and SNS

Index, computed in Kubios HRV software, were used in this study. These or similar indices have been used in other research with samples of civilians (Ayuso-Moreno et al., 2020; Lundell et al., 2021), police (James et al., 2020) and special forces (Giuseppe et al., 2021). The PNS Index uses mean R-R intervals, root mean square of successive differences between normal heartbeats (RMSSD), and normalized Poincaré plot index SD1, which is associated to RMSSD (Kubios Oy, 2021). Importantly, RMSSD reflects cardiac vagal tone, the contribution of the PNS to cardiac regulation, which is relatively free of respiratory influences (Laborde et al., 2017). Poincaré plots are also viewed as indicators of vagal activity and reduced cardiac vagal control, which are associated with both physiological and psychological strain and stress (Laborde et al., 2017). A PNS index value of zero indicates that the three parameters reflecting PNS activity are on average equal to the normal population average, while a positive or negative PNS index value indicates the number of SDs above or below the normal population average (Kubios Oy, 2021). During stress, much lower PNS index values can be expected.

The SNS index is computed using mean HR interval, normalized Poincaré plot index SD2, which is associated with standard deviation of normal to normal (R-R) intervals (SDNN), and the Baevsky Index of Regulatory System Tension or Stress Index (Kubios Oy, 2021). The Baevsky Stress Index is a geometric measure of HRV reflecting cardiovascular system stress (Baevsky, 2009). It is calculated based on a histogram distribution of R-R intervals (bin width 50 msec), using the following formula:

$$SI = \frac{\text{Amo x 100\%}}{\text{2Mo x MxDMn}}$$

Mo (mode) is the most frequently occurring R-R interval. The mode amplitude (AMo) is the count of the mode, presented as a percentage. MxDMn is the difference between minimum and maximum R-R intervals represents the amount of variation. Under psychological or physical stress the distribution of the histogram constricts, while simultaneously increasing in height (Korotkov, 2017). Therefore, high Stress Index values indicate reduced variability and increased SNS activation (Kubios Oy, 2021). The SNS index is interpreted similar to the PNS index, with values ranging as high as 5-35 during stress or high intensity exercise (Kubios Oy, 2021).

Appendix D **Self-Reported Perceptual and Cognitive Distortions Questionnaire**

During the scenario, I experienced:	Not at all	Very little	Somewhat	To a great extent
diminished sound (i.e., inability to hear very loud sounds I would ordinarily obviously hear, such as gunshots, shouting, etc)				
intensified sounds				
heightened visual clarity				
tunnel vision (i.e., loss or narrowing of peripheral vision)				
automatic pilot (i.e., I responded with little or no conscious thought)				
slow motion time (i.e., time slowed down)				
fast motion time (i.e., time sped up)				
temporary paralysis (i.e., froze)				
dissociation (i.e., a sense of detachment or unreality)				
intrusive distracting thoughts (i.e., thoughts not immediately relevant to the tactical situation, often including thoughts about loved ones or other personal matters)				
Post-scenario, I experienced:	Not at all	Very little	Somewhat	To a great extent
memory loss for part of the event				
memory loss for some of my own behavior				
memory distortions (i.e., I saw, heard, or experienced something that didn't really happen or happened very differently)				
"flashbulb" memories, where I have a series of vivid images burned into memory, with the rest of the event somewhat fuzzy or missing.				

(Adapted from Artwohl, 2008)

Appendix E **Agency Training and Assessment of Level of Training**

Prior to becoming an operational police officer with the agency, all recruits must attend an extensive 26-week basic training program where they receive foundational skills. This includes approximately 3 ½ weeks of UoF training, involving 64 hours of firearms safety, law and policy, marksmanship, and decision-making, as well as 75 hours on police defensive tactics, including skills acquisition, principles of UoF,[17] and SBT. Additionally, de-escalation skills (e.g., verbal and non-verbal communication) are taught throughout training and are then applied during a full day of scenarios in which the clients are in various states of emotional distress. This is followed by 26-weeks of on-the-job learning under the supervision of a field training officer. Once in the field, officers complete an average of approximately 40 hours of training per year.[18]

