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## Officers' memory and stress in virtual lethal force scenarios: Implications for policy and training

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### ABSTRACT

Sworn law enforcement officers ( $N = 151$ ) were exposed to two different simulated lethal force encounters, a motorcycle-traffic-stop (MTS) and a workplace violence incident. Workplace violence incidents (WPV) consisted of two versions: an original version (WVO) and an enhanced version (WVE) with additional tactile and auditory stimuli within the simulation environment. Officers' recognition memory (immediate and 48 h later), perceived stress, and physiological stress responses were examined. Delayed reporting led to impaired memory for event information in the MTS and perpetrator information in the WVE simulation. Moreover, perpetrator information was remembered more accurately than event information. Two physiological stress markers – alpha amylase and immunoglobulin-a – were correlated with memory for the simulated experiences; however, cortisol and interleukin-6 were not. These findings support current theory related to arousal and memory suggesting that officers should be interviewed as soon as reasonably possible after a lethal force incident. Implications for legal parameters in defining a 'reasonable officer' exerting lethal force are considered.

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Lethal force; stress response; physiological arousal; memory; virtual simulation; officer-involved-shooting policy

The public's perception of police lethal-force encounters is complicated by race, political orientation (e.g. Balz & Clement, 2015; McElvain & Kposowa, 2008) and legal conceptualizations of what it means to be a 'reasonable officer' justifiably exerting lethal force (i.e. Engel & Smith, 2009; *Graham v. Connor*, 1989; Klinger & Brunson, 2009; *Tennessee v. Garner*, 1985). The public's views of police and use of lethal force are often driven by specific cases in the news. A prime example is the August 2014 shooting death of Michael Brown in the United States (U.S.) in which a Missouri grand jury did not indict Officer Darren Wilson suggesting that Wilson's response was commensurate with a reasonable officer (U.S. Department of Justice, 2015). Cases like these often depend upon an officer's memory of the circumstances leading to the fatal encounter to determine whether an officer's behavior was in fact reasonable. Given the nature of the lethal-force-encounter and current recommendations (e.g. President Obama's Task Force on 21<sup>st</sup> Century Policing, 2015) for evidence-based policies and procedures, a closer examination of the effects of stress and arousal on officers' memory for lethal

force encounters is crucial to determine the likely accuracy of memory, which is central when triers of fact must determine the reasonableness of an officer's actions.

In this research, we examine the extent to which a police officer's stress response in a simulated lethal force encounter and delay between the simulated event and an officer's report affects the accuracy of memory for that event. Specifically, we consider two scenarios, a motorcycle traffic-stop in which a single motorist pulls a weapon on the officer, and a workplace shooting event involving a single gunman and multiple, virtual bystanders. In the traffic-stop, the officer in the simulation is the direct target of gunfire. In the workplace shooting event, the officer in the simulation hears gunfire and must enter the office building in search of the gunman and distinguish between the gunman and bystanders. The study aims to contribute to the growing literature related to officer performance under lethal force (e.g. Hartman, O'Neill, O'Neill, & Lewinski, 2017; Hope et al., 2016) and high-arousal (e.g. Hine, Porter, Westera, Alpert, & Allen, 2018; Hope, Lewinski, Dixon, Blocksidge, & Gabbert, 2012) circumstances. Examining delayed reporting for officers involved in a lethal force encounter has become particularly important as policy (International Association of Chiefs of Police [IACP], 2013) suggests that officer memory will benefit if provided an opportunity to decompress from the experience. Specifically, the policy indicates:

5.2. While officers may be asked to provide pertinent information soon after a shooting to aid the initial investigative process, whenever feasible, officers should have some recovery time before providing a full formal statement. Depending on the nature of the incident, the demands on the agency, and the emotional and physical status of the officers, this can range from a few hours to several days. An officer's memory will often benefit from at least one sleep cycle prior to being interviewed leading to more coherent and accurate statements. Providing a secure setting, insulated from the press and curious coworkers, is important during the interview process. (IACP, 2013)

Is it wise to wait several days before questioning an officer about a past event? Recent critical reviews of the policy (Grady, Butler, & Loftus, 2016; McClure, McGuire, & Chapan, 2019) suggest the fundamental premise – that officer memory benefits from one sleep cycle prior to a formal interview – has never been fully and credibly examined. Moreover, 'benefit' has often been interpreted to mean 'improved accuracy' (e.g. Porter, Ready, & Alpert, 2019) and the basic notion that delay improves memory is contrary to a large cognitive literature indicating that delay is detrimental to memory accuracy (See Grady et al., 2016 for review). Proponents of the policy suggest that a delay allows for memory consolidation through sleep and enables officers to address emotional and physiological responses to the experience; however, this assumption is largely based in the learning and memory literature where methods involve learning lists of words to a criterion, sleeping, and then returning to a laboratory for a final test of the learned list of words (See McClure et al., 2019 for a review). Such methodology is clearly different from a lethal force encounter.

To date, two studies consider memory in relation to the sleep consolidation hypothesis imbedded in this policy. One study on sleep consolidation and eyewitness memory had college students view a 13 sec video-taped event in which a perpetrator planted a bomb on a rooftop (Stepan, Dehnke, & Fenn, 2017). Sleep did not improve identification accuracy for a perpetrator-present lineup (Experiment 1). It did result in more correct rejections; no identification was made, for the perpetrator-absent lineup (Experiment 2). Specific to officer memory of lethal force encounters, a different study assessed officers'

memory for a live active armed offender training scenario and found that officers interviewed immediately after the experience had more accurate memory for non-threat information than those interviewed after a 2-day delay. Notably, threat-relevant information (e.g. identification of the perpetrator) was remembered comparably whether given an immediate, or delayed interview. Overall, delay did not improve memory for the active armed offender scenario (Porter et al., 2019).

