Police Practice and Research: An International Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gppr20

Police officers' actual vs. recalled path of travel in response to a threatening traffic stop scenario

William J. Lewinski[a], Jennifer L. Dysterheft[a], Matthew M. Priem[b] & Robert W. Pettitt[c]
[a] Force Science® Institute, Mankato, MN, USA
[b] Mathematics Department, Minnesota State University, Mankato, Mankato, MN, USA
[c] Human Performance Lab, Minnesota State University, Mankato, Mankato, MN, USA
Published online: 26 Sep 2014.

Police Practice and Research, 2014
http://dx.doi.org/10.1080/15614263.2014.959950

RESEARCH ARTICLE

Police officers' actual vs. recalled path of travel in response to a threatening traffic stop scenario

William J. Lewinski[a]*, Jennifer L. Dysterheft[a], Matthew M. Priem[b] and Robert W. Pettitt[c]

[a]*Force Science® Institute, Mankato, MN, USA;* [b]*Mathematics Department, Minnesota State University, Mankato, Mankato, MN, USA;* [c]*Human Performance Lab, Minnesota State University, Mankato, Mankato, MN, USA*

The purpose of this study was to measure the amount of error incurred by police officers when trying to accurately draw a previously completed movement path, which occurred during their response to a high-stress encounter. Secondary purposes of the study examined whether gridlines on a diagram or a distractor situation would influence memory accuracy. Officers ($n = 23$) were taken through a high-stress stimulus phase, followed by a memory recall phase where they were required to accurately draw their path of travel. Average distance traveled was 5.15 ± 1.98 m. Average discrepancy for all participants was an area of 3.23 ± 4.13 m^2 and length of 1.43 ± 1.30 m. Significant length differences were found between actual and recalled paths of travel ($p < .01$). No other significant area or length differences were found.

Keywords: episodic memory; police officers; movement path; memory; memory error

1. Introduction

Society has given law enforcement officers the authority to use force to accomplish their professional objectives. This force can take the form of a simple restriction of movement, such as a traffic stop or an investigatory stop, to the use of deadly force and the termination of the life of a citizen. An equally high level of accountability accompanies the relatively high level of authority and power given to law enforcement. This high level of accountability includes the officer reporting completely and accurately on their behavioral interaction with the public. Any indication of ineptness or deception arouses suspicion about the officer's motives, training, and supervision and leads to a loss of credibility with the public. This, in turn, lays the foundation for administrative, criminal, and civil sanctions against the officer and the department.

An officer's apparent but reasonable inability to report on precisely all that occurred within an encounter could be perceived by the community as deceitfulness, leading to distrust and suspicion, while the true cause may be a normal failure of memory of a well-trained, but still human, officer, acting professionally within a very stressful event.

Unfortunately, a full and completely accurate recall of any event is impossible for the average human, especially when the event, like many uses of force, is visually and behaviorally complex, dynamic, begins unexpectedly, and unfolds rapidly. Because law enforcement officers are still simply human, society's expectation about the ability of a

*Corresponding author. Email. bl@forcescience.org

police officer to report with exact precision on any event may be unrealistic. The most important question is what can society, and various oversight bodies, expect an officer to most completely and accurately report on and, inversely, where might these professionals normally expect incompleteness or errors in what the officer is reporting?

2. Literature review

The various memory systems and the brain's ability to consolidate event information into long-term memories have been studied for decades. Memory is not stored in a file that can be pulled up in the officer's brain, queried, and then placed back. Memory is stored in a variety of ways and associations, and every time it is examined, it is recreated. Unfortunately, much of the current research on the influence of severe stress on memory consolidation and recall has been conducted in highly controlled laboratory settings, often involving minimal stimulus relating to actual, high stress, life experiences (Mori, 1995, 2008; Payne et al., 2006). For example, McGaugh, one of the leading researchers on stress and memory, used a simple immersion of the subject's forearm in ice water as his stress inducer (2000). Many of the studies available on the effects of stress on memory are performed in a laboratory setting and entail participants memorizing patterns, word lists, or watching a video, shortly followed by a test or recall of what they remembered (McGaugh, 2000; Mori, 1995). However, memory retrieval is influenced not only by retrieval cues and traces given to participants, but also by the context and conditions under which the information of events is initially encoded into memory (Buchanan & Lovallo, 2001; Kim & Diamond, 2002; Kuhlmann, Piel, & Wolf, 2005; Payne et al., 2006; Roozendaal, 2003; Rugg & Wilding, 2000). When examining a high stress and rapidly unfolding event that may include life-threatening elements, such as an eyewitness observing a violent crime that occurs or an officer confronting a threatening suspect with a deadly weapon, it should be recognized that the encoding of information in the brain is highly dependent on multiple environmental aspects of a situation and the psycho/physiological responses of those experiencing it. Most often, those who experience high levels of stress during the event are required to report their whereabouts, actions, and movement patterns, and, for the sake of the investigation, need to be as accurate as possible, sometimes facing consequences for their memory errors. For police officers, the details of the event and their ability to recall them are critically analyzed by investigative and forensic experts; for example, the specific location and action of an officer are often matched with forensic evidence, such as bullet path direction and pattern, shell casing ejections, and blood spatter. However, (1) the type of information from these real-world, high-stress events that are initially encoded during the situation and (2) the specific details that may be recalled accurately later on are pieces of information that need further investigation. Discrepancies between an officer's reported behavior and the forensic evidence serve to impeach an officer's credibility. This may then challenge everything the officer had reported about the incident, including their judgment to use force.

One recent example of this is law enforcement officer, Daniel Lovelace, who was charged with murder after shooting once and killing the driver of a vehicle that had tried to escape and appeared to be attempting to run him over in the process (Force Science Institute, 2009). Prosecutors attempted to discredit Lovelace based upon the landing location of an ejected cartridge casing, as well as a mere six inch discrepancy between his self-reported path of travel during a walk-through of the event and the forensically constructed path of travel of the motor vehicle. In another documented occurrence, reported in Artwohl's (2003) text, during an examination of officer misperceptions and memory distortion, an officer was reported stating:

> I told the SWAT team that the suspect was firing at me from down a long dark hallway about 40 feet long. When I went back to the scene the next day, I was shocked to discover that he had actually been only about 5 feet in front of me in an open room. There was no dark hallway. (Artwohl, 2002, p. 18)

Although this type of inability to recall information, such as firing their weapon, is common (see also Artwohl, 2002; Klinger, 2001; Solomon, 1997), the consequences officers often experience, as previously stated, are severe and may result in the loss of their career or imprisonment. Previous research has demonstrated that officers' memory for peripheral or unimportant objects and events decreases in accuracy during a high-stress simulation (Alpert, Rivera, & Lott, 2012; Artwohl, 2002, 2003; Beehr, Ivanitskaya, Glaser, Erofeev, & Canali, 2004; Klinger, 2001; Lewinski, 2008, Solomon, 1997), yet no research has yet been done examining the ability of an officer to accurately report their location or movement paths during a rapidly unfolding, visually and behaviorally demanding stressful event, such as a shooting. The example of Lovelace's experience, and many others, gives reason to further examine a person's ability to recall specific movement paths and locations during a high-stress situation before enforcing harsh punishments for error. As previously stated, the questions that need answers then become what types of information, from an incident, can professionals reasonably expect officers to accurately recall during their interview and what would an officer realistically be unable to recall or accurately report on?