Officers' training records and the training information captured in the demographics form were used to identify and assess their level of in-service training. To assess the level of training for non-elite and advanced participants, the sum of the

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[17] In Canada, guiding principles for the use of force also come from the national use of force framework or related models (Canadian Association of Chiefs of Police, 2000). These models are visual aids that were developed for training purposes, to assist officers in making appropriate decisions during interactions with the public, and help officers to better articulate their actions after-the-fact (Hoffman et al., 2004). The model and supporting training focus on the totality of the circumstances that should enter into an officer's continuous risk assessment (i.e., officer perceptions, situational factors, tactical consideration and the subject's behavior). The totality of these factors assists officers in determining which intervention option (e.g., communication, intermediate weapon, lethal force) is most appropriate to control the situation. Within the organizational context, the model is fundamental for assessing use of force performance in operational and training settings.

[18] Recall that in the US, the average length of police academy training is approximately 21 weeks (i.e., 840 hours), of which around 171 hours (20%) are dedicated to the use of force (Reaves, 2016). This is typically followed by 13 weeks (i.e., 520 hours) of on-the-job learning under the supervision of a field training officer (Reaves, 2016). Once on active duty, officers receive on average less than one week (i.e., 35 hours) of training per year (Reaves, 2010).

following 12 equally weighted operational skills courses was calculated: (1) crisis intervention and de-escalation, (2) first aid and/or CPR instructor, (3) basic trauma equipment instructor, (4) conducted energy weapon, (5) extended range impact weapon, (6) VIP close protection, (7) tactical support group (i.e., crowd control), (8-9) advanced firearms, and (10-12), active threat training (three separate courses).

To account for the recency and frequency of training experience, courses were only included if they were completed within the last 5 years and/or were completed more than once; with the exception of (2) and (3), which were based on whether participants were ever instructors. Years of police service was also assessed to account for annual firearm qualifications and triennial operational skills maintenance training (i.e., OC spray, baton, carotid control, first aid, CPR and SBT).

Appendix F **Deadly Force Judgment and Decision-Making (DFJDM), Tactical Social Interaction (TSI), and Crisis Intervention Team (CIT; adapted from Vila et al., 2018)**

1. Pre-Planning…seeking accurate information about the situation before arrival (weight: 4)
2. Pre-Planning…seeking accurate information about the person in crisis before arrival (weight: 4)
3. Assess…recognizing weapons of opportunity in the environment (e.g. machete, baseball bat, sledgehammer, axe, or recognizes knife before drawn) (weight: 4)
4. Assess…observing details of the environment before the encounter starts (e.g. note exit strategy, good scan of back room) (weight: 4)
5. Tactics…removing non-involved participants from the encounter (e.g. bystanders, family members) (weight: 4)
6. Officer Behavior...Asking questions that are relevant to the mission... (e.g. for breach, assault, location of victim) (weight: 6)
7. Observe and Assess…the officer is able to identify the suspect's mental or physical health (e.g., understands threat to self-harm) (weight: 3)
8. Interacting with the Person in Crisis/Officer Behavior…being able to actively listen to the person in crisis during the encounter (e.g., paraphrasing, nonverbal cues which show understanding, verbal affirmations) (weight: 4)
9. Interacting with the Person in Crisis/Officer Behavior…being able to show empathy to the person in crisis (e.g., being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience) (weight: 4)
10. Interacting with the Person in Crisis/Officer Behavior…having the ability to de-escalate a situation (calm the person in crisis down) (weight: 4)
11. Officer Behavior - Offering to help the civilian…(e.g., I want to help, I'm here to help) (weight: 6)
12. Interacting with the Person in Crisis/Officer Behavior…demonstrating concern for the person in crisis's safety (weight: 4)
13. Interacting with the Person in Crisis/Officer Behavior…demonstrating patience with the person in crisis (weight: 4)
14. Officer Behavior…the officer makes timely decisions regarding pre-assault indicators (e.g., immediately drawing firearm when knife is pulled) (weight: 5)
15. Observe and Assess…the officer selects reasonable force options (weight: 5)
16. Adapt…the officer recognized the need to transition to other force options (N/A if there was no need to transition - e.g., firearm) (weight: 5)
17. Tactics…being proficient with standard equipment (weight: 4)
18. Officer Behavior…the officer applies deadly force rules of engagement (laws and policies) in a combat situation (weight: 4)
19. Training and Wellness…the officer can shoot proficiently under combat conditions (weight: 5)
20. Training and Wellness…the officer can tactically load and reload weapons under combat conditions (N/A if not applicable) (weight: 5)