The current study considers a delay in memory reporting for a simulated lethal force event to allow officers to sleep, and extends the previous research to examine the relation between physiological stress indices and memory to more closely examine the stress-memory relationship embedded in the IACP (2013) policy. Employing two types of scenarios also examines Kemeny's (2003) integrated specificity model of stress as a framework and extends the literature on eyewitness memory and arousal (See Christianson, 1992; Deffenbacher, 1994; Deffenbacher, Bornstein, Penrod, & McGorty, 2004 for review) to law enforcement officers. According to the integrated framework (e.g. Joëls & Baram, 2009; LeBlanc et al., 2011), stress is a dynamic interaction between situational and individual factors, which is also the premise in considering witness accuracy and arousal (e.g. Bothwell, Brigham, & Pigott, 1987; Fahsing, Ask, & Granhag, 2004; Valentine & Mesout, 2009). In addition to assessing issues of memory and arousal inherent in current lethal force policy, the current study employs virtual simulation (VS), which has several merits. VS approximates actual decision-making under realistic levels of arousal (i.e. stress), emotion, and physiological reactivity that occurs in use-of-force circumstances (e.g. Saus et al., 2006), and thus has better external validity. VS also maintains consistency throughout the simulation experience. That is, the actors within the VS never vary in their behaviors and speech, which is a potential in live simulations involving other officers in the role of perpetrators or witnesses. Research on the effects of stress and corresponding physiological arousal on memory is considered next.

### ***Arousal and memory***

Generally, the influence of stress on memory is dependent upon the circumstance (e.g. Fahsing et al., 2004), a person's appraisal of that circumstance in relation to physiological arousal (e.g. Valentine & Mesout, 2009), and personality factors extant to the individual within the circumstance (e.g. Christianson, 1992). Research investigating memory and arousal indicates that when arousal is too low or high, memory is impaired, while at moderate levels memory accuracy is facilitated (e.g. Andreano & Cahill, 2006); however, facilitation is often dependent upon individual differences in perceptions of 'moderate stress' (See Deffenbacher et al., 2004, for a meta-analysis of evidence related to stress and eyewitness memory; Sapolsky, 2004 for review of physiological effects of arousal). The complexity of the effects of arousal and stress on memory for law enforcement officers specifically, may gain some clarification within the context of adaptive memory (Howe & Otgaar, 2013). Adaptive memory is the notion that during arousal a 'survival processing' strategy is employed. Such a survival processing strategy recruits numerous memory processes including attention to distinctiveness (e.g. suspicious behavior), specific items (e.g. objects held in the hand), relational elements between the environment and items (e.g. call to a high-crime neighborhood), and self-referential aspects of a situation (e.g. familiarity of the officer to the neighborhood or suspect).

These specific processing strategies are likely to be automatically employed in survival processing and suggest that some aspects of a lethal force encounter are more likely to be remembered than elements within the encounter that have no adaptive, or survival value, to the moment. For example, Endsley's (1995) description of situational awareness – perceiving the environment, comprehending the meaning of environmental cues, and anticipating outcomes – implicitly employs adaptive memory processing. Howe and Otgaar (2013) suggest that adaptive processing is invariant. Adaptive memory processing has been evident in better memory for threatening stimuli for officers in hostile circumstances (Hartman et al., 2017; Porter et al., 2019) and has been found to facilitate false memories that are schema consistent with threat – report of a gun where none was present (Hope et al., 2016). Thus, adaptive memory may not lead to more accurate memories but may allow for predictions about what is likely to be recalled through adaptive memory processing. The subsequent discussion considers research on memory, defined by recognition or recall of information, specific for officers and lethal-force circumstances.

Research involving law enforcement officers and the influence of arousal on memory has produced mixed results. Table 1 depicts a synopsis of the research, simulation

**Table 1.** Summary of the relevant research findings related to police officer stress, simulation type, memory outcome and delay presented in chronological order.

Study	Role-play simulation	Stress induction	Memory outcome under stress
Yuille et al. (1994) <sup>a</sup>	Stop-and-Search	Non-Cooperative vs. Cooperative Witness	Incomplete, but more accurate than memory for the cooperative witness; 12-week delay led to poor memory compared to those who reported at 1-week and 12-week delays.
Stanny and Johnson (2000)	Domestic Disturbance; Attempted Abduction	Lethal Force Justified vs. Not Justified	Memory for the perpetrator was more poorly recalled when shooting was justified. Self-report and electrodermal response indicated more stress for officers compared to bystanders.
Beehr et al. (2004)	Prop-House Crime Scene with Mechanical Targets	Live Action vs. Video Review	Memory for people was better in the live simulation. Memory for objects was better in the video review.
Hulse and Memon (2006)	Domestic Dispute	Shooting vs. No-Shoot Scenarios	Memory was less complete, but more accurate particularly for the weapon in the shooting scenario. Self-report and increased heartrate were indicative of more stress in the shooting condition.
Hope et al. (2012)	Search of a Robbery Suspect's Trailer Home	High-Intensity Physical Assault on a Punching Bag vs. Controls	There were fewer correct details and identification of the suspect was poorer for those engaging in the high-intensity physical assault condition. There were no differences between groups related to memory for weapons in the trailer.
Hope et al. (2016)	Classroom Hostage Situation	Operational Officer vs. Bystander Officer	The bystander officers were generally more accurate compared to the operational officers who reported more incorrect details about the weapons and were more likely to report a false memory related to the weapon.
Porter et al. (2019) <sup>a</sup>	Victim and Perpetrator in an Abandoned Building	Not Manipulated	Officers interviewed immediately after the experience had more accurate memory compared to those interviewed after a 2-day delay. Threat-relevant information was remembered comparably whether given an immediate, or delayed interview.

