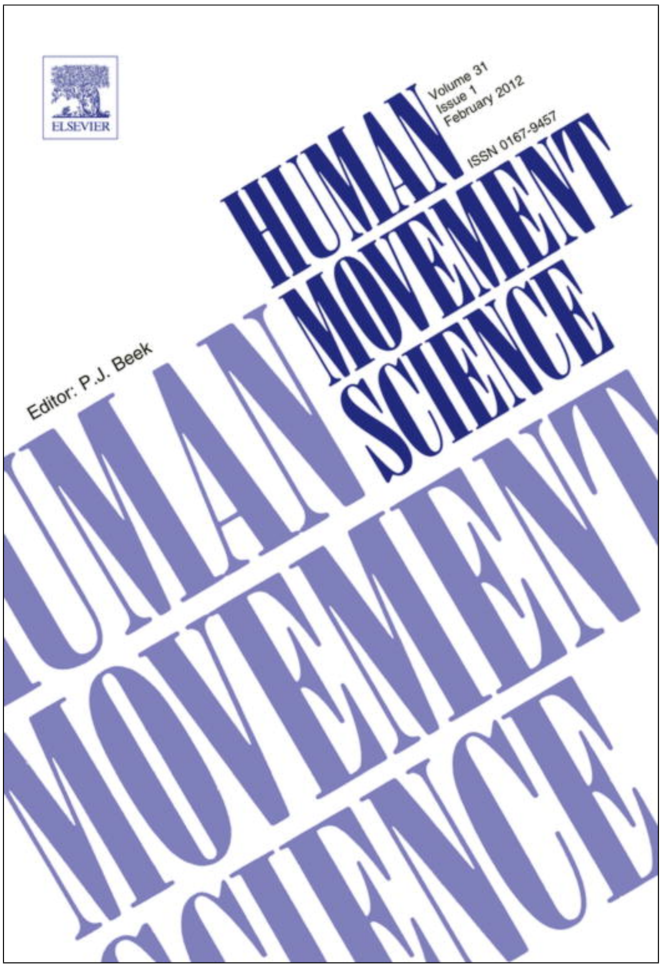
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Performing under pressure: Gaze control, decision making and shooting performance of elite and rookie police officers

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ABSTRACT

Gaze of elite (E) and rookie (R) officers were analyzed as they faced a potentially lethal encounter that required use of a handgun, or inhibition of the shot when a cell phone was drawn. The E shot more accurately than the R (E 74.60%; R 53.80%) and made fewer decisions errors in the cell condition when 18.50% of E and 61.50% of R fired at the assailant. E and R did not differ in duration of the draw/aim/fire phases, but the R's motor onsets were later, during the final second compared to the E's final 2.5 s. Across the final six fixations the E increased the percent of fixations on the assailant's weapon/cell to 71% and to 86% on hits, compared to a high of 34% for the R. Before firing, the R made a rapid saccade to their own weapon on 84% of trials leading to a failure to fixate the assailant on 50% of trials as they fired. Compared to the R, the E had a longer quiet eye duration on the assailant's weapon/cell prior to firing. The results provide new insights into officer weapon focus, firearms training and the role of optimal gaze control when under extreme pressure.

1. Introduction

The ability to perform under extreme pressure is a quality sought by all, whether in the military, law enforcement, emergency medicine or sport. Why are some able to maintain their focus and make

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the right decision under the most trying of circumstances, while others fail in a similar situation? The human's ability to deal with life and death situations is not well understood in science, due to the inherent difficulties associated with simulating extreme events, of testing individuals at the poles of expertise, and of harnessing technology that can provide relevant information in compressed and physically challenging time frames. Yet the prevalence of force on force encounters is growing on our streets as more and more officers are faced with serious crimes involving firearms (Barclay, Tavares, Kenny, Siddique, & Wilby, 2003). Officer involved shootings lead to a costly process where lives are lost, careers ruined and billions of taxpayer dollars spent on investigation and litigation costs (Dumke, 2009; Klinger, 2006). Highly trained special weapons attack officers (SWAT) handle a greater number of serious incidents than non-SWAT officers yet they make fewer errors (Williams & Westhall, 2003). We therefore determined the gaze, decision making and shooting performance of highly trained elite officers who had extensive experience with violent encounters and rookies who were nearing the completion of their training program in an *in situ* encounter where an "assailant" suddenly either drew a weapon from under his coat, spun rapidly and fired, or pulled out a cell phone instead.

Control of the gaze plays a major role in models of visuo-motor control (Corbetta, Patel, & Shulman, 2008; Land, 2009). Corbetta et al. (2008) explain that the gaze is controlled by a neural network that includes a "dominant ventral frontoparietal network that interrupts and resets ongoing activity and a dorsal frontoparietal network specialised for selecting and linking stimuli and responses" (p. 306). Feeding spatial information into both networks is the gaze system which directs attention to important objects or events within a scene in real time and in the service of ongoing perceptual, cognitive, and behavioral activity (Henderson, 2003). Currently most firearms training programs teach officers to focus their gaze on two locations, first on the sights of their gun, and secondly on the target before pulling the trigger (Hendrick, Paradis, & Hornick, 2008; Morrison & Vila, 1998). This gaze strategy works very well in training with rookies achieving high accuracy scores before graduation but once on the street and faced with a violent firearms encounter they shoot poorly, averaging between 10 and 60% accuracy (Morrison & Vila, 1998; Oudejans, 2008).

Eye movements studies show that the type of gaze control rookies are taught in firearms training differs from that used by elite athletes who perform in the pistol, rifle and shotgun sporting events. Ripoll, Papin, Guezennec, Verdy, and Philip (1985) recorded the gaze of elite and near-elite Olympic pistol shooters as they fired at a fixed target. The near-elite shooters first fixated the sights on the pistol and then aligned the sights of their gun to the target resulting in a final fixation that was shorter in duration than that of the elite shooters who fixated the target first and never let their gaze deviate from the target as they raised their pistol and aligned the sights relative to one stable line of gaze. This resulted in a longer final fixation duration and higher accuracy.

Similar results were found by Vickers and Williams (2007) who tested Olympic biathlon rifle shooters under low and high levels of pressure and physiological arousal. The athletes took standing shots at a target after exercising on a bike ergometer at individually prescribed power output *(PO)* from 55% to 100% of their maximum power output. Performance pressure was manipulated by testing them in a low pressure condition where they were told that the purpose of the testing was to give them information about their fixation on the target, while in the high-pressure condition they were told their shooting percentages would be used in Olympic team selections. Although the athletes did not differ in levels of anxiety, heart rate and rate of perceived exertion when under high pressure, those who choked at the highest workload (accuracy <30%) reduced the duration of their final fixation, or quiet eye, on the target while those who did not choke (accuracy >80%) increased their quiet eye duration above any level found during the low or high pressure. In effect, the use of a long duration quiet eye seemed to reduce the normally debilitating effects of high anxiety, pressure and physiological stress. Similar quiet eye findings have been found for elite athletes performing in long distance rifle shooting (Janelle et al., 2000) and the three shotgun events of skeet, trap, and double trap (Causer, Bennett, Holmes, Janelle, & Williams, 2010).

The QE was defined by Vickers (1996, 2007) as the final fixation or tracking gaze that is located on a specific location or object in the performance space within three degrees of visual angle for a minimum of 100 ms prior to the onset of a critical movement. The quiet eye has been shown to underlie higher levels of skill and/or performance in a wide range of skills, including golf (Vickers, 1992, 2004, 2007; Vine, Moore, & Wilson, 2011); basketball (de Oliveira, Oudejans, & Beek, 2008; Harle & Vickers, 2001; Vickers, 1996; Vine & Wilson, 2011); rifle and shot gun shooting (Causer et al., 2010; Janelle et al., 2000; Vickers & Williams, 2007); billiards (Williams, Singer, & Frehlich, 2002) and ice hockey goaltending (Panchuk & Vickers, 2006, 2009). Participants who have been tested in high pressure situations have a higher frequency of gaze, more fixations of shorter duration (Behan & Wilson, 2008; Janelle, 2002; Williams, Vickers, & Rodrigues, 2002; Wilson, Vine, & Wood, 2009), as well as a reduced ability to detect information in the periphery (Janelle, Singer, & Williams, 1999). Janelle et al. (2000) also found progressive quieting of the left hemisphere of elite marksmen before the trigger pull and quiet eye durations that were significantly longer for the elite shooters than for non-elite. In a recent meta-analysis Mann, Williams, and Ward (2007) found that a longer quiet eye duration was one of three predictors of perceptual-motor expertise, along with specific fixation locations and a low frequency of fixations. In every motor task there appears to be a crucial moment when the individual must fixate or track specific task information and this must occur before a critical final movement is made.