21. Training and Wellness…whether the officer can effectively clear malfunctions under combat conditions (N/A if not applicable) (weight: 4)
22. Self-Control/Officer Characteristics…practicing self-control techniques during the encounter (e.g. deep breathing) (weight: 4)
23. Tactics…the officer manages their perceptual narrowing during a deadly encounter (e.g., stuck in loop, stunned, inappropriate behaviour) (weight: 4)
24. Adapt/Repair - Recognizing when their actions are not appropriate and modifying them...(N/A if not applicable) (weight: 7)
25. Tactics…being proficient with control techniques (e.g., tactical disadvantage and handcuffing techniques) (weight: 3)
26. Officer Behavior - Taking action to improve civilian's conditions…(e.g., providing medical attention) (weight: 6)
27. Tactics…calling for back-up when appropriate (e.g., when knife is pulled and shots are fired) (weight: 4)
28. Officer Behavior…the officer is able to communicate key information to [dispatch] (weight: 4)
29. Observe and Assess…when possible, the officer assesses the situation fully before acting (weight: 5)
30. Observe and Assess…the officer overestimates their ability to read a situation (weight: -5)
31. Officer Behavior…the officer used an appropriate level of aggressiveness (weight: 4)
32. Officer Behavior…the officer used an appropriate level of assertiveness (weight: 4)
33. Officer Behavior…the officer maintains control of the encounter until it is resolved (weight: 5)
34. Tactics…the officer gives relevant and meaningful commands (weight: 5)
35. Tactics…the officer knows their position relative to bystanders (e.g., maintains subject in periphery, does not turn back for extended period when in close proximity) (weight: 3)
36. Tactics…the officer makes full use of available cover and concealment (weight: 5)
37. Tactics…the officer makes partial use of available cover and concealment (weight: 2)
38. Tactics…the officer optimizes the distance between him or herself and the identified threat (e.g., back of room, doorway) (weight: 4)
39. Officer Behavior - Maintaining a position of tactical advantage... (weight: 7)

Appendix G **Agency Performance Metrics (adapted)**

Professionalism, law, & policy (3 measures)

- Advises subject of arrest unless situational factors dictate otherwise.
- Makes timely decisions in accordance with the law and policy.
- Interaction is respectful and appropriate.

Skills & techniques (5 measures)

- Precise demonstration of techniques and skills.
- Fluid and subconscious movement.
- Controls the subject effectively.
- Manipulates intervention option(s) effectively.
- Transitions smoothly to other techniques and/or intervention option(s).

Tactics and officer safety (28 measures)

- Uses new strategies.
- Recognizes subtleties in threat cues, environment and body language and responds appropriately.
- Demonstrates fast and fluid actions.
- Adapts to transitions in behaviour rapidly.
- Voices commands precisely and directly.
- Advises subject what they want them to do (versus not do).
- Applies the appropriate tactical considerations in response to the applicable threat cue(s) in a timely manner.
    - Cover & concealment
    - Threat cues
    - Time & distance
    - 1+1 principle
    - Verbalization
    - De-escalation
    - Survival mentality
    - Maintains control of the situation
- Applies the 4 Cs:
    - Check your environment
    - Condition (self)
    - Condition (subject)
    - Communication
    - Combat breathing
- Applies DARCS
    - Double-lock
    - Reason for arrest
    - Charter rights (i.e., right to retain and instruct a lawyer without delay)
    - Caution (i.e., not obliged to say anything, but anything you do say, can be given in evidence)
    - Search
- Applies ALPS for search
    - Ask

    - Look
    - Pat
    - Squeeze

Medical response (8 measures)

