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Improving the Accuracy of Firearm Identification in a Dynamic Use of Force Scenario

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Abstract

Law enforcement officers are sometimes required to make split-second use of force decisions. One factor that can impact their decision-making process is the presence of a weapon. This experiment sought to improve the speed and accuracy of weapon identification in a dynamic use of force scenario through the principles of deliberate practice. This research utilized randomized control trial with random assignment to either a control or test condition. Eighty-seven participants completed the pretest, intervention, and posttest. Participants' vision was recorded via a mobile vision-tracker. With only 20 minutes of training, the test group made 1/3 the amount of decision errors as the control group (Cohen's $d = 0.95$). The test group was about 16% faster than the control group at visually finding the object in the suspect's hand and determining if it was a gun or not (Cohen's $d = 0.91$).

Keywords

decision-making, police training, training, use of force, vision-training

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In recent years, there have been instances where police officers have erroneously applied deadly force (i.e., the deadly force was applied when it should not have been). In these cases, the civilian was either unarmed or had an object other than a gun in his hand (e.g., a wallet). For example, on September 4, 2014, South Carolina State Trooper Sean Groubert initiated a traffic stop for a seat belt violation. The dash-mounted camera within his patrol car captured the whole scene. The driver, Levar Jones, pulled into a gas station parking lot. Once his vehicle came to a stop, Jones stepped out of the vehicle. Groubert asked Jones to produce his driver's license. Mr. Jones abruptly turned toward his vehicle to retrieve his wallet. While Jones was reaching into the vehicle, Groubert repeatedly yelled at him to "get out of the car." As Jones backed out of the vehicle and turned back around with his wallet in hand, Groubert fired four shots. Fortunately, Jones survived being struck in the hip by one bullet (BBC News, 2014).

No weapon was found in Jones' vehicle. Groubert stated that he saw Jones lunge into the vehicle and then make a quick movement back toward the trooper. It appeared Groubert applied a heuristic response (i.e., a mental shortcut to speed up decision-making) to Jones' movement rather than positively identifying the item in his hand. As a result, Groubert was arrested. In March 2016, Groubert plead guilty to one felony count of assault and battery of a high and aggravated nature. He was sentenced to 12 years in prison (McLeod, 2017). Because of this, and other tragic incidents, I wondered if a simple training method could be developed to both (1) improve the speed in which officers are able to visually find, and verbalize, an object in a dynamic (i.e., quickly evolving) use-of-force situation, and (2) improve officers' ability to accurately identify an object as a gun. Therefore, the principal research question was: Can a vision-training program based on the concepts of deliberate practice improve an individual's ability to correctly identify a gun in a dynamic use-of-force scenario?

Literature Review

The case of former trooper Groubert illustrates the life or death decisions that officers must make—sometimes in a matter of seconds—and what can happen when an officer makes an erroneous decision to shoot. Recent use-of-force cases (e.g., George Floyd in Minneapolis, Minnesota; Breonna Taylor in Louisville, Kentucky; Levar Jones in Columbia, South Carolina; Tamir Rice in Cleveland, Ohio; and Charles Kinsey in North Miami, Florida) have highlighted the issues surrounding police training and decision-making. While such cases receive much attention in the media, it is well known that prevalence of police use of force in the general population is exceedingly rare. According to the Police-Public Contact Survey conducted by the Bureau of Justice Statistics, data collected from 2002 to 2011 reveal an estimated annual average of 44 million people aged 16 or older who had one or more face-to-face contacts with police. Of those who experienced police contact, only 1.6% reported the threat or use of nonlethal force (Hyland et al., 2015). For example, a law enforcement officer could threaten to use OC Spray as an application of force, or the officer could actually use OC Spray should the situation call for it. Other forms of nonlethal force include, hand controls, baton, CED (Taser), bean bag, rubber bullets, etc.