To begin the examination of these questions, the initial encoding process of information from an event into memory should be understood. Over the years of extensive research of the encoding process, two very influential factors surfaced for critical consideration: the person's focus of attention and their working memory capacity. Attention is driven by both internal and external factors. During a conflict situation, an officer's visual scan pattern of a potential assailant would be internally driven by the officer's knowledge and experience, as well as be externally drawn to detectable threat cues or weapons. Attentional choices and focus made during a highly stressful event force an officer's working memory capacity to efficiently process, maintain, update, and most importantly, filter information (Kane & Engle, 2002). In general, as a person's focus becomes more intent on a specific object, action, or event, their brain filters out what it believes to be irrelevant for completing the task at hand (Furley & Memmert, 2012; Kane & Engle, 2002; Kane, Conway, Hambrick, & Engle, 2007; Zanto & Gazzaley, 2009). For instance, an officer in a deadly force encounter may be so focused on shooting to save their life or stop a threatening action from an assailant, that they literally are unable to equally focus, nor should they, to their specific location and movement. As demonstrated in previous research (Hope, Lewinski, Dixon, Blocksidge, & Gabbert, 2012), police officers tested during a high-intensity, physical assault exercise were able to remember significantly less accurate information provided to them and experienced during the simulated physical assault and the assault scenario. These results support the compensatory control model (Hockey, 1997) suggesting that high levels of physical arousal compromise information processing resources and therefore result in a decrease in information encoding ability.

In order for a person's working memory capacity to perform at an optimum level, this filtering of information must occur; otherwise their working memory capacity experiences an overload, which causes cognitive deficits, particularly in response time and decision accuracy (Hasher & Zacks, 1988; Zanto & Gazzaley, 2009). Known examples of this filtering process for what is considered extraneous information are the phenomena of inattentional blindness (Mack & Rock, 1998; Simons, 2010; Simons & Chabris, 1999), load-induced blindness (Macdonald & Lavie, 2008), attentional blink (Martens & Wyble, 2010; Raymond, Shapiro, Arnell, 1992), emotional blink (Arnell, Killman, & Fijavz, 2007), the colavita effect (Colavita, 1974; Spence, 2009), the weapon focus effect (Fawcett, Russell, Peace, & Christie, 2013; Hope & Wright, 2007), etc. These examples of related phenomena give evidence that attention is necessary, but not alone sufficient, for conscious awareness or memory consolidation of an event (Chabris, Weinberger, Fontaine, & Simons, 2011; Levin & Angelone, 2008; Prinz, 2010; Simons & Chabris, 1999).

In addition to the exemption of extraneous details during a stressful situation, experiential factors preceding the interview of a witness, suspect, or officer are thought to play a role in the accuracy of information recalled. It has been well documented since the 1900s that the learning of additional information shortly following the initially remembered, important event disrupts memory consolidation of the initial event, known as retroactive inhibition or proactive interference (Glickman, 1961; Hardt, Nader, & Nadel, 2013; McGaugh, 2000; Muller and Pilzecker, 1900; Shadmehr & Holcomb, 1997). More current research supports this theory by examining hippocampal neural activity in rats and determined that sequential replay of spatial experiences normally occurs following an event, while the rat is in an awakened state. This replay of events is suggested to reinforce learning and memory consolidation; therefore, when replay is interrupted, consolidation and recall ability suffers (Carr, Jadhav, & Frank, 2011; Foster & Wilson, 2006; Jadhav, Kemere, German, & Frank, 2012; Muller & Pilzecker, 1900). Although it is recommended, particularly in eyewitness recall, that interviews or reports of an event occur as soon as possible to prevent any memory inference or decay (Caputo & Dunning, 2007; Deffenbacher, Bornstein, McGorty, & Penrod, 2008), formal officer questioning of a use of force situation may not occur for hours, or even days, later (Beehr et al., 2004). This is recommended, as it allows for emotional decompression and further memory consolidation, as is known to occur with REM and slow wave sleep; however, further investigation into the effects of replay interruption is needed.

One currently used method aimed to decrease the amount of incorrect details recalled during these interviews, most commonly utilized with eyewitnesses or crime victims, is visual aids, such as maps, floor plans, or images (Cheery et al., 1996; Martyn, 2012). Although recognized as beneficial to enhancing the accuracy of information provided by eyewitnesses, little research has been completed examining the effectiveness of scaled maps, reference points, or gridlines of these visual aids in facilitating an increase information recall. While much of this research has used events or objects that are unusual and generally occur in low-stress situations, event details that are required to be recalled by officers are often not unusual and are observed while incurring extreme levels of stress. For example, investigators commonly use Google maps to ask officers their exact whereabouts during a shooting, in addition to diagrams depicting where specific items in a room may have been or how the officer moved during a specific incident. Most often people, during low-stress situations, very rarely pay specific attention to how they walked across a room or the specific location of an object they may have passed, however, if an officer is unable to remember their location and movement exactly as a forensics report demonstrates, as aforementioned, they are scrutinized for their errors and often their credibility comes into question (Alpert et al., 2012; Artwohl, 2002, 2003).

Using a realistic, high-stress situation, in which officers were required to cognitively and physically respond, this study aimed to examine the influence of severe stress during a situation involving episodic memory recall of a movement path. Although it has been demonstrated that officers' memory for peripheral or unimportant objects decreases in accuracy during a high-stress situations (Alpert et al., 2012; Beehr et al., 2004), research has yet to be done examining the accuracy of location or retracing movement paths. Therefore, the primary purpose of this investigation was to observe the average amount of error incurred by participants when trying to accurately draw a previously completed movement path onto a scaled diagram, in comparison to their actual, digitally video recorded, movement path. A secondary purpose was to determine whether adding gridlines to represent distance on the diagram would improve subject recall accuracy. Further, the possible effects of a distractor situation on replay interruption and its possible effects on memory consolidation, occurring immediately after the stimulus phase and prior to the memory recall phase of research, were observed.