<sup>a</sup>Denotes the two studies that considered delay in relation to officers' memory reports.

method, and findings related to stress and memory. Notably, only two studies manipulated delay in officers' memory reports (Porter et al., 2019; Yuille, Davies, Gibling, Marxsen, & Porter, 1994). In summarizing the research findings on officer memory in lethal force circumstances, officers tend to have more accurate, but incomplete memory reports (Beehr, Ivanitskaya, Glaser, Erofeev, & Canali, 2004; Hope et al., 2012; Hulse & Memon, 2006; Yuille et al., 1994). Self-report and physiological arousal as measured by electrodermal response (Stanny & Johnson, 2000) and increased heartrate (Hope et al., 2012; Hulse & Memon, 2006) reveals that police perceive live simulations as stressful. And delayed retrieval is detrimental to officers' memory reports for lethal force encounters (Porter et al., 2019; Yuille et al., 1994). Memory detriments in some instances were specific for the perpetrator when a shoot response was required (Experiment 1; Stanny & Johnson, 2000); however, officers have also recalled more details about the weapons in other circumstances (Hulse & Memon, 2006). Contemporary research using an immersive simulation experience involving live and video recorded elements helps to clarify the influence of arousal on officer memory of a lethal force encounter and is discussed next.

Hope and her colleagues recruited 76 officers to take part in an immersive, stressful simulation involving an armed perpetrator and hostages in a classroom situation (Hope et al., 2016). Officers completed the simulation in pairs. One officer was randomly assigned to be the operational (active) witness, and the other the non-operational (observer) witness. Officers viewed a 2 min 10 sec briefing video in which a perpetrator enters a classroom, argues with the professor, brandishes a knife and takes the professor and a student hostage. Using an augmented reality scenario, officers experienced a combination of pre-recorded and live elements depicted as current events ostensibly captured by closed-circuit television (CCTV). Operational officers were tasked with responding to the simulation based upon their training; non-operational officers were required to simply observe. Participants' physiological response was measured through heart-rate monitors and memory was assessed through free and cued recall about the event. Operational officers had higher maximum heartrates and lower heart-rate variability than non-operational officers. Officers' free-recall memory performance was mediated by role (active versus observer) and arousal, with the tendency for officers in the observer role to provide more accurate details. Closed-ended target questions were asked regarding the perpetrator's actions, officer's response, and weapon position. Differences were only found for weapon position; active officers provided more incorrect responses than observer witnesses. Of the 33 operational witnesses who discharged their firearm during the simulation, 18% of them reported that the perpetrator had drawn and pointed his weapon at them even though the gun remained in the perpetrator's waistband throughout the duration of the simulation. Finally, as previously discussed, Porter et al. (2019) considered officers' memory of an active armed offender training and found that officers remembered more threat than non-threat details regardless of whether the memory interview was immediately after the event or delayed. This suggests that threat items may be particularly salient and, as a result, better remembered.

In sum, four studies (Beehr et al., 2004; Hulse & Memon, 2006; Porter et al., 2019; Yuille et al., 1994) suggest a facilitative effect of arousal on memory and are congruent with an adaptive memory framework (Howe & Otgaar, 2013). In contrast, three studies (Hope et al., 2012; Hope et al., 2016; Stanny & Johnson, 2000) suggest that arousal is detrimental to memory, even facilitating false memories related to schematic expectations within the simulation (Hope et al.,

2016). Notably, the methods are similar to the extent that they all employ some form of simulation involving lethal force. Those that measured arousal (Hope et al., 2016; Hulse & Memon, 2006; Stanny & Johnson, 2000) found that simulations did indeed result in physiological arousal. A more nuanced examination considering physiological markers of arousal and adaptive memory accuracy (e.g. memory for a perpetrator versus memory for event details) is likely to clarify the effects of arousal in lethal force encounters on memory accuracy.

### ***Physiological correlates of arousal and memory***

In evaluating the effects of VS of a lethal force encounter in relation to physiological markers of stress, research has found elevated levels of stress hormones in officers' saliva (Groer et al., 2010). Cortisol levels, as one index for hypothalamic-pituitary-adrenocortical activity, the biological hallmark for stress, was elevated. They also found that interleukin-6, salivary immunoglobulin A, and alpha amylase were elevated. These are important markers for sympathetic nervous system response and as indices for stress induced immune system suppression. These markers may also be related to memory for threat-relevant retrieval as they likely trigger adaptive memory processing. Specific to the type of VS employed, Groer et al. found that officers in a workplace violence simulation experienced physiological stress at greater levels than officers completing a motorcycle traffic stop simulation. In both simulations the perpetrator ultimately brandishes a weapon; however, the motorcycle simulation may have been too brief for the physiological indices of stress to show up in officers' saliva. While Groer and colleagues analyzed the physiological indices of stress, they did not consider those markers in relation to officers' perception of stress and memory. We consider elements in the VS important to process for officer survival (i.e. perpetrator information) and elements that may be legally important (i.e. event information) in connection to physiological indices of stress and memory accuracy.

Collectively, previous research suggests that officer memory is selective under high-arousal circumstances and physiological indices of stress are induced through simulation experiences. The current study is designed to clarify the effects of delayed reporting that includes a period of sleep and physiological indices of stress in relation to the accuracy of officer memory for a motorcycle traffic stop and workplace violence simulation using the Survival Humanistic Factors<sup>©</sup> Stress Inoculator (Murphy & Ross, 2009). Of interest was adaptive memory related to the perpetrator (i.e. physical characteristics and weapon use) versus event information that may be legally important, but less relevant to an officer's survival in that moment. It was expected that delayed reporting would lead to errors in officers' memory of the simulation and that officers' memory for the perpetrator would be more accurate than memory for the event as the perpetrator represents the primary threat. It was also expected that the level of physiological biomarkers present in officers' saliva post-simulation would be correlated to officers' memory.