- Simulated or verbalized basic first aid (e.g., wound pressure)
- Assessed for penetrating chest injury by exposing wound and/or conducting a closed claw rake of the chest/abdominal injury site(s)
- Immediately occluded/covered the penetrating open chest wound (e.g., with hand)
- Thoroughly raked (close claw technique) all sides of the chest (front and back) to assess for additional injury sites (i.e., exit wounds)
- Simulated or verbalized application of a chest seal (vented chest seal preferred)
- Placed casualty in the recovery position (injured side down for unconscious casualty) or a position of comfort (conscious casualty)
- Assessed airway, and quality of breathing frequently
- Verbalized the need to transport the casualty to EMS ASAP via radio communication

Appendix H **Scenario Training Assessment and Review (STAR) Scale (adapted from Wollert et al., 2011)**

For the current study, categories and descriptors were slightly adapted to reflect Canadian law, as well as agency terminology, training, policy, procedures, and the national use of force framework. Additionally, articulation/after action review performance was not assessed as part of this study and was instead replaced with a medical attention performance category.

1. **Situational awareness:** Awareness of surroundings, threats, risks and understanding of how information, events, and actions will impact goals and objectives, both now and in the near future.
2. **Threat/risk assessment and identification:** Threats, non-threats and risks are accounted for, properly prioritized, effectively communicated, and appropriate response is efficiently planned.
3. **Initial response:** Strategy to properly respond to threats, risks and situation including position of advantage, tactics, or other corrective actions.
4. **Scene control after the initial response:** Strategy to maintain control of the situation including evidence, crime scene, threats, victims, and witnesses.
5. **Use of force:** Application of appropriate/timely force options consistent with Charter of Rights, Criminal Code and case law.
6. **Arrest procedures:** Initiation of correct procedures during an arrest including position of disadvantage, handcuffing, rights, caution and search.
7. **Communication:** Information exchange between entities through correct/timely verbal commands, non-verbal behaviors, and de-escalation.
8. **Medical:** Application of skills necessary to help sustain life and minimize the consequences of injury until advanced medical help is available (e.g., Desirable = Tactical first aid and trauma equipment; Acceptable = Basic First Aid; Least desirable = wound pressure only; Not acceptable = no medical attention).

Rating & description:

0. Not acceptable: Critical errors. Performance is not consistent with legal standard, creates serious risk, or did not perform.
1. Least desirable: Non-critical errors. Performance is generally acceptable but creates identifiable risk.
2. Acceptable: Working level. Performance is consistent with training but not the most effective method (e.g., action, tactic).

3. Desirable: Demonstrates sound and effective performance.

Not applicable: Does not apply or is not observable.

Appendix I **Performance by Level of Training**

Level of Training	Overall performance rating		DFJDM, TSI, and CIT metric		Agency performance metric		STAR scale	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Elite (level 2)	73.57	9.92	77.72	15.42	74.84	7.37	68.15	13.44
Elite (level 1)	69.84	10.90	76.53	15.17	68.40	9.11	64.58	15.81
Advanced	59.47	8.32	63.39	13.60	65.72	7.38	49.31	15.87
Intermediate (level 3)	56.18	14.29	61.93	20.02	61.18	9.99	45.42	19.19
Intermediate (level 2)	55.60	10.89	64.09	17.01	58.87	8.79	43.83	12.74
Intermediate (level 1)	57.89	11.17	66.56	14.00	58.56	11.24	48.54	16.57
Novice/basic (level 2)	50.76	17.15	56.07	20.40	53.31	13.72	42.89	20.40
Novice/basic (level 1)	50.24	11.92	55.64	12.59	56.82	10.78	38.28	19.79
Total	59.31	13.96	65.77	17.53	61.86	11.73	50.29	18.60

Note. $N = 122$

Appendix J **Type of Lethal Force Error by Level of Training**

	Type of lethal force error							
	None		Decision-making error		Mistake of fact error		Both	
Level of Training	*n*	%	*n*	%	*n*	%	*n*	%
Elite (level 2)	12	85.7%	1	7.1%	1	7.1%	0	0.0%
Elite (level 1)	10	62.5%	1	6.3%	4	25.0%	1	6.3%
Advanced	5	41.7%	3	25.0%	2	16.7%	2	16.7%
Intermediate (level 3)	5	50.0%	1	10.0%	3	30.0%	1	10.0%
Intermediate (level 2)	18	72.0%	2	8.0%	5	20.0%	0	0.0%
Intermediate (level 1)	18	90.0%	0	0.0%	2	10.0%	0	0.0%
Novice/basic (level 2)	13	76.5%	0	0.0%	3	17.6%	1	5.9%
Novice/basic (level 1)	7	87.5%	1	12.5%	0	0.0%	0	0.0%
Total	88	72.1%	9	7.4%	20	16.4%	5	4.1%