3. Methods

3.1. Participants

A total of 40 participants (37 males, 3 females) were randomly selected from a volunteer group of 93 officers participating in an adjacent study on traffic stop performance. Officers volunteered for participation in the adjacent study after reading information provided to participating departments in the states of Oregon and Washington. During mathematical analysis, 16 of the 40 participant data-sets were eliminated due to researcher inability to accurately and reliably measure the variable (*see* Section 3.6 *for details*), resulting in a sample size of 24 males between the ages of 27 and 54 ($M = 40.79$, SD = 7.44). The sample included the following rankings: 1 corporal, 2 detectives, 18 officers, 2 sergeants, and 1 senior reserve officer. The participants' experience in law enforcement was between 3.5 and 31 years ($M = 13.96$, SD = 7.60). Participants were not informed of any specifics of the study until meeting with an investigator immediately prior to data collection. All participants completed informed consent waivers and fitness questionnaires before entering the testing site to ensure no previous injuries or conditions would be worsened, cause serious risk to participants, or compromise results. Procedures were preapproved by the sponsoring institutional review board.

3.2. Equipment

For the stimulus phase of the study, all participants were directed into a warehouse, which held a police department cruiser and a 2004 Ford Taurus. The vehicles were positioned so the cruiser was aligned off-center to the Taurus to simulate a roadside traffic stop (see Figure 1((a) and (b))) (Payton & Amaral, 1996; Perry, 1998). Prior to entering the testing area, all officers were required to safety check their firearms and received an approved training gun with one round of Simunition® ammunition and an empty magazine. Participants were also given a SOLO 915 men's wrist heart rate monitor, earplugs, safety glasses, identification information, and an orange armband to indicate they had cleared the safety check portion of the study. One investigator played the role of the driver in the traffic stop scenario and, for stimulus purposes, was equipped with a handgun loaded with Simunition ammunition.

Of the three scenario trials during the stimulus phase, only the third trial for each participant was digitally recorded from an overhead position, with aid of a scissor lift

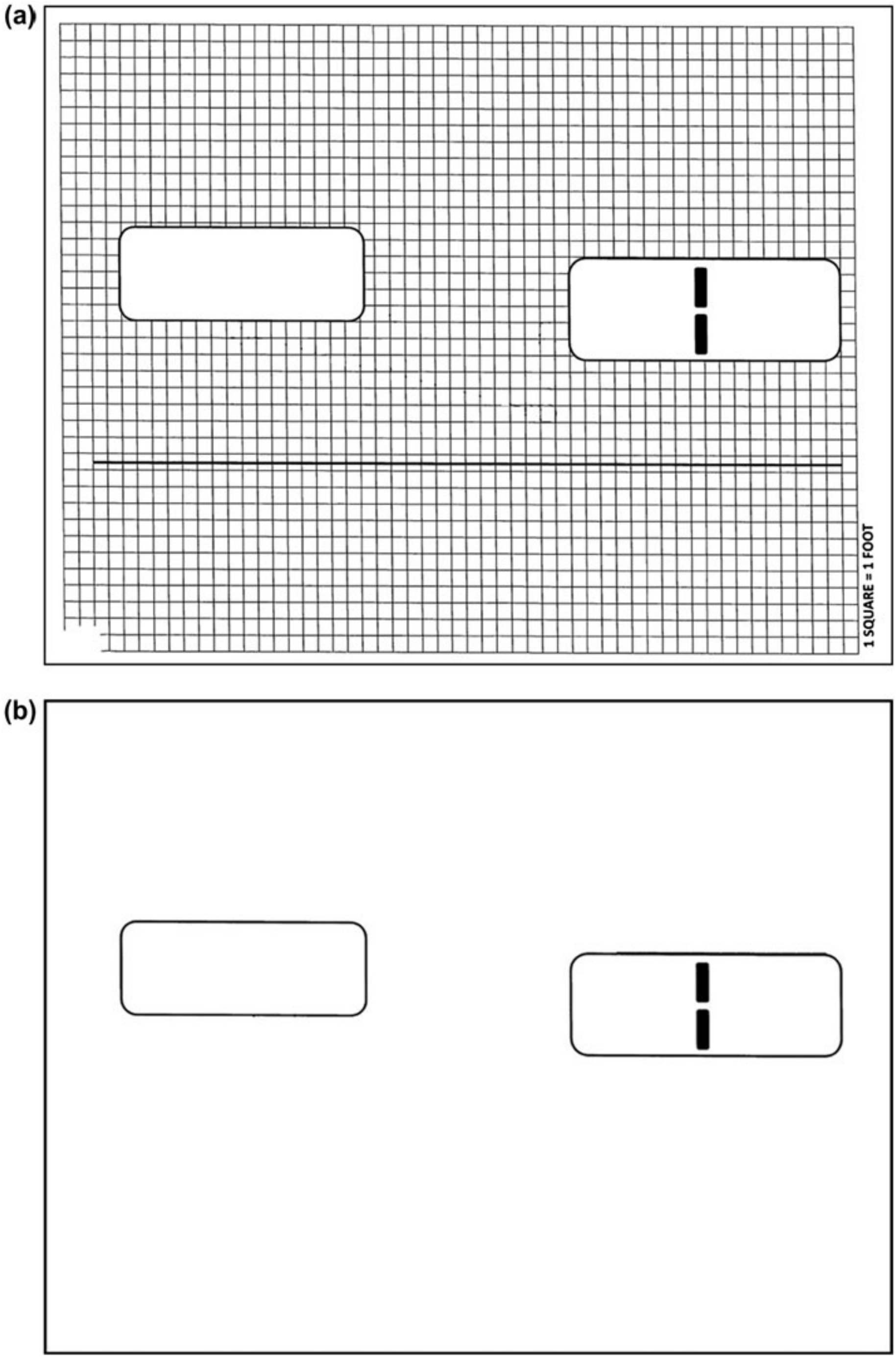

Figure 1. (a) Grid lined diagram; (b) Non-grid lined diagram.

(Genie, Redmond, WA, USA), at 30 Hz (Flip Video Ultra HD, Flip Technology, Irvine, CA, USA). The camera frame was zoomed to capture the entirety of each officer's movement path and prevent the need for panning. For digital analysis, tape was placed on the floor to represent one meter, allowing for pixel-to-meter calibration when performing a digital video analysis of the path of travel. Also, officer foot movement was easily detected, as all participants wore black shoes and the warehouse floor was white tile.

For the post-incident, memory recall phase, participants were given a drawn-to-scale diagram of the warehouse and vehicles used during the stimulus phase. Chosen at random, 20 of the participants were given a grid lined diagram, in which the drawing of the scene included gridlines displaying approximate square footage of the stimulus scenario, as well as a distance key (Figure 1(a)). The remainder of the participants received a non-grid lined diagram of the stimulus scenario, key, and no indictors of approximate distance (Figure 1(b)).