Most QE studies have been carried out in sport tasks where the participants were familiar with the conditions of performance. In the current study the officers were not aware of the scenario, but instead were faced with an unknown "assailant" in a strange room and events they could not predict in advance. As such, the situation was similar to that found during the commission of crime, where the intentions of the perpetrator are most often unknown until the last few seconds. A number of studies have shown that the gaze of eye witnesses to a crime is drawn to only one location – the weapon being used by the perpetrator (Hendrick et al., 2008; Hope & Wright, 2007; Hulse & Memon, 2006; Kassin, Tubb, Hosch, & Memon, 2001; Pickel, 1999; Stanny & Johnson, 2000; Steblay, 1992). Weapon focus refers to "the concentration of a crime witness's attention on a weapon, and the resultant reduction in ability to remember other details of the crime" (Loftus, Loftus, & Messo, 1987, p. 55). While weapon focus is considered a robust finding, applicable to both lay-persons and police officers, some reservations have been expressed due to there being no empirical support during an actual live encounter (for example, Turtle, Read, Lindsay, & Brimacomb, 2008). The gaze of officers has also not been determined during a situation where they must fulfil the dual role of a witness to a crime and that of an officer who must draw, aim and fire accurately under extreme pressure, or alternatively inhibit its use when a benign object such as a cell phone is pulled from a pocket in a manner similar to when a gun is drawn.

Weapon focus studies have largely been carried out using video simulations, yet there is growing evidence that the gaze differs in simulated environments from that found in real world *situations* where performers are able to physically perform the motor skills being investigated. Müller and Abernethy (2006) and Mann, Abernethy, and Farrow (2010) have shown that cricket batsmen step earlier and track the ball longer against a live bowler than when addressing video simulations of pitches. Dicks, Button, and Davids (2010) found similar results in a soccer goaltending penalty kick study which used five experimental conditions – a video simulation of kicks with verbal and joystick responses, and on the field responses against a kicker using verbal, step and normal interceptive responses. Not only did the goalkeepers make more saves in the *in situ* condition, but they focused on fewer locations and had earlier reaction times and faster movement times. Van der Kamp, Rivas, van Doorn, and Savelsbergh (2008), Mann et al. (2010) and Dicks et al. (2010) have commented that when simulators are used, critical elements are often removed leading to activation of only the ventral system, while in the *in situ* setting both ventral and dorsal processing occurs. The ventral system is the slower of the two systems and facilitates the reorienting of attention and cognitive processing, whereas the dorsal system is designed to control fast actions that are controlled automatically (Corbetta et al., 2008; Milner & Goodale, 1995, 2008). Elite performers use both systems, switching back and forth as needed, whereas novices may rely too much on one or the other depending on how they are assessed. When simulators are used the dorsal and ventral systems may become de-coupled as there is no real consequences or immediacy built into the task, while during *in situ* situations the specificity of action is maintained and perception–action coupling occurs which more accurately reflects the true nature of the visuo-motor system as it has been trained to function. Since video simulators are used extensively in police training, there is an added importance of a study where the gaze and motor responses of officers are assessed under conditions that are very similar to those encountered in the field.

In summary, it is not known if officers involved in a lethal firearms encounter control their gaze as taught in training, or as found for elite athletes in the shooting sports, or as described by the weapon focus literature. We therefore determined the gaze and shooting performance of elite and rookie officers during a gun condition where shots were always fired, and a cell condition where all aspects of the scenario were the same but a cell phone was drawn instead of a gun. Shooting performance was assessed using shot accuracy (%), location of shots (%) and shot speed (ms). Decision making was determined during the cell condition using the percentage of officers who inhibited both shots. Overall performance (low, high) took into account combined measures of shot accuracy, shot speed and shots inhibited. The officers motor phase durations (ms) were determined for the first seven seconds (prepare, unholster) and last seven seconds (assess, draw, hold, aim/fire), while the assailant's phase durations (ms) were determined during the final seven seconds: (confront, pivot, aim/fire). Fixation variables were fixation location (%), fixation duration (ms), QE duration (ms) and final saccade location (%).

During the initial part of the encounter, we expected both the elite and rookie officers to employ a weapon focus fixating locations on the assailant where a weapon could be hidden. If the weapon's focus literature holds true the officers should fixate the weapon being used, or the cell phone, with other areas being secondary. As the assailant pivoted, aimed and fired (or appeared to) we therefore expected the elite officers to maintain a longer duration QE on the assailant's weapon or cell prior to firing or inhibiting the shot, while the rookies QE period would be briefer and to locations that were more varied. Consequently, we expected the elite officers to shoot with greater accuracy during the gun condition and make fewer decision errors during the cell condition, while the rookies would exhibit less control over their gaze leading to lower shooting accuracy and more decision errors.

2. Methods

2.1. Participants

24 officers volunteered for the study, 11 elite (E) male members of an Emergency Response Team and 13 rookies (R) from the same department, 6 males and 7 females. The E officers had extensive field experience dealing with firearms incidents through-out their career, while the R were at the end of their training program. The E were significantly older, $F(1, 22) = 7.11$, $p < .01$, $\eta_p^2 = .24$ ($M = 38.82$ yrs ± 4.60 yrs) than the R ($M = 30.54$ yrs ± 6.55 yrs). The shooting eye of the officers was predominately right (E 9/11; R 9/13), as was their shooting hand (E 10/11; R 13/13). Shooting performance results were available for all 24 officers, but coupled gaze and motor data were available for 18 officers (elite, male $n = 8$; rookie, $n = 10$, 6 males, 4 females). Gaze data were not available for six officers due to squinting as they fired, or tilting the head laterally causing loss of scene by the eye tracker. Testing occurred within a police training academy over a period of two weeks under the supervision of trained safety personnel. All officers gave their informed consent prior to participating and ethics approval was received prior to testing.

2.2. Materials and procedures

The vision-in-action (VIA) system (Vickers, 1996, 2007) was used to record the coupled gaze and motor behaviors of the officers. The Mobile Eye is a light (76 g) monocular eye-tracking system that uses corneal reflection to measure eye-line-of-gaze with respect to the field of view (accuracy of ±1° visual angle and precision of 0.5°). Three frames of VIA data (A–C) are shown in Fig. 1, as recorded during the final two seconds. Image 1 of each frame (A–C) was recorded by the cameras on the eye tracker worn by the officer. The small circle shows the location of the officer's gaze and the larger circle indicates normal pupil recognition. Image 2 was recorded by an external camera that simultaneously captured the officer's shooting movements. Audio of the assailant and officer's shots was determined using a central microphone connected to a Shure SCM 268 mixer. Precise synchronization of images 1 and 2 and the audio output occurred post-data collection using Final Cut Pro (Apple Corporation).

Fig. 1. Three frames of coupled gaze and motor data collected during the final 2 seconds of the encounter.