## **Method**

### ***Participants***

Sworn law enforcement officers ( $N = 151$ ) completed one of two simulated lethal force shooting events. The two themes consisted of a motorcycle traffic stop ( $n = 53$ ) or a



workplace violence incident ( $n = 97$ ) both described below. One participant was excluded because more than 50% of the assessments were missing. Of the remaining sample ( $M_{\text{age}} = 36.7$ ,  $SE = .72$ ), there were 28 females. Approximately 75% of the sample was Caucasian ( $n = 112$ ), 10% was African American ( $n = 15$ ), 8% Hispanic ( $n = 12$ ), and 7% were of mixed race ( $n = 11$ ). The median number of years in policing was 8–9 years. Officers were predominantly sheriff deputies (82%,  $n = 124$ ), while approximately 17% were municipal officers ( $n = 26$ ) and one officer did not state an affiliation. Approximately 10% ( $n = 14$ ) of officers sampled reported ever being involved in a shooting (MTS,  $n = 4$ ; WPO,  $n = 3$ ; WPE,  $n = 7$ ) however, for those completing the immediate and delayed memory assessments ( $n = 12$ ) their memory for the simulation ( $M = .60$ ,  $SE = .02$ ) did not appreciably differ from their colleagues ( $M = .60$ ,  $SE = .01$ ) with no on-the-job shooting experience and thus their responses were combined for the analyses.

Participants were paid \$175.00 USD to complete perception, memory, and physiological assessments and one of the simulated scenarios, which took approximately 1 h. Those in the delay condition returned to the site 48 h later to complete the memory assessment, which took approximately 20 min. Officers were recruited through various contacts at police organizations in the South Eastern United States and were generally off-duty or had permission to complete the study during shift hours; it was made clear that their performance in the study was not part of their normal training, results were deidentified to be anonymous and confidential and only reported at the group level. The study was conducted in accordance with APA ethics governing human participation in research.

## Materials

### Simulations

A single version of a 'motorcycle traffic stop' (MTS) and two versions of a workplace violence incident (WPV) were employed. Both versions of the WPV were identical in story content; however, one version included enhanced visual (e.g. emergency lights flashing on and off within the building), tactile (e.g. blasts of air as doors open and slam shut) and auditory (e.g. sirens from the arriving back-up officers) stimuli in the room with the officer to intensify physiological arousal and increase realism for a complete sensory experience. This version will be referred to as 'workplace violence enhanced' (WVE). The other version contained no enhancements and will be referred to as workplace violence original (WVO).

All simulations occurred in a large 18 by 16 ft room with black painted walls. The recorded lethal-force scenarios were projected onto a 16 ft wide by 10 ft high white screen. Officers completed either a 1 min 30 sec MTS scenario or a 4 min 59 sec WPV scenario. The MTS scenario involved a traffic stop in which the driver of the motorcycle is verbally abusive as the officer pulls him over to the side of an expressway in moderate traffic. The subject, dismounts, reaches over the bike with his right hand grabbing a firearm, and points it at the officer and shoots. The WPV scenarios (i.e. WVO and WVE) involved an armed perpetrator inside a building reportedly moving through the building shooting co-workers. The simulation begins as the officer is met by the office building security officer who provides the officer in the simulation with a basic physical description of the perpetrator. As the security officer is providing the briefing, shots are heard within the office building. The officer enters the building and begins an office-by-office search



encountering workers crouched under desks and hiding in various rooms. Shots continue to be heard. As one door opens a bystander suddenly appears telling the officer, 'He went that way!'. The door closes and the officer continues through the building closing in on the perpetrator who exits out a back door. The officer at that point is moving from indoor lighting to bright sunlight. Back-up officers have arrived on the scene and the officer must distinguish between officers and the shooter who is running across a field and has been tackled to the ground and cuffed by another officer.

### *Memory assessments*

Recognition memory was assessed. Participants responded to force-choice items about the event (e.g. the duration of the event, the lighting, bystanders, etc.) and perpetrator's description (e.g. type of clothing, verbal communication, number of shots fired, etc.). Items included four response options, including the correct option, that is, the ground truth based upon the simulation event. An option was counted correct if it occurred during the VS. There were 15 memory items (6 event, 9 perpetrator description) for the MTS scenario. Given that the WPV simulations were over three times the duration of the MTS simulation, 42 items were initially developed and used for both WPV memory assessments. Many of the 42 items were redundant and so were eventually reduced to 21 items (15 event, 6 perpetrator description). An analysis of the assessment instruments revealed that the 42 item and 21 item WPV memory assessments did not differ in overall accuracy. Therefore, all items were retained, and the mean accuracy was calculated. That is, whether officers completed 21 or 42 items the proportions of items correct for event and perpetrator description categories were used in the analyses.

### *Self-report perceived stress*

Officers' rated their subjective levels of stress during the simulation. A 26-item questionnaire assessed how demanding, stressful, and threatening participants perceived the simulation task. Items were rated on a five-point Likert-type scale ranging from 1 (not at all) to 5 (very). Higher scores on the scale indicate higher levels of stress with possible scores ranging from 26–130.