Note. $N = 122$

Appendix K **Case Study Included in Agency's Annual Mandatory Training**

The following case study (see Figure K1), which was included in the training, provides an example of a post-incident maladaptive response that our bodies can experience when faced with psychological stressors. During this particular call, the officer was conducting patrols for a suicidal 16-year-old girl who was withdrawing from heroin and had said she was going to "jump off the bridge". She was last seen walking towards the river. During patrols, the officer located the subject at an intersection. The officer pulled into the convenience store parking lot at the corner of the intersection, exited his police vehicle and called out to the subject to get her attention. The subject turned to look at the officer and took several steps towards him, walking into traffic. She was struck by a vehicle, rolled onto the hood of the vehicle and hit the windshield. The officer ran over and immediately started providing her medical attention, holding her head to stabilize her neck and spine.

In Figure K1, you can observe that the officer's heart rate quickly spiked up to 177 beats per minute when running over to the subject. Once the officer got over to the subject, it took over a minute for his heart rate to begin to decrease from that level. Given the physical movement, it was difficult to determine to what extent the increase and sustained heart rate was due to physical versus psychological stress, but regardless, a fight-or-flight response in this context would have been an adaptive response. The subject was conscious, but complained of pain in her legs and arm. Luckily, there was an off-duty nurse on the scene that helped provide treatment. She was then transported to hospital by emergency medical services. Backup arrived approximately four minutes after the accident and then the supervisor arrived nearly four minutes after that. In Figure

K1, you can then see the officer's heart rate spiked back up to 169 beats per minute and then stay at an elevated rate for approximately 25 minutes.

Figure K1

Example of a Maladaptive Stress Response to a Psychological Stressor

In speaking with the officer after his shift, he indicated that after his supervisor arrived on scene, he was asked to go sit in his police vehicle and wait, because the independent civilian oversight body was likely going to need to investigate due to the circumstances. At this point, the officer was still unaware of the extent of the girl's injuries. This post-incident increase demonstrates a more maladaptive response that our bodies can have to psychological stressors. Maladaptive, in that the fight-or-flight response at this point, while sitting in the police vehicle, likely ruminating over the unfortunate circumstances in his head, served no functional purpose and can have detrimental effects (i.e., “wear and tear”) on the body. Thankfully in this situation, the girl only suffered a fractured arm and the external oversight body did not assert jurisdiction. However, despite the significant stress this incident took on the officer, he went back in-service an hour and a half after this incident and on to the next call for service.

Appendix L **Force Science News - Study Tracks Officers' Response to Stress During Calls for Service**

New Study Tracks Officers' Response to Stress During Calls for Service

forcescience.org/2019/11/new-study-tracks-officers-response-to-stress-during-calls-for-service

By Von Kliem, JD, LL.M November 7, 2019

It is widely understood that the body can automatically prepare us to respond to threats. Not just actual threats, but those that are perceived or merely expected. Ideally, when this process is engaged, the nervous system is activated and we benefit from heightened senses, faster decision-making, improved mental function, and increased strength.

But when this acute stress response is "maladaptive" or prolonged, our health can suffer over the long term. And in the short term, under extreme stress—attention, perception, decision-making, and even physical performance can be severely impaired.

For those committed to public safety, learning to recognize, manage, and operate under extreme stress is critical. For the police, that process begins by understanding when and how they experience stress.

In a recent study, Simon Baldwin (PhD Candidate and Force Science Advanced Specialist) and a team of researchers from Carleton University's Police Research Lab (Ontario, Canada), provided valuable insight into these important questions. Specifically, researchers studied how frequently police officers experienced "physiological stress responses" during a shift, whether those responses changed during the distinct phases of a call, and whether the priority of a call or other factors (e.g. arrest, use of force) affected physiological arousal.