2.3. The Scenario

The scripted scenario was designed to simulate situations common in law enforcement where officers are faced with a rapidly unfolding event in which critical cues are visible for only a short period of time and where they have to make a decision under extreme time pressure to fire their handgun or inhibit the shot. The scenario was about one minute in length and consisted of an entrance phase of seven seconds, a middle phase of about 45 s and a final attack phase of seven seconds. The assailant entered from a side door and approached a receptionist who was seated at a desk 7 m from the officer who stood on duty guarding the entrance to a government office (see Fig. 1). Upon reaching the desk he turned his back to the officer and complained to the receptionist that he had been unjustly jailed for the past three days. He requested a meeting with an official so that he could get his passport back. The receptionist was polite, but not helpful, leading the man to become increasingly agitated. During the final seven seconds the scenario escalated with the assailant slamming his hands on the table and angrily raising his voice. Suddenly, with two seconds remaining he pulled a handgun (or cell phone) from under his coat with his right hand, executed a rapid reverse pivot and shot at the officer, or brandished the cell phone in such a way he appeared to shoot. There was no hesitation in his movements as he aimed and fired from a distance of about 5 m. The scenario was designed so there was a very brief window of time at the very beginning and at the end when critical cues were available that could be fixated only at that time. The assailant's coat was open during the first three seconds as he entered the room and it was only during the final two seconds that the gun or cell phone was visible prior to firing. These points of time were therefore critically important and in many respects simulated conditions found on the street when events unfold rapidly and critical information is available for only a brief period of time. Four and five seconds were added, respectively, after each of these critical moments to also allow for an analysis of fixations while the assailant stood with the weapon hidden, resulting in an equal seven seconds at the beginning and seven second at the end of the scenario that was analyzed. Prior to the study, both the assailant and receptionist worked with an acting coach who trained them to maintain the same timing and mannerisms throughout. The man who played the assailant was a police lieutenant who had extensive handgun and role playing experience. The receptionist worked in law enforcement and had taken part previously in scenarios for research purposes.

2.4. Procedures

The officer and assailant were fitted with protective gear and a standard Glock handgun loaded with one Simunition shell by a safety officer. All had used a similar weapon in training. The eye tracker was fitted and calibrated to a nine-point grid, followed by a second calibration to locations on the receptionist's desk. Before the first trial the assailant was located out of sight in a side room. Prior to beginning, each officer was read the following instructions in order to ensure the same information was delivered:

"Your task today is to provide security for a government entrance. Behind you are the doors you must guard. We have intelligence information that an armed encounter will happen on your location today. You are to handle the threat using only your handgun. Recognizing the first shot is the most important, you are limited to only one shot – your magazine is loaded with one round. You may not step outside this designated area; you may not move forward of the red cones".

The two conditions were then performed consisting of five gun trials and two cell trials. Trial one was always a gun trial, while the cell trials were randomly assigned from trials two to seven. A recorder kept track of shot accuracy (hit, miss) and the location of shots (head, upper body/arms, lower body/legs, missed). The data as shown in Fig. 1 were monitored throughout using a firewire connection thus ensuring accuracy of the calibration. When necessary re-calibration was carried out by having the officer fixate objects on the desk. Data collection took approximately 45 min.

2.5. Officer and assailant motor phases

Motor phases were coded for the first seven seconds and final seven seconds using the Quiet Eye Solutions v2 (QES v2) software, a software package that synchronizes the gaze, motor and audio data. During the first seven seconds, two officer phases were identified (prepare, unholster). The prepare phase occurred from the first frame as the assailant entered the room until the officer's hand moved to his or her gun. The unholster phase continued from the hand on the gun until 7000 ms had elapsed. During the final seven seconds, four officer phases were determined (assess, draw, hold, aim/fire) and three assailant phases (confront, pivot, aim/fire). The officer's assess phase began 7000 ms before the end of the trial until the first frame showing the officer's gun being drawn upward from the holster; the draw occurred from the upward movement of the hand to maximum flexion of the elbow; the hold phase occurred from maximum flexion of the elbow until the frame showing extension of the gun toward the assailant; the aim/fire phase occurred from the frame showing extension of the gun arm toward the assailant until the shot was fired (audio of shot), or during the cell trials when the gun slowed and was maximally extended. The assailant's confront phase began 7000 ms before the end of the trial and lasted until the frame showing the first movement of the shooting hand/arm upward to draw the gun or cell phone from under the coat; the pivot phase occurred from the first movement of the shooting arm/elbow until the gun or cell was first visible; the phase occurred from the gun/cell first being visible until the a shot was fired, or the hand with the cell phone was maximally extended. The trigger pull was estimated from previous studies as occurring a constant 100 ms prior to the shots being recorded by the audio (Bumgarner, Lewinski, Hudson, & Sapp, 2006; Tobin & Fackler, 1997).

2.6. Coding officer fixations

The officers fixations were coded during the first seven seconds and during the final seven seconds using the QES v2 software. Since the goal during the first seven seconds was to determine how soon the E and R fixated potential weapon locations and for how long, the fixations were ordered sequentially from first to last in the trial using a sort function of QES v2. During the final seven seconds fixations were sorted in reverse order (last to first). By ordering the fixations from last to first it was possible to determine the sequence and duration of locations fixated prior to the shot and their importance in performance. This procedure has been used previously in studies where a culminating action occurred at the end of the trial, such as stepping over a barrier (Patla & Vickers, 1997), stopping a shot in ice hockey goaltending (Panchuk & Vickers, 2009), or firing a gun (Vickers & Williams, 2007). Fixations and saccades were coded using definitions from previous studies (Vickers, 1996, 2007; Vickers & Williams, 2007). A fixation occurred when the gaze was held stable on a location for a minimum of 100 ms within two degrees of visual angle (the width of the cursor in Fig. 1). Four fixation locations were identified: assailant weapon/cell, assailant non-weapon, officer weapon and off the assailant. Weapon/cell sub-locations included the assailant's gun, hand/elbow, arm, inside coat, chest, right pocket, belt). Non-weapon sub-locations included the assailant's non-gun hand/arm, back, head, face, shoulders, legs, non-gun pocket. Fixations on the officer's gun included the Glock pistol and shooting hand. Off the assailant occurred when a fixation was more than two degrees off the assailants body, or on the receptionist, or any other location in the room. Saccades were coded when the eyes moved rapidly from one fixated location to another with a minimum duration of 66.66 ms (2 frames). Code-recode reliability was established using two independent coders. Intra-class correlations in excess of .90 were established for the all phases and quiet eye duration using procedures from Thomas and Nelson (2001).

2.7. Statistical analysis

Shooting accuracy (%) was determined in the gun trials using a one way (expertise, E, R) factorial ANOVA. Percent of officers who successfully inhibited the shots during the cell condition was analyzed using a one way (expertise, E, R) factorial ANOVA. Overall shooting performance took into account measures of shooting accuracy, shot speed and decision making and was analyzed using Chi square procedures. Officer and assailant motor phase durations and onsets were analyzed using an Expertise × Phase × Condition ANOVA, with repeated measures on the last two factors. Percent of fixations during the first seven seconds was determined using an Expertise (E, R) × Fix Sequence (Fix 1–10) × Location (assailant weapon/cell, assailant non-weapon, off the assailant) ANOVA, with repeated measures on the last two factors. During the final seven seconds, percent fixations was analyzed using an Expertise (E, R) × Fix Sequence (Fix 1–6) × Location (assailant weapon/cell, assailant non-weapon, off-assailant, officer weapon) ANOVA, with repeated measures on the last two factors. Fixation durations were analyzed using an Expertise (E, R) × Fixation Sequence (1–6) and Performance (high, low) × Fixation Sequence (1–6) ANOVA, with repeated measures on the last factor. QE duration was determined using an Expertise (E, R) × Location (assailant weapon/cell, officer weapon) factorial ANOVA. Greenhouse-Geisser epsilon was used to control for violations of sphericity in the repeated measures designs and adjusted *p*-values are reported where necessary. The effect sizes were calculated using partial eta squared (η_p^2). Significance level was set at $p < .05$ for all tests.

3. Results

3.1. Shooting accuracy

A significant difference was found due to expertise, $F(1, 22) = 8.23$, $p < .009$, $\eta_p^2 = .27$. The E hit the assailant on 74.54% ± 5.44 of shots compared to 53.85% ± 4.74 for the R.

3.2. Decision making

Significant difference were found due to expertise, $F(1, 22) = 5.22$, $p < .03$, $\eta_p^2 = .14$. During the cell condition, 18.18% ± 12.19% of the E officers (2 of 11) fired at the assailant compared to 61.54% ± 14.04% of the R (8 of 13).