Digital video analysis of recorded officer reactions was completed on a frame-by-frame basis using commercial software (Dartfish Prosuite 6.0, Dartfish, Alphretta, GA, USA). Using the software's tracking device, the x- and y- coordinates were found for participants' center of mass by averaging the x- and y- coordinates from the left and right feet (5th metatarsal). Additionally, using the x- and y- coordinates of each step, the video analysis software was able to measure the total actual distance traveled by officers through calculating the displacement of each stride and then, collectively summing the stride lengths. The equation used by the software to find each stride displacement was:

$$\text{displacement}\,(r) = \sqrt{}((x_2 - x_1)^2 + (y_1 - y_2)^2).$$

The same digital video analysis software was used to examine the participants' responses for the memory recall phase and record the x- and y- coordinates for their recalled paths of travel, as well as measure the estimated distance traveled.

A mathematical analysis of the x- and y- coordinates was performed using statistical analysis software to find best-fit polynomials (SPSS, IBM Corporation, Armonk, NY, USA). Additional mathematical analysis software was used (Maple 16, Maplesoft, Waterloo, ON, Canada) to measure the area between the actual and recalled curves for each officer.

3.3. Procedures

3.3.1. Stimulus phase

Prior to entering the warehouse and beginning the stimulus phase of the research, all participants were informed that they would be completing a number of trials of a traffic stop scenario that may or may not escalate. To ensure that his or her reactions were as close to natural as possible, participants were neither informed of the exact number of trials nor when or how the traffic stop would escalate. Upon arrival to the study location, participants' heart rates were measured (for baseline), as well as after entering the warehouse and receiving instruction, and immediately after each trial. For this study, the physiological response of heart rate increase was used as general indicator of subject stress level and intensity. Although heart rate is an indirect measure of the physiological stress, it is generally accepted as an indicator of subject stress response (Frankenhaeuser, 1986; Lewinski, Dysterheft, Seefeldt, & Pettitt, 2013; Payne & Amaral, 1996). Heart rates are expressed relative to each participant's age-predicted maximal heart rate (HR_{max}) using the following equation (Tanaka, Monahan, & Seals, 2001):

$$HR_{max} = 208 - (\text{Age} \times 0.7).$$

After entering the warehouse, one researcher instructed participants, using a preset script, that the scenario they would be completing was a roadside traffic stop occurring because the driver exceeded the posted speed limit by 16.09 km/h (10 mph). Each of the stimulus trials began with the participants standing at the driver's side door of the police vehicle. With the sound of a whistle blown by the instructing researcher, participants were allowed to begin their self-selected approach to the driver's vehicle, stopping at a predetermined stance alongside the driver's door. Participants were also instructed that a second whistle blow indicated the end of the trial.

For the first two trials, participants only experienced verbal confrontation with the driver, which lasted 45 s. The driver's confrontation consisted of his proclamation that he was a confederate, sovereign nation, no longer a citizen of the USA, and was not required to follow US or state laws. The confederate driver was given two pieces of documentation to aid in the scenario: a homemade "conveyance pass" and a written declaration of his status as a sovereign nation. He was not given any state-issued identification, registration, proof of insurance, or a driver's license. The first two trials, with this script, were intended to distract participants and ensure a naturalistic, high-stress response during the third trial.

The third trial began similarly to the previous two, with verbal confrontation; however, the trial was escalated to a high-stress stimulus when the confederate driver pulled and fired his weapon multiple times at the participant. Researchers digitally recorded this trial for reaction movement analysis and comparison to later participant memory recall. Following each participant, the warehouse was ventilated between trials to remove excess smoke created by the firearms and to prevent participants from detecting that there would be gunfire during the experiment.

Immediately after the third trial, each participant's heart rate was measured and recorded. Participants were then guided to either a distractor scenario ($n = 9$) or to the memory recall portion ($n = 15$). The distractor scenario involved participants performing a dropping task, in which they were instructed to drop or duck below a specified point multiple times, marked across the wall of the testing room. Researchers told participants this action simulated officers choosing to duck or drop backward below the window line of a vehicle for cover when confronted with a weapon, rather than retreating. Participants were instructed to 'drop below the designated line as quickly as possible' and could draw their weapon if they chose to do so. All participants were given one practice trial and three performance trials to perform the task, which were digitally recorded. Afterward, participants were brought immediately to the memory recall phase of the study.

3.3.2. *Memory recall phase*

For the memory recall portion of the study, participants were brought into a separate room and, again, heart rate measures were taken. Participants were given a sheet of paper with an approximate, scaled figure of the stimulus traffic stop scenario. Through random selection, participants were either given a figure with gridlines ($n = 12$), showing square foot measurements (Figure 1(a)), or a figure without gridlines ($n = 12$) (Figure 1(b)). On the diagram, participants were instructed to draw their path of travel, from the time the confederate drew his weapon to the point that they heard the whistle blow to end the trial, 'as accurately as possible' and 'to their best ability'. No further instruction or guidance was given and participants were allowed as much time as necessary to complete the task (see Figure 2((a) and (b)) *for subject memory representation*). Upon the completion of the diagram, participant heart rates were measured one final time. After memory task completion, all participants were debriefed with the true intent of the study by a retired police psychologist and were given the opportunity to review their third trial footage.

3.4. Digital analysis

Digital video analysis of recorded officer reactions during the stimulus phase was completed on a frame-by-frame basis using commercial software. The *x*- and *y*- coordinates of participant movement paths were collected and recorded. Using these coordinates, a replica of each participant's path of travel was placed on the same uploaded image of their completed memory diagram using the digital analysis software. The *x*- and *y*- coordinates of participant's drawn path on the memory diagram were also recorded. These two data-sets were used for mathematical line comparison. Additionally, the total distance traveled of both the actual and recalled paths of travel was recorded.