Intuitively, readers might expect that an officer's experience and training would improve their response to stress. Researchers examined these factors as well—with important findings.

The Study

Using an officer's heart rate as a measure of stress response, researchers attached pulse monitors with GPS capability to track 64 officers over various shifts. To help distinguish between heart rate resulting from physical exertion and heart rate resulting from psychological stress, the researchers attached foot-mounted "stride sensors" to the officers. When combined with the GPS, these stride sensors provided researchers with important speed measurements.

After collecting data from 754 calls for service, the researchers examined the participants' heart rates throughout the phases of the calls (dispatch, travel, arrival, and encounter). Additionally, the calls were categorized and analyzed by priority level (routine, urgent, very urgent), type (e.g. shots fired, assault in progress, suicidal person, etc.), and incident factors (e.g. arrest, use of force, weapon presence).

Finally, the relevant training and experience of the officers was considered for any impact on the physiological stress response (as measured by heart rate variability).

Notable Results

The researchers noted significant heart rate reactions during the calls for service. More significant reactions corresponded to the higher priority calls—with increased arousal noted as the officers moved through the phases of the call; beginning with the dispatch, continuing through travel, and peaking at the encounter.

Readers who remember their first months of police work, may not be surprised by the finding that dispatch alone caused an increase in heart rate. Training officers may recall recruits who experienced emotional responses triggered upon hearing the description or type of call. These reactions were likely noted well-before officers arrived at the scene where they could assess actual threats.

As might be expected, the study also found that the presence of weapons, carrying out of arrests, and drawing firearms also resulted in notable heart rate increases. Researchers were able to collect vital data and graphically display the effect of these factors during real-world interactions—including a call for service, during which an officer drew his rifle and ultimately deployed his taser on an armed subject.

Finally, researchers looked at the impact of training and experience on the stress responses identified in this study. They found that the officers' demographic (e.g. age, sex, etc.), experience, and operational skills training *did not* significantly impact (or mitigate) stress induced heart rates.

Dr. Bill Lewinski, executive director of the Force Science Institute, had this to say: "Simon's observation that physiological responses were triggered across the range of experience was consistent with what we've seen in other research. For example, in sports, we've seen that pre-event arousal is impacted by the meaning that is assigned to the event. Both novice and elite athletes can experience pre-competition anxiety when they view the outcome as important. That said, we've seen world-class performance from athletes and law enforcement officers operating with extremely high heart rates. There continues to be mounting evidence that the ability to recognize, manage, and confidently perform under the effects of physiological arousal remains a key to optimum performance."

The Carleton University researchers also recognized previous studies in which officers' experience and training were shown to improve decision-making processes, attention, control, shot accuracy, and cue recognition[1]. Given these findings, the researchers encouraged further examination into the interaction between stress, training, and performance.

A Recommended Read

Simon Baldwin is among the growing ranks of Force Science Advanced Specialists at the intersection of science and police practice. With this latest study, his team of researchers have provided important insights for officers training and preparing for exceptional performance and increased resilience during high-stress encounters.

> ***"While most are familiar with the concept of 'fight-or-flight,' this research aims to provide officers with a better understanding of what this threat response actually looks like, factors that impact it, and how frequently it occurs in the general duty policing context. Our hope is the research will improve self-awareness and promote the importance of evidence-based training methods that develop stress resilient skills."***
>
> ***Simon Baldwin***

The full report of this latest research is titled ***Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters***[2] and can be accessed for free. It not only advances the study of officer resiliency but provides an excellent primer on the terminology and processes involved in physiological stress response. Readers are encouraged to consider the full report.

Questions, comments, and recommendations for further research in this area can be sent to Simon Baldwin.

1. Vickers, J. N., and Lewinski, W. J. (2012). Performing under pressure: Gaze control, decision making and shooting performance of elite and rookie police officers. Hum. Mov. Sci. 31:16. doi: 10.1016/j.humov.2011.04.004 []
2. Baldwin S, Bennell C, Andersen JP, Semple T and Jenkins B (2019) Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters. Front. Psychol. 10:2216. doi: 10.3389/fpsyg.2019.02216 []

3 Responses

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