3.3. Firing speed

The E fired before the assailant on 92.50% of trials compared to 42.22% for the R. They were also faster than the assailant by an average of 179.05 ms (36.84 ± 6.06) and the R were slower than the E by an average of 13.26 ms. Four shots ended in a draw (2 E; 2 R). The E hit the assailant in the upper torso (62.07%), the arms/hands (31.03%) and legs (6.90%). Respective percentages for the R were upper torso (48.39%), arms/hands (35.48%), legs (6.45%) and head (9.67%).

3.4. Overall performance

Overall performance (high, low) was determined by combining measures of shooting accuracy, shot speed and decision making. High performance trials occurred when all three of the following criteria were met per trial: on gun trials the shot was accurate; on gun trials accurate shots occurred before the assailant's shot, and on cell trials the shot was inhibited. Low performance trials occurred when the shot missed, the shot occurred after the assailant's shot and on cell trials a shot was fired. Failing to draw during a gun trial was a low performance characteristic (4 R trials). The E group recorded a significantly more high performance trials than the R, $X2$ $(1, N = 255) = 6.63$, $p < .0009$, $\phi = .51$. On 75.00% of trials the E officers met the criteria of high performance compared to 52.86% of trials for the R.

3.5. Percent fixations during first seven seconds

During the first seven seconds three trials were analyzed per officer (the first hit, the first miss, and the first cell trial). No significant differences were found in fixation frequency or duration due to condition, but significant differences were found in location due to expertise, $F(1, 270) = 9.19$, $p < .008$, $\eta_p^2 = .38$, location, $F(2, 270) = 25.14$, $p < .0001$, $\eta_p^2 = .63$, and the interaction of Expertise × Location, $F(2, 270) = 5.60$, $p < .009$, $\eta_p^2 = .16$. Fig. 2 shows that the E fixated more locations where a weapon could be concealed ($M = 50.29\% \pm 3.53$) than the R ($M = 30.62\% \pm 2.89$), while the R looked more to non-weapon locations ($M = 51.13 \pm 3.35$; E $M = 42.11 \pm 3.53$), or off the assailant ($M = 18.07$, $SE \pm 2.43$; $M + 7.59 \pm 2.26$). Frequency distributions were determined for the sub-locations. The E looked inside the assailant's coat more than the rookies during the brief time this was possible (E = 9.44; R = 3.18). E and R were similar in percent fixations to the assailant's face (E = 11.165; R = 13.43), which was visible only as the assailant entered the room. They were also similar in the percent of fixations on the receptionist (E = 5.15%, R = 5.65%).

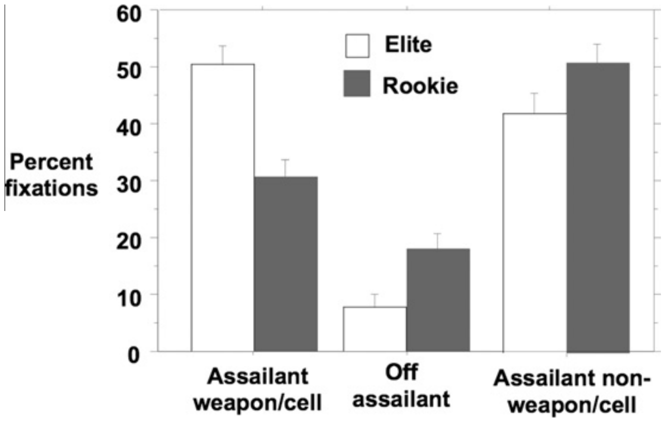

Fig. 2. Percent of elite and rookie fixations to the assailant's weapon/cell, off the assailant and on assailant non-weapon locations.

3.6. Officer's phase duration (ms) during first seven seconds

Of interest was how soon the officer's moved their hand to unholster their gun as this signaled the officer's awareness of an escalating situation. Significant differences were found for phase, $F(1, 50) = 4.46$, $p < .04$, $\eta_p^2 = .08$, and the interaction of Expertise × Phase, $F(1, 50) = 49.41$, $p < .0001$, $\eta_p^2 = .50$. The E officers unholstered within 1774.75 ms ± 3056 ms of the assailant entering the room, while the R did not unholster until 6275 ms ± 1529 ms had elapsed.

3.7. Assailant's phase durations during final seven seconds

Since all officers faced the same assailant, it was important to determine if his movement durations were similar against the E and R. No significant differences were found due to expertise, $p > .05$, or the interactions of Expertise × Condition, $p > .05$ or Expertise × Condition × Phase, $p > .05$, but significant differences were found for phase, $F(1, 122) = 43.78$, $p < .0001$, $\eta_p^2 = .26$, and the interaction of expertise by phase, $F(1, 122) = 13.76$, $p < .0003$, $\eta_p^2 = .10$. Table 1 shows that against the E, the assailant's pivot and aim/fire phase durations were, respectively, $M = 995.21$ ms ± 459.21 ms and $M = 579.81$ ms ± 100.93 ms. Corresponding values against the rookies were $M = 919.56$ ms ± 483.13 ms and $M = 887.16$ ms ± 313.89 ms. This meant that the assailant's pivot phase was similar against E and R, but he slowed his aim/fire phase against the R. Review of the video data showed this occurred on trials when the R were having great difficulty and the assailant slowed his shot to give them more time to aim and fire.

3.8. Officer's phase durations and onsets during final seven seconds

No significant differences were found in phase durations due to condition $p > .05$, or the interactions of Expertise × Condition $p > .05$, or Expertise × Condition × Phase $p > .05$, but significant differences were found for expertise, $F(1, 244) = 10.42$, $p < .002$, $\eta_p^2 = .08$, phase, $F(2, 244) = 6.88$, $p < .001$, $\eta_p^2 = .08$, and the interactions of expertise by phase, $F(2, 244) = 11.09$, $p < .0001$, $\eta_p^2 = .01$. Table 2 shows that the E draw, hold and aim/fire durations were $M = 180.34$ ms ± 88.79 ms, 1016.02 ms ±

Table 1
Mean duration (ms, SE) of the assailant's pivot and aim/fire against the elite and rookie officers.

Phase	Against elite		Against rookie		*F* value	*p*
	M	SE	*M*	SE		
Pivot	995.21	61.38	919.56	57.74	.79	.38
Aim/fire	579.81	13.46	887.16	37.14	49.54	.0001

Table 2
Mean duration (ms, SE) of the elite and rookie draw, hold and aim/fire phases.

Phase	Elite		Rookie		*F* value	*p*
	M	SE	*M*	SE		
Draw	180.34	11.86	226.70	179.62	21.47	.08
Hold	1016.02	264.17	96.71	75.64	13.44	.0004
Aim/fire	611.47	55.94	567.63	287.48	34.36	.483

1976.83 ms and 611.43 ms ± 418.64 ms, respectively. Corresponding means for the R were 226.70 ms ± 179.62 ms, 96.67 ms ± 632.88 ms and 567.63 ms ± 287.49 ms. Contrast of means was significant for the hold phase only, $F(1) = 39.61$, $p < .0001$, the R having shorter durations.

Significant differences were found in the officer's phase onsets due to expertise, $F(1, 372) = 19.31$, $p < .0001$, $\eta_p^2 = .13$, phase, $F(3, 372) = 63.79$, $p < .0001$, $\eta_p^2 = .34$ and the interaction of expertise by phase, $F(1, 372) = 15.186$, $p < .0001$, $\eta_p^2 = .11$. The R were later drawing, holding, aiming and firing than the E (see Fig. 3). Onsets (with SE) for the E were M = 4628.45 ms ± 333.68 ms, 4808.89 ms ± 342.19 ms, 5826.75 ms ± 217.58 ms and 6866.61 ms ± 16.03 ms, respectively. Corresponding means for the R were 6037.61 ms ± 97.95 ms, 6263.33 ms ± 99.19 ms, 6360.47 ms ± 40.09 ms and 6928.13 ms ± 15.79 ms.

3.9. Fixation analysis: Final seven seconds

A total of 15 fixations were found per officer during the final seven seconds. Onset, offset and duration were analyzed separately using an Expertise (E, R) × Condition (gun, cell) factorial ANOVA and no significant differences were found until the final six fixations which occurred during the final two seconds when the events shown in Fig. 1 (A-C) occurred. Image A shows the assailant's raised elbow which signaled the beginning of the attack, image B the moment the gun or cell first became visible and image C the moment the shots were fired by the officer and assailant.