### *Salivary measures of stress*

Salivary samples were collected via the drool method 5-min prior to the scenario to assess baseline levels for alpha amylase, cortisol, interleukin (IL-6), and secretory immunoglobulin (sIgA). Groer et al. (2010) suggested that these four measures are indicative of officers' arousal responses to stressful stimuli. Cortisol levels are one index for hypothalamic-pituitary-adrenocortical activity, which is the biological hallmark for stress. Additionally, interleukin-6, salivary immunoglobulin A, and alpha amylase are important markers for sympathetic nervous system response (e.g. fight or flight) and as indices for stress induced immune system suppression. Baseline salivary samples were collected after officers had engaged in various movements (e.g. walking forward/backward and kneeling) in a 12 × 20 ft room with a projector providing instructions to the officers. Movements were intended to mimic officer responses in a lethal force encounter – kneeling, back-peddling, etc., but without the actual threatening content to assess baseline levels and compare them with levels after the simulation was complete (See Groer et al., 2010). Salivary samples were also collected 10 and 30 min post-simulation. Difference scores were

calculated for each of the measures between base scores and 10 min, and base scores and 30 min after completing the VS. These 10- and 30-min post-difference-scores were used to calculate correlations between stress and memory.

### **Procedure**

Participants were immersed in either the MTS ( $n = 53$ ), WVO ( $n = 25$ ), or WVE ( $n = 72$ )<sup>1</sup> VS experiences. Participants completed informed consent and background information. Salivary samples were collected from each participant for baseline physiological data after performing basic movements as previously described. Subsequently, officers completed the MTS or one of the WPV scenarios. All officers were provided with a police uniform shirt, a radio, and a Blue Fire® Glock simulator weapon with the officers' own gun belt. Officers were dispatched using a 10-code system familiar to them. Officers completed post-event psychological (e.g. perceived stress level, etc.) and memory assessments immediately after the simulation and completed another memory assessment 48 h later. Salivary samples were collected 10- and 30-min post simulation experience. After completing the delayed memory assessment, participants were debriefed, paid, and thanked for their time.

### **Design and hypotheses**

Consistent with adaptive memory theory, it was expected that details about the perpetrator, versus details about the event, would be remembered better. It was also predicted that delayed reporting, whereby officers ostensibly slept, would have a detrimental effect on memory regardless of the VS type. To test these hypotheses, a 2 (Time: immediate vs. delay) by 2 (Information Type: event vs. perpetrator) mixed design was employed. Information Type was the within-subjects repeated-measure and memory accuracy was the dependent variable. One limitation of the current design is the unequal cell sizes for the type of simulation, which precludes any direct test of the impact that the type of simulation (MTS vs. WPV) may have had on officers' memory. Moreover, the MTS ( $n = 53$ ) simulation differed in duration, nature of the event, questions about the event and the number of officers participating from the WVO ( $n = 25$ ), and WVE ( $n = 72$ ) scenarios. Thus, the number of differences existing between simulations would make it impossible to isolate any causal factors of interest related to the simulation type. In addition, the unequal cell sizes and unequal variance on memory measures across simulations, required a more conservative statistical approach. While this precluded a direct comparison between memory performance for simulation types (Howell, 2013), it did not affect tests of the primary hypotheses and in fact allowed for possible replication of the predicted effects across simulation types.

Correlational analyses were also conducted between the four stress biomarkers (alpha amylase, immunoglobulin-A, cortisol, and interleukin-6) and memory (event and perpetrator description tested immediately and after a delay). As with the above analyses, correlational analyses were also calculated separately by VS type. Adaptive memory (Howe & Otgaar, 2013) suggests a relationship between arousal and memory for threat relevant information, making this information more salient. Porter et al. (2019) findings support adaptive memory, suggesting threat relevant information that is salient may be

remembered better. Therefore, it was expected that biomarkers of stress would show a relationship with memory. More specifically, arousal measures should be associated with, though not necessarily predictive of, better memory for threat relevant information (i.e. perpetrator descriptions).

## Results

### Memory and delay

Table 2 depicts the recognition means and standard errors by delay and question type for each of the VS scenarios. Items were scored as correct and the sum was divided by the total possible correct for each category. Occasionally participants failed to answer some items on either the immediate or delayed measures. For these participants ( $n = 19$ ; 5 in the MTS, 3 in the WVO and 11 in the WVE simulations), proportions were calculated accordingly by adjusting the total number of correct items possible. If participants failed to answer more than 20% of items, they were excluded from the respective analysis. This equated to one participant in the MTS scenario, two in the WVO scenario, and four in the WVE scenario. For each of the analyses describing memory and delay, a 2 (Time: immediate vs. delay) by 2 (Type of Information: event vs. perpetrator) repeated-measures ANOVA was conducted on percent correct of remembered items.

### Motorcycle traffic stop (MTS)

As expected, immediate memory was better than memory after delay. Moreover, officers remembered more about the perpetrator than the event after the delay. There was a main effect for time, where officers reported more accurate information immediately ( $M = .62$ ,  $SE = .01$ ) than after a 48 h delay ( $M = .58$ ,  $SE = .01$ ),  $F(1, 51) = 12.37$ ,  $p < .01$ ,  $\eta_p^2 = .20$ . A main effect was also found for the type of information being recalled  $F(1, 51) = 7.34$ ,  $p < .01$ ,  $\eta_p^2 = .13$ . Information about the perpetrator ( $M = .63$ ,  $SE = .01$ ) was recognized better than information about events ( $M = .57$ ,  $SE = .02$ ). There was also a Type of Information by Time interaction,  $F(1, 51) = 8.19$ ,  $p < .01$ ,  $\eta_p^2 = .14$ . Simple effects revealed accuracy decreased after a delay for events ( $M_D = -.09$ ,  $t(51) = 4.00$ ,  $p < .001$ ) but not for perpetrator descriptions ( $M_D = -.002$ ,  $t(51) = .14$ ,  $p = .89$ ). See Table 2.