(a)

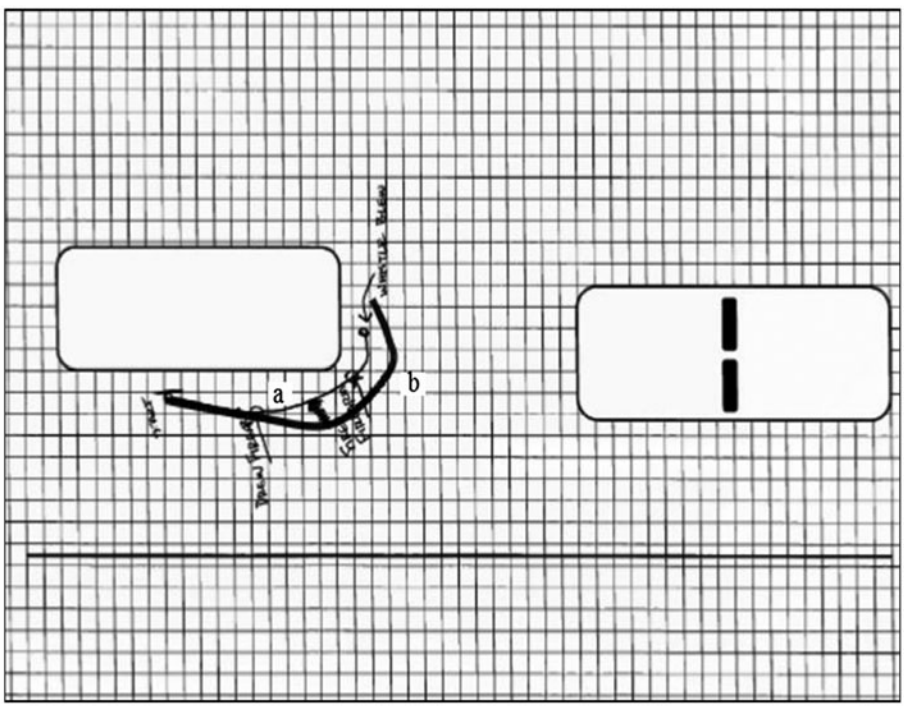

Figure 2. (a) Participant recall sample using grid lined diagram. Grid lined diagram with both digitally traced, actual path of travel and officer hand drawn, recalled path of travel. a denotes recalled path of travel (drawn onto diagram). b denotes actual path of travel (placed by researcher with digital analysis software). (b) Participant recall sample using non-grid lined diagram. Non-grid lined diagram with both digitally traced, actual path of travel and officer hand drawn, recalled path of travel. a denotes recalled path of travel (hand drawn onto diagram). b denotes actual path of travel (placed by researcher with digital analysis software).

(b)

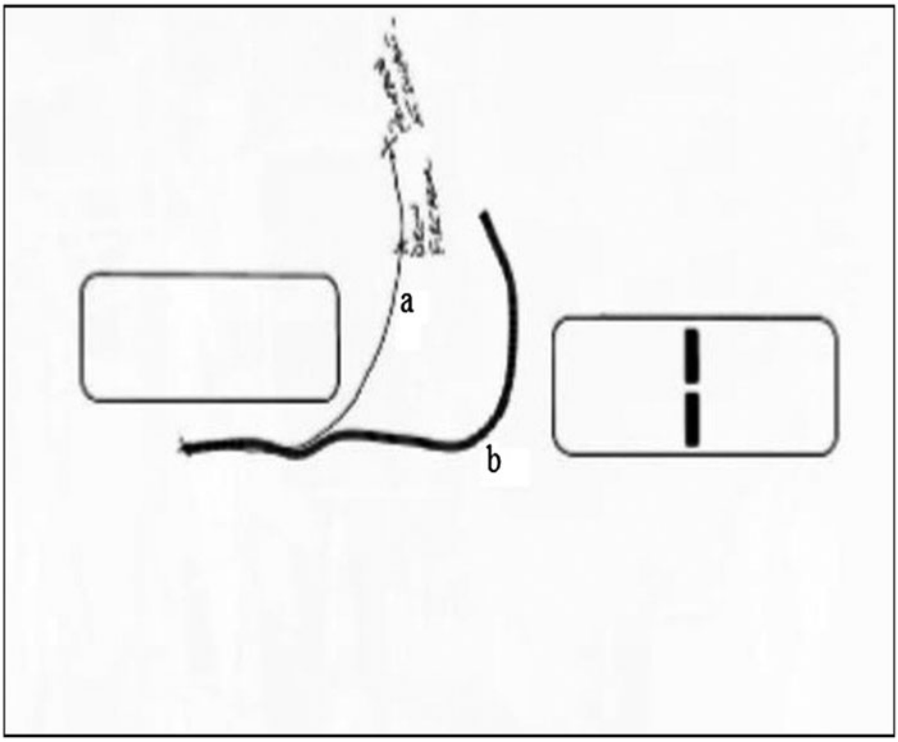

Figure 2. (*Continued*).

3.5. Mathematical analysis

All x- and y- coordinates of the actual and recalled paths of travel, for each officer, were used to create individualized best-fit polynomials (curves) using, up to, a cubic power. Using the equations derived in SPSS software, the two curves (actual and recalled paths of travel for each participant) were analyzed in MAPLE mathematic analysis software in order to find the discrepancy, or area, between them. To find the area between the curves, the points of intersection (p_1, p_2, … p_n) were located. With the points of intersection, the curves were then integrated using:

$$\int_{a}^{p_1} (\text{upper} - \text{lower})dx + \int_{p_1}^{p_2} (\text{upper} - \text{lower})dx + \ldots + \int_{p_n}^{b} (\text{upper} - \text{lower})dx,$$

where a is the smallest data point and b is the largest. The accuracy of the estimated curve's fit to the data points is reported as the coefficient of determination (R^2).

3.6 Statistical analysis

Comparisons of the dependent variables, area of discrepancy (reported in m^2), and difference in length (reported in m) between actual and remembered path of travel were made between the independent variables of grid lined vs. non-grid lined conditions and attending vs. not attending a distractor scenario. The criterion for accepting individualized curves to fit x- and y- coordinates was $p < .10$. As aforementioned, during analysis, 16 participants were eliminated from data analysis due to researcher inability to accurately match a best-fit polynomial curve to participants' path of travel within the $p < .10$ parameters (*see* Section 5 *for details)*. Due to the distribution of data having a skewness of 1.99 (SE = 1.02), nonparametric analysis with a Mann–Whitney U test was performed for area analysis and one extreme outlier was eliminated from the data-set (grid lined: $n = 12$, non-grid lined: $n = 11$). A repeated measures ANOVA was used for length and heart rate analysis. A paired samples *t*-test was used to compare the length variables for actual and recalled distances traveled. The criterion to reject the null hypothesis was $p < .05$. All descriptive statistics are reported as mean (M) ± standard deviation (SD).

4. Results

The individualized curves created during mathematical analysis strongly fit the *x*- and *y*-coordinate sets of the original paths of travel (actual: $R^2 = .90$, $p = .07$; remembered: $R^2 = .88$, $p = .05$). Participants traveled an average distance of 5.15 ± 1.98 m (4.69 ± 4.27 ft) overall. The average discrepancy for all participants was an area of 3.23 ± 4.13 m^2 (34.77 ± 44.45 ft^2) and length of 1.43 ± 1.30 m (see Table 1). Significant length differences were found between the actual and recalled paths of travel ($t(22) = 3.17$, $p < .01$).