Percent of fixations during the final two seconds differed due to expertise, $F(1, 240) = 5.00$, $p < .04$, $\eta_p^2 = .24$, location, $F(3, 240) = 54.58$, $p < .0001$, $\eta_p^2 = .77$, and interactions of Location × Fixation Sequence, $F(15, 240) = 18.87$, $p < .0001$, $\eta_p^2 = 54$. and Location × Expertise × Fixation Sequence, $F(15, 240) = 3.811$, $p < .0001$, $\eta_p^2 = .19$. Each fixation location was then analyzed separately in order to isolate expertise differences by location during the final sequence of six fixations.

Percent fixations on the assailant's weapon/cell (Fig. 4A) differed due to expertise, $F(1, 96) = 9.91$, $p < .002$, $\eta_p^2 = .09$, fix sequence, $F(5, 96) = 5.93$, $p < .0001$, $\eta_p^2 = .24$, and the interaction of Expertise × Fix Sequence, $F(5, 96) = 3.56$, $p < .005$, $\eta_p^2 = .16$. Across the six fixations, the E increased fixations to the assailants weapon or cell from 18% to 71%, compared to 18% to 34% for the R. Contrast of means indicated E and R differed during fixation five, $F(1) = 9.03$, $p < .003$, and fixation six, $F(1) = 13.52$, $p < .0004$.

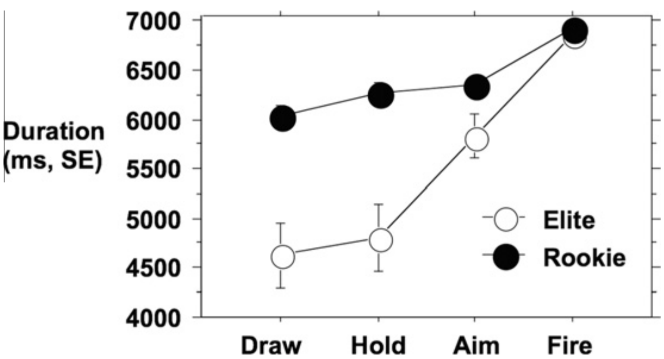

Fig. 3. Onset (ms) of the elite and rookie officers draw, aim and fire phases differed, with the rookie officers being later in all four phases.

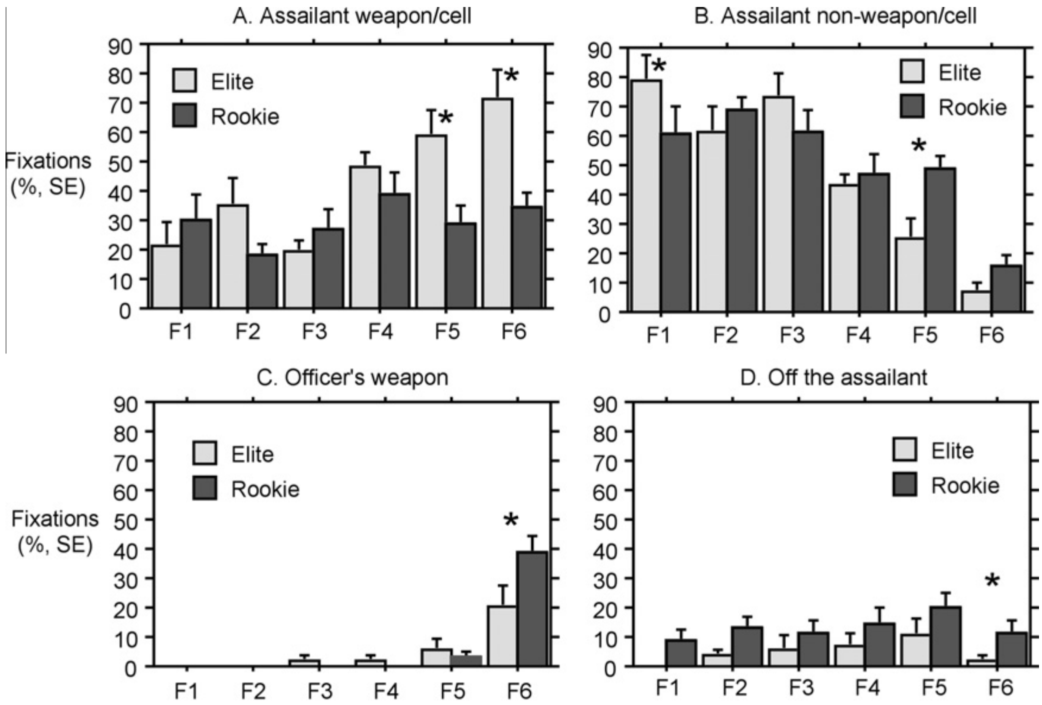

Fig. 4. Percent fixations by location (assailant weapon/cell; assailant non-weapon/cell, officers weapon, off target) of the elite and rookie officers during the final six fixations of the encounter.

Fixations on non-weapon locations (Fig. 4B) differed due to fix sequence, F(5, 96) = 24.45, $p < .0001$, $\eta_p^2 = .56$, and the interaction of Expertise × Fix Sequence, $F(5, 96) = 2.66$, $p < .03$, $\eta_p^2 = .12$. The E decreased fixations to non-weapon locations from 78% to 7% compared to 62% to 16% for the R. Means comparisons showed the E and R differed during fixation one, $F(1) = 3.82$, $p < .05$, and fixation five, $F(1) = 6.50$, $p < .01$.

Fixations on the officer's own weapon (Fig. 4C) differed due to fix sequence, $F(5, 96) = 28.23$, $p < .0001$, $\eta_p^2 = .60$, and the interaction of Expertise × Fix Sequence, $F(5, 96) = 3.66$, $p < .005$, $\eta_p^2 = .16$. The R increased the percent of fixations to their own weapon to 39% on fixation 6 compared to 20% for the E. Means contrast indicated E and R differed during fixation six, $F(1) = 19.11$, $p < .0001$.

Fixations off the assailant (Fig. 4D) differed due to expertise, $F(1, 96) = 11.83$, $p < .0009$, $\eta_p^2 = .11$. During all six fixations more R fixations ($M = 13.21 \pm 14.09$) were off target more than the E ($M = 4.76 \pm 10.35$).

3.10. Expertise and performance differences in fixation duration

The final six fixation durations were analyzed and significant differences found for fixation sequence, $F(5, 715) = 3.15$, $p < .008$, $\eta_p^2 = .02$; the effect for expertise neared significance, $F(1, 715) = 3.29$, $p < .069$, $\eta_p^2 = .01$. Fig. 5 shows the E maintained a mean duration of 275–350 ms across fixations, while the rookies took longer during fixations one and two (475–425 ms) and then had shorter durations during fixations five and six (250 ms). Contrast of means showed E and R differed in fixation duration on the officer's weapon, $F(1) = 20.38$, $p < .0004$.

The analysis of performance (high, low) fix sequence (fix 1–6) found significant differences due to fixation sequence, $F(5, 715) = 4.48$, $p < .0005$, $\eta_p^2 = .03$, and the interaction of Fixation Sequence × Performance, $F(5, 715) = 2.42$, $p < .03$, $\eta_p^2 = 02$. Fixations one and two occurred as the assailant drew and executed the pivot, fixations four and five occurred as the gun or cell first became visible and fixation 6 as the shots were fired or inhibited. Fig. 6 shows that during the low performance trials, fixations one and two were longer and were followed by shorter fixations four and five, while the opposite occurred during the high performance trials. The results show that, irrespective of expertise, if too much time was taken to fixate locations as the assailant began his pivot (f1 and f2) this was then followed by very

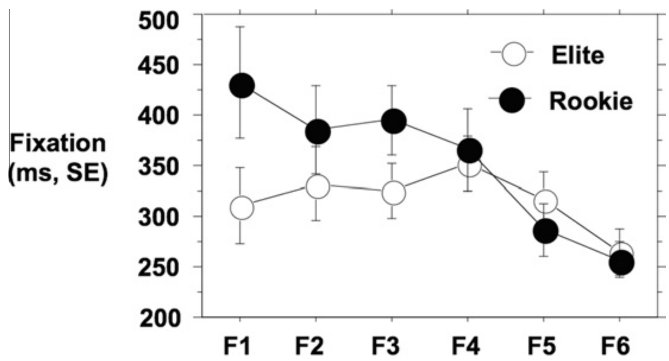

Fig. 5. Duration (ms, SE) of final six fixations of the elite and rookie officers.