**Table 2.** Mean proportion correct and standard errors, immediate and delayed (48 h post simulation), for the three simulations (MTS, WVO, and WVE) by type of information (Event and Perpetrator).

	Event	Perpetrator
MTS ( $N = 52$ )	Mean (SE)	Mean (SE)
Immediate	.62 (.02)	.63 (.02)
Delayed	.53 (.02)	.63 (.02)
WVO ( $N = 23$ )		
Immediate	.54 (.02)	.74 (.04)
Delayed	.53 (.03)	.71 (.04)
WVE ( $N = 68$ )		
Immediate	.52 (.01)	.68 (.02)
Delayed	.53 (.01)	.65 (.02)

### Workplace violence-original (WVO)

Comparable to the MTS, and in support of the current hypothesis, information about the perpetrator was remembered better than information about the event; however, delay did not influence officers' memory. The main effect for the type of information being recognized  $F(1, 22) = 18.72, p < .001, \eta_p^2 = .46$ , demonstrated that information about the perpetrator ( $M = .73, SE = .04$ ) was again remembered better than information about events ( $M = .53, SE = .02$ ). However, there was no main effect for the delay nor was there an interaction between delay and category of information (See Table 2).

### Workplace violence-enhanced (WVE)

For the enhanced simulation, perpetrator information was again remembered better than event information; notably, delay decreased accuracy for perpetrator, but not event information. The main effect for the type of information being recognized was reproduced ( $F(1, 67) = 66.51, p < .001, \eta_p^2 = .50$ ). Information about the perpetrator ( $M = .67, SE = .02$ ) was remembered better than information about events ( $M = .52, SE = .01$ ). There was no main effect for delay. However, there was a Type of Information by Time interaction,  $F(1, 67) = 4.22, p < .05, \eta_p^2 = .06$ . Simple effects revealed accuracy decreased after a delay for perpetrator descriptions ( $M_D = -.03, t(68) = 1.99, p = .05$ ) but not for events ( $M_D = .01, t(68) = -.76, p = .45$ ). See Table 2.

## Memory and stress

### Correlations between memory and biomarkers of stress

Table 3 depicts the correlation coefficients between physiological stress measures and immediate and delayed memory performance for perpetrator and event information for the MTS simulation. Similarly, Tables 4 and 5 present findings for the WVO and WVE simulations, respectively. All analyses conducted control for baseline levels of physiological markers of stress. Of note is the overall absence of correlation between cortisol, interleukin-6, and memory for any of the simulations; however, these indices also did not appreciably demonstrate changes from baseline levels.

**Table 3.** Correlation between memory accuracy, immediate and delayed (48 h post simulation) by type of information (event or perpetrator), and salivary stress hormone differences measured between baseline and 10 min and baseline and 30 min after the MTS simulation.

	Immediate event	Delayed event	Immediate perpetrator	Delayed perpetrator
<i>Alpha-Amylase</i>				
Base/10 min difference	-.08	.14	-.11	-.22
Base/30 min difference	.16	-.12	-.04	-.25
<i>Cortisol</i>				
Base/10 min difference	.05	.01	.09	.07
Base/30 min difference	-.08	-.06	.08	.12
<i>Interleukin-6</i>				
Base/10 min difference	.11	.16	-.17	.09
Base/30 min difference	-.01	-.04	.18	-.05
<i>Immunoglobulin-A</i>				
Base/10 min difference	-.29*	-.33*	.04	-.03
Base/30 min difference	-.15	-.49**	-.11	.02

\* $p < .05$ .

\*\* $p < .01$ .

**Table 4.** Correlation between memory accuracy, immediate and delayed (48 h post simulation) by type of information (event or perpetrator), and salivary stress hormone differences measured between baseline and 10 min and baseline and 30 min after the WVO simulation.

	Immediate event	Delayed event	Immediate perpetrator	Delayed perpetrator
<i>Alpha-Amylase</i>				
Base/10 min difference	-.19	-.59**	.03	.07
Base/30 min difference	-.20	-.19	-.19	-.07
<i>Cortisol</i>				
Base/10 min difference	-.15	-.22	-.13	-.17
Base/30 min difference	-.08	-.07	-.24	-.26
<i>Interleukin-6</i>				
Base/10 min difference	-.32	.04	-.02	.10
Base/30 min difference	-.24	-.08	.00	.06
<i>Immunoglobulin-A</i>				
Base/10 min difference	.00	.22	.36	.10
Base/30 min difference	-.30	-.43	.20	-.09

\*\* $p < .01$ .

For the MTS scenario, increases in levels of immunoglobulin-A, suggestive of immune system suppression in response to stress, were related to poorer memory for the simulation. Levels of immunoglobulin-A at 10 min post simulation was inversely related to event memory for immediate ( $r = -.29, p < .05$ ) and delayed ( $r = -.33, p < .05$ ) memory tests. Levels of immunoglobulin-A at 30 min post-simulation was inversely related to event memory only for the delayed memory test ( $r = -.49, p < .01$ , See Table 3).

For the WVO scenario, levels of alpha amylase, which is indicative of sympathetic nervous system activation, was inversely related to memory. Notably, it was only levels of alpha amylase at 10 min post-simulation that was related to poorer event memory, but only after the delay ( $r = -.59, p < .01$ , See Table 4).

In contrast to the WVO simulation, the presence of physiological indices for sympathetic nervous system activation and immunological suppression was positively related to immediate memory in the WVE simulation suggesting better memory as levels increased. Specifically, alpha amylase and immunoglobulin-A at 10 min post-simulation was positively related to immediate memory for event (alpha amylase,  $r = .32, p < .05$ ) and perpetrator memory (immunoglobulin-A,  $r = .32, p < .05$ , See Table 5).