No significant area differences were found between the grid lined and non-grid lined conditions ($z = 1.10$, $p = .27$) or the attending and not attending distractor scenarios ($z = .72$, $p = .47$). Additionally, the ANOVA demonstrated that no significant length differences were found between the diagram conditions ($F = 2.83$, $p = .10$) or the distractor scenario participation ($F = 1.05$, $p = .90$).

Participant heart rates were increased immediately following each of the traffic stop scenarios when compared to pretrial heart rate measures (Figure 3) ($F = 163$, $p < .01$). The third stimulus scenario elicited the highest heart rate response from participants, indicating a genuine startle response was evoked.

Table 1. Discrepancy data for variables and subgroups.

		M (SD)[a]	Max (Min)
Area discrepancy[a]			
	Overall ($n = 23$)	3.23 (4.13)	15.82 (.08)
	Gridlined diagram ($n = 11$)	3.08 (4.77)	
	Non-gridlined diagram ($n = 12$)	3.37 (3.65)	
	Distractor scenario ($n = 14$)	3.02 (4.37)	
	No distractor scenario ($n = 9$)	3.57 (3.95)	
Distance discrepancy[b]			
	Overall ($n = 23$)	1.43 (1.30)	5.01 (.14)
	Gridlined diagram ($n = 11$)	1.12 (.94)	
	Non-gridlined diagram ($n= 12$)	1.77 (1.58)	
	Distractor scenario ($n= 14$)	1.37 (1.32)	
	No distractor scenario ($n= 9$)	1.52 (1.35)	
Average actual distance traveled ($n = 23$)		5.15 (1.98)	

Note: M = mean; SD = standard deviation; Max = maximum; Min = minimum.
[a]Denotes area reported in m^2.
[b]Denotes length reported in meters.

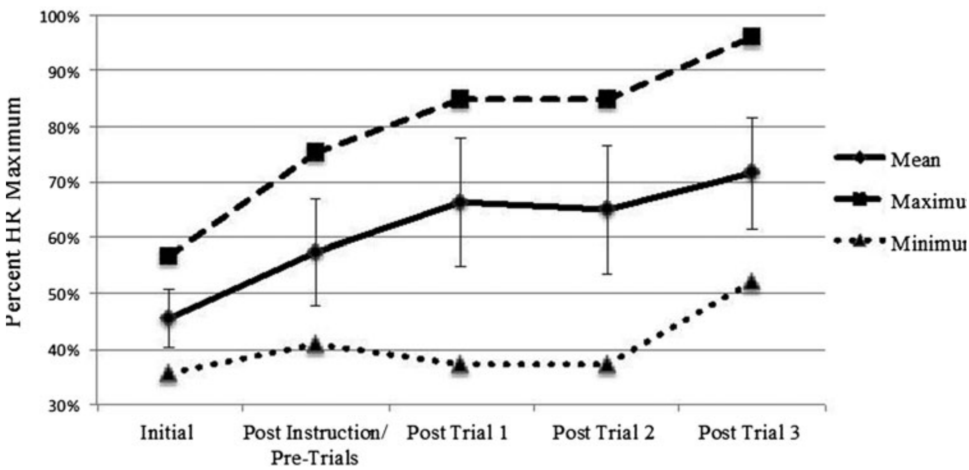

Figure 3. Changes in officer heart rate. Changes in officers' heart rate maximum to stimulus (presented in Trial 3), represented as percentage heart rate maximum.

5. Discussion

This is the first study to examine the accuracy of episodic memory recall for a movement path used by a participant, after encountering and reacting to an actual, high-stress situation. The primary purpose of the study was to examine the average amount of error produced when trying to accurately recall a movement path from a high-stress situation. The secondary purpose of the research was to observe whether the addition of gridlines to demonstrate distance on a diagram would aid in the accuracy of recall, as well as whether a distractor scenario immediately after the stressful event would impair subject recall accuracy.

Due to researcher inability to accurately ($p > .10$) replicate and/or fit movement paths using the mathematical analysis software, 16 of the participants were eliminated from data analysis. Researchers felt using this data would have decreased the validity of the results. Therefore, if the data had been used during analysis, greater but inaccurate results in memory errors would have been found. Also, one additional subject was eliminated from the final data-set due to the extreme skewness their results created in the data.

As demonstrated by the heart rates taken by participants, the confederate driver was able to effectively evoke an authentic, high-stress response during the stimulus phase of the study. The heart rate data collected demonstrate that officers entered the third, stimulus phase at only 65 ± 12% of HR_{max}, yet increased to above 72 ± 10% of their HR_{max} during the third trial (Figure 2). Correlating to previous research, these heart rates are associated with intense levels of aerobic exercise (Frankenhaeuser, 1986; Lewinski et al., 2013; Payne & Rick, 1986; Sime, 1985), thus indicating that the first two trials of the stimulus phase were effective in distracting officers from the primary premise of the study. The researchers are confident that the heart rate reading on the third trial indicates the officers were in a high-stress condition, which indicates that the movement reactions and stress responses generated by officers were genuine and that the study reflects a realistic response to officers responding to a deadly threat and then recalling the event.

The primary results of the study indicate that officers' recalled path of travel differed from their actual path of travel by 3.23 ± 4.13 m^2 (34.77 ± 44.45 ft^2). Participants also produced length discrepancies of 1.43 ± 1.30 m (4.69 ± 4.27 ft) when trying to accurately retrace their movement paths. This data support the previously recognized spatial discrepancies in officer statements collected by Artwohl (2002) and others, as well as demonstrate the large amount of error that may be anticipated with recalled movement and location during a high-stress event. It can be suggested that the errors of officers' reports were most likely due to the information filtering that had occurred in officers during the high-stress situation (stimulus phase) (Hockey, 1997; Hope et al., 2012). This is the most likely cause, as high errors were observed in officers in all groups and occurred even with the aid of memory facilitation with a scaled diagram of the scene. However, further research is suggested to more deeply analyze and examine the cause of these errors.

The implications of this are quite profound, as it is clear that the officers placed themselves at least 20% further than their actual location when they stopped and shot, or shot and stopped. These results indicate that the discrepancy in shot pattern between where an officer stated they fired from and their actual firing placement and shot pattern could unjustly elicit suspicion about the officer's testimony. Generally, the inaccuracy of their memory could be interpreted by critics of law enforcement, such as plaintiffs' attorneys, as meaning they were not really in danger, had more time to consider other options, or a number of other possibilities including intentional deception by the officers.

The secondary investigation demonstrated that, contrary to investigator predictions, the use of gridlines to aid in subject recall accuracy was not effective in decreasing the amount of error in area or length, when compared to a non-grid lined diagram. Although visual aids have been demonstrated to improve memory recall and ability, this study showed no difference between the use of scaled gridlines and no gridlines on a diagram of the scene (Cherry, Park, Frieske, & Smith, 1996; Martyn, 2012). One aspect that may be explored in future research is whether the scaled diagram itself was an aid to recall accuracy and how much error might occur without its use.