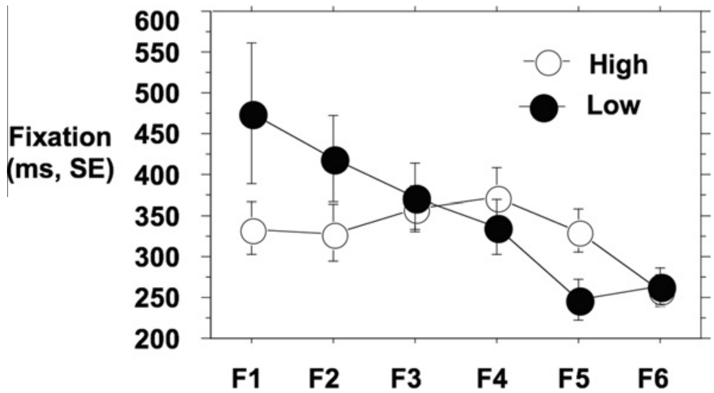

Fig. 6. Durations (ms, SE) of the final six fixations during low and high performance trials.

brief fixations on the gun or cell when these first became visible. Contrast of means was significant for fixation one, $F(1) = 6.03$, $p < .01$, and fixation five, $F(1) = 4.69$, $p < .03$.

3.11. Percent of final saccades by location

Interconnecting fixations five and six was a final saccade. Significant differences were found for location, $F(2, 34) = 9.86$, $p < .0004$, $\eta_p^2 = .37$, and the interaction of Expertise $\times$ Location, $F(2, 34) = 11.78$, $p < .0001$, $\eta_p^2 = .41$ (see Fig. 7). E percent saccades on the assailant weapon, non-weapon and, officer's own weapon were, respectively, M = 44.07% ± 9.90%, 23.89% ± 8.8% and 32.04% ± 11.24%,. Corresponding percentages for the R were 4.00% ± 2.66%, 12.00% ± 6.80% and 84.00% ± 6.50%. Overall, 84% of the R groups final saccades were to their own weapon compared to 32% for the E.

3.12. Quiet eye duration

Normally the QE is located on only one location, but since both the assailant's weapon and the officer's weapon were fixated during fixation six it was important to determine how long both locations were fixated before the trigger pull. Since it takes at least 350 ms for an officer to aim and fire accurately at a target (Bumgarner et al., 2006; Tobin & Fackler, 1997) a viable QE should be close to this value on one location or another. QE duration was analyzed using an Expertise (E, R) $\times$ Location (assailant's weapon/cell, officer weapon) factorial ANOVA. Significant differences were found due to location, $F(1, 98) = 10.63$, $p < .0002$, $\eta_p^2 = .10$, and the interaction of expertise by location, $F(1, 98) = 6.61$, $p < .01$, $\eta_p^2 = .06$, as shown in Fig. 8. The E group had a longer mean duration on the assailant's weapon/cell (318.33 ms ± 27.72 ms) and shorter on their own weapon (121.00 ms ± 14.41 ms). Comparable QE durations for the R were $M = 265.33$ ms ± 33.50 ms on the assailant's weapon/cell

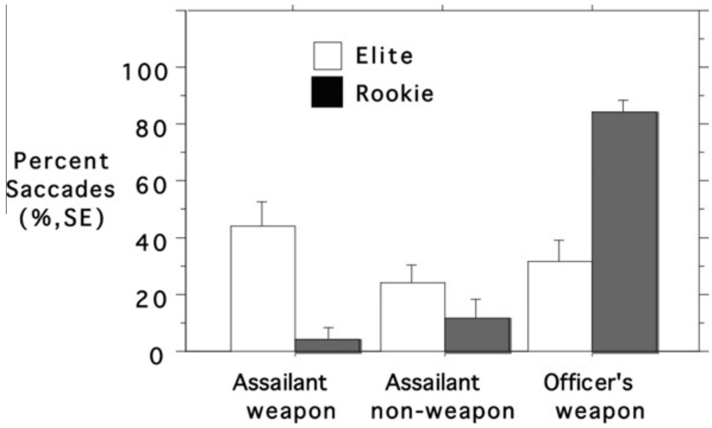

Fig. 7. Percent of final saccades of the elite and rookie officers on the assailant's weapon/cell locations, assailant non-weapon/cell locations and the officer's own weapon.

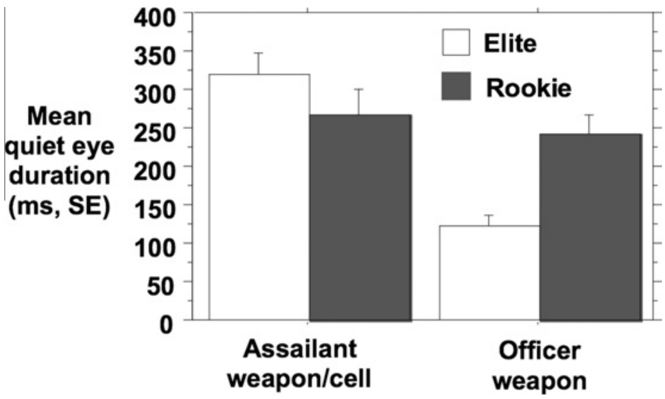

Fig. 8. Quiet eye duration of elite and rookie officers to the assailant's weapon/cell and to their own weapon.

and $M = 242.04$ ms ± 11.28 ms on their own weapon. Contrast of means showed the E and R differed in durations to their own weapon, $F(1) = 4.87$, $p < .03$.

3.13. Discussion

At the outset we expected the elite officers to shoot with greater accuracy during the gun condition and make fewer decision errors during the cell condition, while the rookies would exhibit less control over their gaze resulting in lower shooting accuracy and more decision errors. These expectations were met on the three combined measures of shooting performance accuracy, shot speed, and decision making during the cell trials. The E officer's met the criteria for high performance on 75.0% of all trials compared to 52.9% for the R. Most noticeable was the high percentage of R (61.5%) who made a decision error and fired during the cell condition, compared to 18.2% for the E. These differences in performance could not be attributed to differences in the duration of the motor phases, as E and R did not differ in the time it took them to draw, aim and fire. However, the R performed all three actions in the last second compared to the last 2.5 s for the E (see Fig. 3). The E's significantly earlier motor onsets were indicative of their greater anticipation and prior programming which contributed to their firing before the assailant and R on most trials. The E's significantly earlier draw, aim and fire phases were also preceded in the first seven seconds of the trial by significantly more fixations on locations where a weapon could be hidden and to unholstering almost immediately, while the R had a lower percentage of fixations on non-weapon locations and off target and did not prepare their weapon to draw and fire until the assailant was near to the end of his attack.

Our expectation that both the E and R officers would employ a weapon focus during the first seven seconds of the trial was upheld, but for the E only, who focused a higher percentage of their fixations on locations where a gun could be hidden, while the R looked more at non-weapon locations or to locations outside the immediate location of the assailant. E and R did not differ in the percentage of fixations on the assailant's face which was visible for only three seconds as he entered, or on the receptionist. Fixation durations averaged about 500 ms per location, therefore both E and R had enough time to identify both individuals.

During the final two seconds we also found differences in weapon focus that have not been reported in the literature previously. During the final six fixations the E increased the percent of fixations on the assailant's weapon/cell from 18% to 71%. During hits this percentage increased the duration to 86% revealing a remarkable degree of focus and concentration under fire. The R did not show the same funneling of their gaze on the assailant's weapon or cell, but instead allocated 39% of their final fixations to their own gun and only 34% to the assailant's weapon/cell. Most disruptive for the rookies was a saccade to their own weapon prior to the final fixation on 84% of trials, compared to 23% for the E. Since during saccades information is suppressed (Bridgeman, Hendry, & Start, 1975) these results show that on a high percent of trials the rookie's ability to maintain their focus on the assailant was seriously compromised. Indeed, on 50% of trials they took their gaze off the assailant completely as they fired (see Fig. 4). The rookies shift of gaze from the assailant to their own weapon suggests a vital re-allocation of attentional resources, which given the time pressures of the encounter, was unsuccessful in a high percentage of trials.