**Table 5.** Correlation between memory accuracy, immediate and delayed (48 h post simulation) by type of information (event or perpetrator), and salivary stress hormone differences measured between baseline and 10 min and baseline and 30 min after the WVE simulation.

	Immediate event	Delayed event	Immediate perpetrator	Delayed perpetrator
<i>Alpha-Amylase</i>				
Base/10 min difference	.32*	.09	.22	.25
Base/30 min difference	.23	-.02	.09	.07
<i>Cortisol</i>				
Base/10 min difference	-.03	-.07	-.01	.20
Base/30 min difference	.02	-.13	-.04	.21
<i>Interleukin-6</i>				
Base/10 min difference	-.02	-.07	-.06	-.03
Base/30 min difference	.05	.03	-.13	-.09
<i>Immunoglobulin-A</i>				
Base/10 min difference	.11	.13	.32*	.21
Base/30 min difference	.03	-.13	-.03	-.17

\* $p < .05$ .

Overall, these findings revealed that the expectation that improved memory for threat (i.e. perpetrator descriptions) would be associated with biomarkers of stress was only evidenced in the WVE condition. However, this relationship was also evidenced for memories of less stressful stimuli (i.e. events) in the WVE condition.

### *Officers' self-reported stress and memory*

Similar to the findings from biomarkers, better memory for threatening information was not associated with higher levels of self-reported stress. Table 6 depicts the correlation coefficients between memory accuracy and self-reported stress for immediate and delayed reporting across the three simulation types. After a delay officers reporting more stress had greater memory accuracy for event information ( $r = .58, p < .01$ ) in the WVO simulation; however, officers in the WVE simulation who reported more stress had poorer memory accuracy for perpetrator information ( $r = -.30, p < .05$ ). We consider these findings within the theoretical framework related to adaptive memory and the integrated specificity model of arousal.

## Discussion

### *Reconsidering memory of lethal force encounters*

The current findings support an adaptive memory approach (Howe & Otgaar, 2013) for officer memory in lethal force circumstances (i.e. that officers are more likely to remember threat-relevant information). For all three simulation types, information about the perpetrator description was remembered better than information about events, suggesting officers attend to and define the central event relevant to a perpetrator – that which poses the greatest threat. Notably, while delay resulted in poorer recognition memory for event information in the MTS simulation, the reverse was true for the WVE simulation in which delay resulted in poorer memory for the perpetrator. One explanation for the differential interaction effects could be due to the type of simulation, which we were unable to assess and is a limitation of the current study. The MTS simulation was brief, and the threat was immediately directed at the officer; in contrast, the WVE simulation was of longer duration, the officer was moving towards the gun fire in search of the perpetrator and threat, while present, was not immediately directed at the officer. Concerns regarding unequal cell sizes and variance across the types of simulations employed prevented a direct examination of the impact of the situation, which should be examined in subsequent research. Delay had no effect on perpetrator or event information for the WVO simulation, which may have been due to the condition being potentially underpowered ( $n = 23$ ) or the additional stimulation experienced by officers in the WVE

**Table 6.** Correlation between memory accuracy, immediate and delayed (48 h post simulation) by type of information (event or perpetrator), and self-reported stress for the three simulations.

Simulation type	Immediate event	Delayed event	Immediate perpetrator	Delayed perpetrator
MTS	.15	.28	.09	-.01
WVO	.31	.58**	.20	-.16
WVE	-.01	-.01	-.07	-.30*

\* $p < .05$ .

\*\* $p < .01$ .

condition that may have drawn officers' attention away from perpetrator elements within the simulation. Generally, these results are consistent with those from Porter et al. (2019), who also found that threat information was better recalled, but contrast their findings in relation to delay being less likely to affect threat-relevant memories. Variation in the memory assessments across the simulation types precluded a more refined examination of event and perpetrator information and is also a limitation of the current data.

Delay adversely affected recognition memory for event (MTS simulation) and perpetrator (WVE simulation) information. An important consideration of these effects and the absence of more pronounced effects, particularly in the WVO simulation, relate to measuring memory twice for all officers immediately after the simulation and again after a two-day delay. The prior exposure to items likely facilitated officers' memory when asked to remember these same items two days later (c.f., Porter et al., 2019; Yuille et al., 1994) producing a rehearsal effect. This is important to consider in light of policy recommending delayed reporting. Comparable to Porter and colleagues, officers in this study had a memory advantage with an immediate memory test and subsequent delayed test. Even with the memory rehearsal advantage delay did not benefit memory for any of the simulations.

### ***Physiological stress response and memory***

Consistent with the literature on arousal and memory (e.g. Sapolsky, 2004), officers demonstrated expected physiological stress responses particularly within the WPV simulation (See Groer et al., 2010). Notably, not all physiological indices of stress were related to memory. Specifically, higher levels of alpha amylase and immunoglobulin-A in the MTS and WVO led to less memory accuracy. In contrast, as these same levels increased during the WVE simulation memory accuracy improved. Furthermore, while officers' subjective perceptions of stress in the WVO simulation was related to better memory performance on event descriptions after a delay, they were related to poorer memory performance on perpetrator descriptions after a delay in the WVE simulation.