Additionally, the distractor scenario, taking place between the stress stimulus phase and the memory recall phase, had no negative influence on subject ability to recall their movement path accurately. These results give support that events occurring shortly after a high-stress event may not have a significant impact on the officer's ability to recall movement and location. Although previous research has recommended that officer interviews take place as soon as possible in order to minimize recall errors or omissions (Caputo & Dunning, 2007; Deffenbacher et al., 2008), this study suggests that events occurring after a use of force situation and before an interview may have no negative influence on officer recall ability. Thus, these results support the International Association of Chiefs of Police (IACP) recommendation that officers delay post-incident interviews and that this delay may have no effect on the accuracy of police officers' memory recall (IACP, 2009).

6. Conclusion

Police investigators, administrators, the justice system, and society have been known to heavily rely on eyewitness testimony and officer reports to provide evidence about an event. By examining the memory capabilities of trained officers when recalling their movement and location during a high-stress situation, these inconsistencies may be better understood and the expectations for memory accuracy redefined. Conclusively, it should be anticipated that trained officers might have significant errors in area, placement, and distance when recalling information from stressful situations due to possible filtering during the encoding process. As noted previously, this filtering process is likely to occur while an officer is more appropriately focused on the more relevant and perhaps immediately critical elements of an event. Additionally, similar error results may be expected for eyewitnesses and suspects; however, further investigation is advised. Although grid lined diagrams had no demonstrated benefit to memory recall, events taking place after the event had no detriments to memory either; however, further research is suggested. Therefore, the only recommendation is to continue support for delayed interviewing for emotional decompression and memory consolidation.

Acknowledgments

We would like to give our great appreciation to Scott Buhrmaster, who served as the confederate driver for the study, to Patricia Thiem and Dawn Seefeldt for coordination of and directing participants through the study, to Dr. Alexis Artwohl for her expertise and the debriefing of participants, and to Sergeant Craig Allen, the Hillsboro Police Department Force Tactics Team, and the Hillsboro Police Department for their efforts in coordinating the study and the recruitment of officers to serve as participants. We would also like to thank Joel Suss for his help in the writing process of this article.

Notes on Contributors

William J. Lewinski is a behavioral scientist specializing in law enforcement related issues. He has a PhD in psychology with a concentration in Police Psychology and is a professor emeritus at Minnesota State University, Mankato, where he taught for nearly three decades. He is the founder and director of the Force Science Institute, Ltd. His research interests are in human behavior in force encounters, focusing on attention/reaction, perception, attention/memory, and judgment. His research and expertise have been published in peer-reviewed journals, national law enforcement publications, websites, and e-newslines, as well as been highlighted on 48 h Investigates, BBC's Panorama, and CNN news.

Jennifer Dysterheft is a doctoral student in Biobehavioral Kinesiolgy at the University of Illinois, Champaign-Urbana, and a research assistant at the Force Science Institute. She received her MS degree in Exercise Physiology from Minnesota State University, Mankato. Her primary research interests are biomechanics and kinesiology, human movement and performance, and movement analysis.

Matthew Priem is a mathematics instructor at Minnesota State University, Mankato. Matthew received his MA in mathematics from Minnesota State University, Mankato. His primary research interests include the cohomology of tiling spaces and mathematics education.

Robert Pettitt is an exercise scientist at Minnesota State University, Mankato, and has worked in various capacities of sports performance and strength and conditioning across the USA. He has a PhD in Exercise Science with emphasis in Exercise Physiology from the University of Utah. Bob is a certified strength and conditioning specialist with the NSCA and a certified athletic trainer with the NATA. He is an expert in the assessment of endurance athletes and has published over 50 research articles/abstracts on the validity of endurance exercise measurements, along with the prevention and treatment of musculoskeletal injuries associated with distance running. His textbook, *Exercise Physiology Laboratories* (2009), is available through Kendall-Hunt Publishing.

References

Alpert, G. P., Rivera, J., & Lott, L. (2012). Working toward the truth in officer-involved shootings. *FBI Law Enforcement Bulletin, 81*(5), 1–7.

Arnell, K. M., Killman, K. V., & Fijavz, D. (2007). Blinded by emotion: Target misses follow attention capture by arousing distractors in RSVP. *Emotion, 7*, 465–477.

Artwohl, A. (2002). Perceptual and memory distortion during officer-involved shootings. *FBI Law Enforcement Bulletin, 71*, 18–24.

Artwohl, A. (2003). No recall of weapon discharge. *Law Enforcement Executive Forum, 3*, 41–49.

Beehr, T. A., Ivanitskaya, L., Glaser, K., Erofeev, D., & Canali, K. (2004). Working in a violent environment: The accuracy of police officers' reports about shooting incidents. *Journal of Occupational and Organizational Psychology, 77*, 217–235.

Buchanan, T. W., & Lovallo, W. R. (2001). Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology, 26*, 307–317.

Caputo, D. D., & Dunning, D. (2007). Distinguishing accurate eyewitness identifications from erroneous ones: Post-dictive indicators of eyewitness accuracy. In R. C. L. Lindsay, D. F. Ross, J. D. Read, & M. P. Toglia (Eds.), *Handbook of eyewitness psychology: Volume 2: Memory for people* (pp. 427–452). Mahwah, NJ: Erlbaum.

Carr, M. F., Jadhav, S. P., & Frank, L. M. (2011). Hippocampal replay in the awake state: A potential substrate for memory consolidation and retrieval. *Nature Neuroscience, 14*, 147–153.

Chabris, C. F., Weinberger, A., Fontaine, M., & Simons, D. J. (2011). You do not talk about Fight Club if you do not notice Fight Club: Inattentional blindness for a simulated real-world assault. *i-Perception, 2*, 150–153.

Cherry, K. E., Park, D. C., Frieske, D. A., & Smith, A. D. (1996). Verbal and pictorial elaborations enhance memory in younger and older adults. *Aging, Neuropsychology, and Cognition, 3*, 15–29.

Colavita, F. B. (1974). Human sensory dominance. *Perception & Psychophysics, 16*, 409–412.

Deffenbacher, K. A., Bornstein, B. H., McGorty, E. K., & Penrod, S. D. (2008). Forgetting the once-seen face: Estimating the strength of an eyewitness's memory representation. *Journal of Experimental Psychology: Applied, 14*, 139–150.

Fawcett, J. M., Russell, E. J., Peace, K. A., & Christie, J. (2013). Of guns and geese: A meta-analytic review of the 'weapon focus' literature. *Psychology, Crime & Law, 19*, 35–66.