The frequency of the erroneous application of force is difficult to determine. In 2016, the *Washington Post* recorded 963 police shootings nationwide that resulted in the loss of a civilian's life. Of these, 48 events resulted in an unarmed civilian being shot.[1] Five of these 48 events occurred because the police officer misidentified an item as a gun. Five deaths out of 963 is not a trivial loss of life. The loss of an innocent life is not merely an emotional loss for the civilian's loved ones. Each of these incidents can also result in multimillion-dollar monetary settlements by the law enforcement agency or city. Additionally, although rare, an officer may lose his or her job, or even go to prison. The effects of an erroneous shooting are far reaching. Furthermore, these data do not capture events where the civilian did not die from injuries, wasn't struck by the officer's shot, or in which the officer applied more force than was legally justified due to misidentifying the threat level posed by the suspect. Because of these facets, the actual number of cases where erroneous force was applied is unknown.

Visual Acuity

The core of the research seeks to train officers to more effectively distinguish between firearms and innocuous objects (e.g., wallets). It is important to have a basic understanding of how the human visual system works. In simple terms, light that is reflected from surfaces in the environment is focused through the eye's lens. The refracted light then comes in contact with the retina. The retina is composed of sensory cells known as rods and cones. Rods and cones are responsible for converting the light to electrical impulses to be processed by the visual cortex (Ahmad et al., 2003). The concentration of rods and cones are densest in an area at the back of the retina known as the fovea. Because of this dense concentration, it is the fovea that is responsible for the most accurate vision. Visual acuity drops rapidly as imagery moves away from the optimal angular distance from the fovea—1 to 2 degrees of arc (Ruch, 1965). Foveal vision is the area where an individual's primary visual focus is concentrated.

To put foveal vision into perspective, 2 degrees of arc is equivalent to the width of the thumb when the arm is fully extended in front of an individual. If the individual concentrates on the thumb, she is utilizing her foveal vision. However, if she were to try and see items outside of her foveal vision, without shifting her eyes, her visual acuity would drop precipitously (she would be using peripheral vision in this instance; see Figure 1 below; Billinghurst & Thomas, 2016). Ruch (1965) found that acuity falls to 50% at 2.5 degrees,

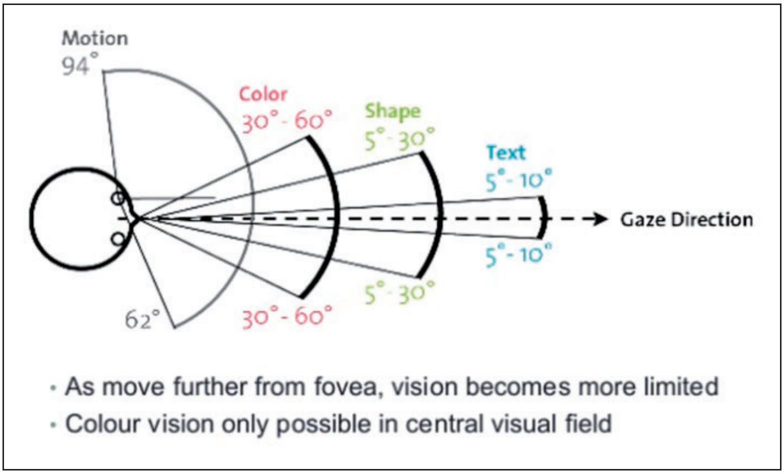

Figure 1. Peripheral Vision Diagram.

25% at 7.5 degrees, and 4% in the furthest periphery. In other words, only 50% of the available visual data is gathered when foveal vision is merely 0.5 degrees away from an item. However, it is not apparent that visual data are missing because the visual system will fill in the missing information based upon what is present, previous experiences, and what one expects to see (Otten et al., 2017). In short, when information is missing, the brain will guess at the missing details and fill them in to complete the visual world. The images the brain uses to fill in missing information may be dependent on a variety of factors including heuristics developed through direct experiences or implicit biases (see the Visual performance and law enforcement section for additional discussion). Consider the following example: A law enforcement officer approaches a group of people. An individual standing to the right of the officer pulls out a black object (the individual is in the officer's peripheral vision). The vision literature would suggest when it comes to identifying items during a dynamic situation such as this, it is critical that officers place their foveal vision on the item to positively identify any potential weapon. If they do not, the brain will fill in the details which may result in the officer "seeing" a firearm when the suspect is holding a wallet, for example.