Fixations durations also differed for E and R as the assailant drew and began to pivot spinning rapidly toward them over a distance of about 2 m, moving laterally from the officer's left to right. This presented the officers with a rapidly moving target which the E fixated using a series of six fixations that ranged between 250–350 ms. This sequence of fixations allowed the E to quickly read the significance of the assailant's raised elbow and pivot, which signaled the onset of the attack (see Fig 4A) and anticipated the appearance of the gun or cell. Often the E shifted their gaze to the location of the gun or cell phone before it first became visible (see Fig. 4B), giving them more time to make the decision to aim and fire, or alternatively suppress the shot. The R also had six fixations during the final two seconds, but the first two were too long to enable them to keep up with the spinning lateral action of the gunman. They appeared to take too long to process the significance of the raised elbow and pivot making them late in fixating the gun or cell when they first became visible. This combined with the costs of programming a saccade on 84% of trials signaled a re-orienting of their attention to a second goal – that of fixating the sights on their own gun which was successful in only 39% of trials. Corbetta et al. (2008) provided fMRI evidence showing the re-orienting of attention is a time consuming process as the ventral system is activated requiring cognitive processing, whereas the dorsal system is faster and allows actions to be controlled continuously and automatically. Combined with the rookies late shift of gaze to their own gun as they drew, aimed and fired, this meant the rookies whole visuomotor system was pressured to the breaking point leading to lower accuracy in the gun condition and poor decision making in the cell trials.

The elite officer's final QE duration averaged 318 ms, which was barely within the time limits needed to accurately fire a handgun (Bumgarner et al., 2006; Tobin & Fackler, 1997), while that of the rookies was even lower, average 262 ms. The E's longer QE duration was therefore similar to elite athletes in the shooting sports in being longer during high performance, while the R behaved like lower skilled athletes taking less time to fixate the intended target. The longer duration of the E group supports previous QE studies showing the visuo-motor system needs a long duration of external task information to perform well. These results therefore join a growing number of studies that show a long duration QE on a critical locations prior to a final action is an important factor in the ability to perform under pressure (Behan & Wilson, 2008; Janelle, 2002; Mann et al., 2007; Murray and Janelle, 2003; Vickers, 2009; Williams et al., 2002).

Since the type of training a person initially receives often dictates how well they perform in the future (Schmidt & Lee, 2005; Vickers, 2007) our results suggest that firearms training should change from a process that inadvertently teaches novices to fixate the sights of their own weapon first and the target second, to a type of training that establishes the line of gaze on the target from the outset, followed by alignment of the sights of the weapon to the line of gaze. This change in gaze control would lead to a longer QE duration on the target prior to pulling the trigger and should contribute to better decision making and performance. If these changes in firearm's training were implemented then the gaze control of novice officers should be similar to that of elite athletes and elite officers from the first day of training, thereby increasing the likelihood that they would be able to maintain visual control over any situation they encountered. This, in turn, should decrease errors in decision making and improve shooting accuracy and may help reduce the tremendous costs that ensue after all officer involved shootings (Dumke, 2009; Klinger, 2006).

Finally, our results also suggest that officer's would benefit from training under conditions where the levels of pressure and anxiety are high. Recent studies have established the efficacy of this type of training for police officers (Nieuwenhuys & Oudejans, 2010; Oudejans, 2008; Oudejans & Pijpers, 2009, 2010). Not only did handgun performance improve compared to traditional forms of training, but practicing under conditions of high anxiety reduced choking and enhanced decision making under extreme pressure.

3.14. Limitations and Conclusions

While the current study sheds light on the control of the gaze during a lethal force on force encounter it has some limitations. First, the number of officers tested was low ($N = 24$). A greater number of officers need to be tested under a variety of conditions. Second, the officers tested may have been trained in specific ways that affected the results. For example, many forces do not allow or recommend the "hold" position used by so many of the E in this study. Third, while all other measures were precisely measured we did not assess the onset of trigger time but estimated it from previous research studies. Fourth, the results of the current study may be context or task specific and not apply to a greater range of police skills. More research will be needed to determine whether the gaze control strategies carry over into other situations that police officers encounter. Fifth, we did not interview the officers after the encounter therefore we do not know how much agreement there would be between their gaze control and what they verbally may have reported later on. Gaze control studies where the officers are interviewed before and after an i*n situ* encounter would provide objective information. Six, our results suggest that both elite and rookie officer's may be limited in the extent to which they act as eye witnesses once they begin the process of drawing, aiming and firing their weapon. Since the E maintained a weapon focus on the assailant's gun or cell during the final seconds of the encounter they may have a reduced ability to identify faces and report on events that occurred outside of this narrow field of view. And rookie officers who attempt to fixate the sights on their gun prior to firing may not be able to report on the presence or absence of a weapon during the final seconds due to their use of a disruptive saccade that suppresses vision followed by very brief fixations on their own weapon a high percent of trials. More research is needed to determine if this is the case. Studies of this nature may also shed light on the veracity of eye witness testimony and determine the congruence between what is actually fixated during an encounter and what is reported later on. Finally, our results show that officer's who have extensive training and experience as tactical team members have a superior ability to control their gaze and optimally focus their attention when under extreme stress thus leading to fewer decision errors in the line of duty. Whether this superior ability is present prior to training or emerges as a result of training cannot be answered by this study and requires further research.

In conclusion, we show that at the beginning of a deadly firearms encounter, elite officers fixate locations where a weapon is hidden significantly more than rookies, and do this earlier and for longer durations. Elite and rookie officers did not differ in the time it took to draw, aim and fire but the elite officers performed all three of these actions earlier. In contrast, the rookies were very late performing all three actions, indicating critical deficiencies in anticipation, cue detection, gaze control and decision making when under pressure. When the attack occurred (or appeared to occur) the rookies shifted their gaze to their own weapon in a failed attempt to sight their own weapon, while the elite officers never lost sight of the assailant's moving weapon (or cell phone) before pulling the trigger. We therefore conclude that the significant differences in accuracy and decision making observed between the elite and rookie officers were due as much, if not more, to deficits in the gaze control and focus of attention of the rookies as to any limitations in their physical ability to handle the firearm.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.humov.2011.04.004.