These findings contribute to research considering physiological arousal, stress, and performance. Morgan and his associates studied military recruits in a training survival prisoner of war camp. Generally, military-trainees experience four days of class instruction followed by four days of evasion stress, 30 min of interrogation, four hours of isolation, and finally 30 min of group propaganda stress. Memory for these experiences is particularly vulnerable to the effects of misinformation (Morgan, Southwick, Steffian, Hazlett, & Loftus, 2013) and poor recognition for the interrogator when trainees are under high (versus low) levels of stress (Morgan et al., 2004a). Moreover, the long duration of the training stress also impacts military-trainees' visuo-spatial capacity and working memory (Morgan, Doran, Steffian, Hazlett, & Southwick, 2006). Notably, Morgan's research group found that the stress hormone dehydroepiandrosterone sulfate – cortisol has some protective effects, moderating levels of disassociation under duress and thus, improving performance (Morgan et al., 2004b). In contrast to the current findings, cortisol was unrelated to memory performance for officers across the simulation types. One explanation is the apparent difference between a lethal force versus a prisoner of war encounter. While both encounters are stressful, the prisoner of war circumstance is longer in duration and inherently more coercive with interrogation tactics that differ in the extreme from a post-incident interview for police officers.



The lethal force encounters utilized in this research were more likely to induce psychological stress rather than extreme physiological reactions found in the prisoner of war military training scenarios. Psychologically induced stress also fosters cortisol response (Andreano & Cahill, 2006; Dickerson & Kemeny, 2004) and immune system suppression (e.g. Cohen et al., 1999). In a meta-analysis combining 208 studies on the psychological induction of stress, Dickerson and Kemeny found that motivated performance (e.g. search and discrimination tasks) fostered marked cortisol responses, indicating participants were experiencing arousal in response to a task. Also, Andreano and Cahill found that men, in response to stress induced by immersing an arm in ice water for 3-min, exhibited an inverted-U shape relationship between cortisol change and memory accuracy for a literary passage after a two-week retention interval. In sum, when psychologically induced stress fosters physiological arousal (See Sapolsky, 2004, for a review), stress responses are particularly evident when a task is complex (e.g. discriminating between a perpetrator with a gun or a cell phone) and negative evaluation of performance is possible (e.g. determining whether use of lethal force is justifiable given the circumstance).

While there was no correlation between cortisol levels and memory there were positive correlations between alpha amylase and immunoglobulin A in the enhanced workplace violence simulation. These physiological markers are indices of sympathetic nervous system activation and immune suppression that is part of a normal stress response. It is clear, however, that these data are far from conclusive in understanding the connection between physiological stress and memory. Primarily, these positive correlations only emerged for officers' immediate memory reports. The current findings do not support the stress-decompression-memory-consolidation hypothesis embedded in the IACP (2013) recommendation, suggesting that officers be given an opportunity to sleep one or two nights after a lethal force encounter before being formally interviewed.

### **Conclusions and future directions**

The current findings contribute to the growing literature on officer stress and memory responses in lethal-force situations and tests fundamental assumptions about human performance embedded within current organizational policy related to the aftermath of lethal force encounters. The findings here are consistent with the evolving research on adaptive memory and arousal (e.g. Hope et al., 2016; Porter et al., 2019; Yuille et al., 1994) and extend that research by considering the relation between physiological arousal indices and memory. To date, the research suggests that threat-relevant information is more likely to be remembered (Porter et al., 2019) or mis-remembered (Hope et al., 2016) and, as evidenced by the current results, threat is most relevant to perpetrator behavior rather than event details.

The recommendation consistent with this growing body of research is that formal interviews with officers involved in lethal force encounters should be conducted as soon as reasonably possible for better memory accuracy. Future research should consider more directly how officer memory for lethal force encounters coincide with the Four Factor Test embedded in the U.S. Supreme Court Ruling for *Graham v. Conner* (1989) in determining 'objective reasonableness'. In considering whether an officer's use of force was reasonable one should consider, (1) the need for the application of force, (2) the relationship between the need and the actual amount of force exerted in the circumstance, (3) the

extent of injury inflicted on the target, and (4) whether the force was applied in a good faith effort to maintain or restore order. Notably, these factors may best be assessed with information about a perpetrator in relation to the event context. Given that perpetrator information was better remembered than event information in these findings suggests that officers may be at a disadvantage when convincing others that their use of force was reasonable. Those deciding upon the reasonableness of an officer's use of force have the luxury of hindsight, and if an officer is unable to remember details of the event context his or her behavior may indeed appear unreasonable. Witness interview strategies to improve witness recall with cooperative witnesses (e.g. the Cognitive Interview, Fisher, Milne, & Bull, 2011) may also work for officers in aiding them to recall more event details. Currently, we know of no published research that considers cognitive interview strategies with police officers following lethal force encounters. Although the effectiveness of the cognitive interview is well established with other witnesses (See Fisher et al., 2011).

A closer examination of the various methods used to train officer decision-making in these circumstances will likely identify factors beyond the memory and arousal issues considered here that contribute to reasonable responses in lethal force circumstances. Do current training strategies effectively prepare officers for decision-making under extreme physiological arousal, perceptual distortions, and cognitive impairment that can occur? What type of method, role play, prop houses, simulation – virtual or otherwise – present sufficiently realistic decision-making circumstances that help distinguish reasonable from unreasonable responses? Training method effectiveness, follow-up interviews, co-officer information, and organizational policy likely influence the accuracy of officers' memory and their confidence in the reliability of their memory reports. In turn, understanding the basis of officer stress, perceptions, and memory will better inform police organizations and the courts in determining how reasonable an officer is when exerting force in the line of duty.

## Notes

1. The WPO condition was designed to serve as a comparison group for the WVE in relation to officers' physiological reactivity. It was estimated by Groer that 25 officers would be enough for a comparison to determine whether the simulation without the enhanced environmental stimuli was effective in increasing officers' physiological response (See Groer et al., 2010). This approach resulted in unequal cell sizes across types of simulation (Randall Murphy, Personal Communication, July 9, 2019). It is for this reason that we did not assess the impact of simulation condition on memory in the statistical analyses.

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