Force Science Institute. (2009). "I took an oath …": Dan Lovelace's battle back to law enforcement. *Force Science News*, #129. Retrieved from http://www.forcescience.org/fsinews/2009/08/force-science-news-129-%E2%80%9Ci-took-an-oath%E2%80%A6%E2%80%9D-dan-lovelace%E2%80%99s-battle-back-to-law-enforcement/

Foster, D. J., & Wilson, M. A. (2006). Reverse replay of behavioural sequences in hippocampal place cells during the awake state. *Nature, 440*, 680–683.

Frankenhaeuser, M. (1986). A psychobiological framework for research on human stress and coping. In M. H. Appley & R. A. Trumbull (Eds.), *Dynamics of stress* (pp. 101–116). New York, NY: Springer.

Furley, P. A., & Memmert, D. (2012). Working memory capacity as controlled attention in tactical decision making. *Journal of Sport and Exercise Psychology, 34*, 322–344.

Glickman, S. E. (1961). Perseverative neural processes and consolidation of the memory trace. *Psychological Bulletin, 58*, 218–233.

Hardt, O., Nader, K., & Nadel, L. (2013). Decay happens: The role of active forgetting in memory. *Trends in Cognitive Sciences, 17*, 111–120.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). San Diego, CA: Academic Press.

Hockey, G. R. J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology, 45*, 73–93.

Hope, L., Lewinski, W., Dixon, J., Blocksidge, D., & Gabbert, F. (2012). Witnesses in action: The effect of physical exertion on recall and recognition. *Psychological Science, 23*, 386–390.

Hope, L., & Wright, D. (2007). Beyond unusual? Examining the role of attention in the weapon focus effect. *Applied Cognitive Psychology, 21*, 951–961.

International Association of Chiefs of Police. (2009). *Officer-involved shooting guidelines*. Philadelphia, PA: IACP Police Psychological Services Section.

Jadhav, S. P., Kemere, C., German, P. W., & Frank, L. M. (2012). Awake hippocampal sharp-wave ripples support spatial memory. *Science, 336*, 1454–1458.

Kane, M. J., Conway, A. R., Hambrick, D. Z., & Engle, R. W. (2007). Variation in working memory capacity as variation in executive attention and control. *Variation in Working Memory, 1*, 21–48.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review, 9*, 637–671.

Kim, J. J., & Diamond, D. M. (2002). The stressed hippocampus, synaptic plasticity and lost memories. *Nature Reviews Neuroscience, 3*, 453–462.

Klinger, D. (2001). *Police responses to officer-involved shootings*. Washington, DC: U.S. Government Printing Office: NCJ 192286.

Kuhlmann, S., Piel, M., & Wolf, O. T. (2005). Impaired memory retrieval after psychosocial stress in healthy young men. *Journal of Neuroscience, 25*, 2977–2982.

Levin, D. T., & Angelone, B. L. (2008). The visual metacognition questionnaire: A measure of intuitions about vision. *The American Journal of Psychology,* 451–472.

Lewinski, W. J. (2008). The attention study. *Law Enforcement Executive Forum, 8*, 107–139.

Lewinski, W. J., Dysterheft, J. L., Seefeldt, D. A., & Pettitt, R. W. (2013). The influence of officer positioning on movement during a threatening traffic stop scenario. *Law Enforcement Executive Forum, 13*, 98–109.

Macdonald, J. S., & Lavie, N. (2008). Load induced blindness. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 1078.

Mack, A., & Rock, I. (1998). *Inattentional blindness* (pp. 286–290). Cambridge, MA: MIT press.

Martens, S., & Wyble, B. (2010). The attentional blink: Past, present, and future of a blind spot in perceptual awareness. *Neuroscience and Biobehavioral Reviews, 34*, 947–957.

Martyn, E. (2012). *Picture this: Visual aids facilitate children's, adolescents' and adults' eyewitness recall* (Master's thesis). Otago University Research Archive. (10523/2668).

McGaugh, J. L. (2000). Memory – A century of consolidation. *Science, 287*, 248–251.

Mori, N. (1995). The function of remembering and the nature of a group in joint remembering. *Japanese Psychological Review, 38*, 107–136 (In Japanese with an English abstract).

Mori, N. (2008). Styles of remembering and types of experience: An experimental investigation of reconstructive memory. *Integrative Psychological and Behavioral Science, 42*, 291–314.

Muller, G. E., & Pilzecker, A. (1900). Experimentelle beitrage zur lehre vom gedachtnis [Experimental contributions to the theory of memory]. *Journal of Psychology, 1*, 1–300.

Payne, J., Jackson, E., Ryan, L., Hoscheidt, S., Jacobs, J., & Nadel, L. (2006). The impact of stress on neutral and emotional aspects of episodic memory. *Memory, 14*(1), 1–16.

Payne, R. L., & Rick, J. T. (1986). Heart rate as an indicator of stress in surgeons and anaesthetists. *Journal of Psychosomatic Research, 30*, 411–420.

Payton, G. T., & Amaral, M. (1996). *Patrol operations and enforcement tactics* (10th ed.). San Jose, CA: Criminal Justice Services.

Perry, T., & A. (1998). *Basic patrol procedures* (2nd ed.). Salem, WI: Sheffield Publishing Company.

Prinz, J. J. (2010). When is perception conscious? In B. Nanay (Ed.), *Perceiving the world: New essays on perception* (pp. 310–332). New York, NY: Oxford Press.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849–860.

Roozendaal, B. (2003). Systems mediating acute glucocorticoid effects on memory consolidation and retrieval. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 27*, 1213–1223.

Rugg, M. D., & Wilding, E. L. (2000). Retrieval processing and episodic memory. *Trends in Cognitive Sciences, 4*, 108–115.

Shadmehr, R., & Holcomb, H. H. (1997). Neural correlates of motor memory consolidation. *Science, 277*, 821–825.

Sime, W. E. (1985). Physiological perception: The key to peak performance in athletic competition. In J. H. Sandweiss & S. L. Wolf (Eds.), *Biofeedback and sports science* (pp. 80–82). New York, NY: Plenum Press.

Simons, D. J. (2010). Monkeying around with the gorillas in our midst: Familiarity with an inattentional-blindness task does not improve the detection of unexpected events. *i-Perception, 1*, 3–6.

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception, 28*, 1059–1074.
Solomon, R. M. (1997). I know I must have shot, but I can't remember. *The Police Marksman, 21*, 48–51.
Spence, C. (2009). Explaining the Colavita visual dominance effect. *Progress in Brain Research, 176*, 245–258.
Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*, 153–156.
Zanto, T. P., & Gazzaley, A. (2009). Neural suppression of irrelevant information underlies optimal working memory performance. *Journal of Neuroscience, 29*, 3059–3066.