References

Barclay, B., Tavares, C., Kenny, A., Siddique, A., & Wilby, E. (2003). International comparisons of international justice statistics 2001. *London: Home Office Statistical Bulletin*, No. 12, 03.
Behan, M., & Wilson, M. (2008). State anxiety and visual attention: The role of the quiet eye period in aiming to a far target. *Journal of Sports Sciences, 26*, 207–215.
Bridgeman, G., Hendry, D., & Start, L. (1975). Failure to detect displacement of visual world during saccadic eye movements. *Vision Research, 15*, 719–722.
Bumgarner, J., Lewinski, B., Hudson, B., & Sapp, C. (2006). An examination of police officer mental chronometry. *Journal of the Association for Crime Scene Reconstruction, 12*, 11–25.
Causer, J., Bennett, S. J., Holmes, P., Janelle, C., & Williams, A. M. (2010). Quiet eye duration and gun motion in elite shotgun shooting. *Medicine and Science in Sports and Exercise, 42*, 1599–1608.
Corbetta, M., Patel, G., & Shulman, G. (2008). The reorienting system of the human brain: From environment to a theory of mind. *Neuron, 58*, 306–324.
de Oliveira, R. F., Oudejans, R. R. D., & Beek, P. J. (2008). Gaze behavior in basketball shooting: Further evidence for online visual control. *Research Quarterly for Sport and Exercise, 79*, 399–404.
Dicks, M., Button, C., & Davids, K. (2010). Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in the information used for perception and action. *Attention, Perception and Psychophysics, 72*, 706–720.
Dumke, M. (2009). *The City Pays Out. What law firms are collecting large legal fees from the city of Chicago*, http://www.chicagoreader.com/features/stories/legalfees/, Wed, Aug 26.
Harle, S. K., & Vickers, J. N. (2001). Training quiet eye improves accuracy in the basketball free throw. *Sport Psychologist, 15*, 289–305.
Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in Cognitive Science, 7*, 498–504.
Hendrick, H. W., Paradis, P., & Hornick, R. J. (2008). *Human factors issues in handgun safety and forensics*. London: CRC Press/Taylor Francis.
Hope, L., & Wright, D. (2007). Beyond unusual? Examining the role of attention in the weapon focus effect. *Applied Cognitive Psychology, 21*, 951–962.
Hulse, L. M., & Memon, A. (2006). Fatal impact? The effects of emotional arousal and weapon presence on police officers' memories for a simulated crime. *Legal and Criminological Psychology, 11*, 313–325.
Janelle, C. M. (2002). Anxiety, arousal and visual attention: A mechanistic account of performance variability. *Journal of Sports Sciences, 20*, 237–251.
Janelle, C. M., Singer, R. N., & Williams, A. M. (1999). External distraction and attentional narrowing: Visual search evidence. *Journal of Sport and Exercise Psychology, 21*, 70–91.
Janelle, C. M., Hillman, C. H., Apparies, R. J., Murray, N. P., Meili, L., Fallon, E. A., et al (2000). Expertise differences in cortical activation and gaze behavior during rifle shooting. *Journal of Sport and Exercise Psychology, 22*, 167–182.
Kassin, S. M., Tubb, V. A., Hosch, H., & Memon, A. (2001). On the "general acceptance" of eyewitness testimony research. *American Psychologist, 56*, 405–416.
Klinger, D. (2006). Police responses to officer-involved shootings. *National Institute of Justice*, January, NCJRS (NCJ 192286).
Land, M. F. (2009). Vision, eye movements, and natural behavior. *Visual Neuroscience, 26*, 51–62.
Loftus, E. F., Loftus, G. R., & Messo, J. (1987). Some facts about 'weapon focus'. *Law and Human Behavior, 11*, 55–62.
Mann, D. L., Abernethy, B., & Farrow, D. (2010). Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychologica, 135*, 17–23.
Mann, D., Williams, A., & Ward, P. (2007). Perceptual-cognitive expertise in sport: A meta analysis. *Journal of Sport and Exercise Psychology, 29*, 457–478.
Morrison, G., & Vila, B. (1998). Police handgun qualification: Practical measure or aimless activity?. *Policing: An International Journal of Police Strategies and Management 21*, 510–533.
Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford: Oxford University Press.
Milner, A. D., & Goodale, M. A. (2008). Two visual systems re-viewed. *Neuropsychologia, 46*, 774–785.
Müller, S., & Abernethy, B. (2006). Batting with occluded vision: An in situ examination of the information pick-up and interceptive skills of high- and low-skilled cricket batsmen. *Journal Science Medicine in Sport, 9*, 446–458.
Murray, N. P., & Janelle, C. M. (2003). Anxiety and performance: A visual search examination of the processing efficiency theory. *Journal of Sport & Exercise Psychology, 25*, 171–187.
Nieuwenhuys, A., & Oudejans, R. R. D. (2010). Effects of anxiety on handgun shooting behavior of police officers: A pilot study. *Anxiety, Stress, and Coping, 23*, 225–233.

Oudejans, R. R. D. (2008). Reality-based practice under pressure improves handgun shooting performance of police officers. *Ergonomics, 51*, 261–273.

Oudejans, R. R. D., & Pijpers, J. R. (2009). Training with anxiety has a positive effect on expert perceptual-motor performance under pressure. *Quarterly Journal of Experimental Psychology, 62*, 1631–1647.

Oudejans, R. R. D., & Pijpers, J. R. (2010). Training with mild anxiety may prevent choking under higher levels of anxiety. *Psychology of Sport and Exercise, 11*, 44–50.

Panchuk, D., & Vickers, J. N. (2006). Gaze behaviours of goaltenders under spatial temporal constraints. *Human Movement Science, 25*, 733–752.

Panchuk, D., & Vickers, J. N. (2009). Using spatial occlusion to explore the control strategies used in rapid interceptive actions: Predictive or prospective control? *Journal of Sports Sciences, 27*, 1249–1260.

Patla, A., & Vickers, J. N. (1997). When and where do we look as we approach and step over an obstacle in the travel path. *NeuroReport, 8*, 3661–3665.

Pickel, K. L. (1999). The influence of context on the "weapon focus" effect. *Law and Human Behavior, 23*, 299–311.

Ripoll, H., Papin, J. P., Guezennec, J. Y., Verdy, J. P., & Philip, M. (1985). Analysis of visual scanning patterns of pistol shooters. *Journal of Sports Sciences, 3*, 93–101.

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis (4th ed.)*. Champaign, IL: Human Kinetics Publishers.

Stanny, C. J., & Johnson, T. C. (2000). Effects of stress induced by a simulated shooting on recall by police and citizen witnesses. *American Journal of Psychology, 113*, 359–386.

Steblay, N. (1992). Commentary on "studying eyewitness investigations in the field": A look forward. *Law and Human Behavior, 32*, 11–15.

Thomas, J. R., & Nelson, J. K. (2001). *Research methods in physical activity* (3rd Ed). Champaign, IL: Human Kinetics.

Tobin, E. J., & Fackler, M. L. (1997). Officer reaction-response times in firing a hand gun. *Wound Ballistics Review: Journal of the International Wound Ballistics Association, 3*, 6–9.

Turtle, J., Read, D. J., Lindsay, D. S., & Brimacomb, A. E. (2008). Toward a more informative psychological science of eyewitness evidence. *Applied Cognitive Psychology, 22*, 769–778.

van der Kamp, J., Rivas, F., van Doorn, H., & Savelsbergh, G. J. P. (2008). Ventral and dorsal contributions in visual anticipation in fast ball sports. *International Journal of Sport Psychology, 39*, 100–130.

Vickers, J. N. (1992). Gaze control in putting. *Perception, 21*, 117–132.

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 342–354.

Vickers, J. N. (2004). The quiet eye: It's the difference between a good putter and a poor one, here's proof. *Golf Digest*, January, pp. 96–101.

Vickers, J. N. (2007). *Perception, cognition and decision training: The quiet eye in action*. Champaign, IL: Human Kinetics Publishers.

Vickers, J. N., & Williams, A. M. (2007). Performing under pressure: The interactive effects of physiological arousal, cognitive anxiety and gaze control in elite biathlon shooters. *Journal of Motor Behavior, 39*, 381–394.

Vickers, J. N. (2009). Recent advances in coupling perception and action: The quiet eye as a bidirectional link between the gaze, focus of attention and action. In M. Raab, J. Johnson, & H. Heekeren (Eds.), *Progress in brain research 174: Mind and motion: The bidirectional link between thought and action* (pp. 279–288). Amsterdam: Elsevier.

Vine, S. J., Moore, L., & Wilson, M. R. (2011). Quiet eye training facilitates competitive putting performance in elite golfers. *Frontiers Psychology*, doi:10.3389/fpsyg.2011.00008.

Vine, S. J. & Wilson, M. R. (2011). The influence of quiet eye training and pressure on attention and visuo-motor control. *Acta Psychologica*, doi:10.1016/j.actpsy.2010.12.008.

Williams, A. M., Singer, R. A., & Frehlich, S. (2002). Quiet eye duration, expertise, and task complexity in a near and far aiming task. *Journal of Motor Behavior, 34*, 197–207.

Williams, A. M., Vickers, J. N., & Rodrigues, S. T. (2002). The effects of anxiety on visual search, movement kinematics, and performance in table tennis: A test of Eysenck's and Calvo's processing efficiency theory. *Journal of Sport and Exercise Science, 24*, 438–456.

Williams, J. J., & Westhall, D. (2003). SWAT and non-SWAT police officers and the use of force. *Journal of Criminal Justice, 31*, 469–474.

Wilson, M. R., Vine, S. J., & Wood, G. (2009). The influence of anxiety on visual attentional control in basketball free throw shooting. *Journal of Sport and Exercise Psychology, 31*, 152–168.