Vision Training and Performance

Scholars have long sought to understand how vision training may impact sports performance. Much of the scholarly efforts focused on differences between expert and novice athletes' ability to visually fixate (i.e., utilize foveal vision) on important cues in their respective sports (Bard & Fleury, 1981; Petrakis, 1986, 1987; Salmela & Fiorito, 1979; Tyldesley et al., 1982; Vickers, 1992). Tyldesley et al. (1982) examined differences between novice and expert soccer players' ability to anticipate penalty-kick direction based on pictures of players in the process of kicking a ball. Expert players visually fixated on the shooting leg, while novice players searched the entire image. Expert player fixation was 26.6 meters per second faster, on average, than the novice players.

Video-Based Vision Training

Scholars have also examined the impact of video-based visual training on sports performance. In fact, several scholars have found that video-based training improves sports performance along multiple dimensions (see, for example, Burroughs, 1984; Christina et al., 1990; Singer et al., 1994; Williams & Burwitz, 1993). There are two key takeaways from video-based visual training research.

Visual Training Can Improve Speed and Accuracy of Object Recognition and Decision-Making. Christina et al. (1990) studied the efficacy of video-based training on football linebackers' ability to make accurate decisions. The authors utilized video to give linebackers practice deciding on the correct direction to move based on recognizing offensive play. The video was taped so it was representative of what the linebacker would see in a game situation. As the play unfolded, the linebacker would move a joystick as soon as he knew which direction he would move based on recognizing typical offensive moves. Christina et al. found that accuracy improved dramatically over the four-week training period. Furthermore, while accuracy increased, there was no sacrifice in the speed of decisions.

While Christina et al. (1990) did not find marked changes in the speed of decisions after video-based training, Haskins (1965) was able to. Haskins developed a video in hopes of shortening the time needed to determine the direction of a tennis ball return shot. Participants viewed a series of return shots from where their point of view would be on a tennis court. Haskins found statistically significant improvements in player response time following the video training sessions.

Visual Training Can Teach People Where to Look for Important Cues. An important aspect of a fast visual search strategy is knowing where to look. Salmela and Fiorito (1979) utilized visual training video for hockey goaltenders. The goaltenders were shown point-of-view video of a hockey player shooting a puck in their direction. The goaltenders were asked to predict where the shot would go. The authors found that goaltenders learned how to accurately predict the location of the shots based on the visual cues highlighted in the video. Additionally, Burroughs (1984) studied the effectiveness of visual training to enhance baseball players' ability to recognize pitch locations based on visual cues from the pitchers' natural movements. The participants were shown training videos in both slow motion and real time. Burroughs discovered that players participating in the video-based training were more accurate at perceiving the correct location of the pitch than players who did not participate in video-based training. These two sports-related studies show that video-based visual training can teach people where to look for visual cues.

This method of training should cross over to other fields beyond sports, such as a law enforcement officer's ability to learn where to look for a weapon. These two key points (i.e., visual training can improve speed and accuracy and vision training can teach people where to look) were conceptually vital for the development of the vision-training program utilized in this study. In fact, these findings suggest that video-based training may improve the speed and accuracy of decision-making in a sports setting while teaching participants where to focus their vision. While these experiments have yet to be replicated in law enforcement situations where the consequences are more dire (e.g., a wrong decision can lead to the loss of a life versus the loss of a game), they do suggest that law enforcement officers' ability to correctly identify a weapon may be improved through visual training. For instance, the sports training literature suggests that visual training improves an athlete's ability to correctly focus foveal vision to gather the most accurate data (e.g., where to look for cues from a baseball pitcher). It stands within reason that visual training could also improve a law enforcement officer's ability to correctly focus foveal vision on areas where a weapon is likely to be located and to pick up on distinct features of a weapon quickly.

Visual Performance and Law Enforcement. There is a paucity of vision-related topics in the criminal justice and criminology literature. Several scholars have examined the foveal vision of eyewitnesses to crimes (Hendrick et al., 2007; Hulse & Memon, 2006; Kassin et al., 2001; Pickel, 1999; Stanny & Johnson, 2000). These efforts have shown that eyewitnesses focus their foveal vision on the weapon—a phenomena known as weapon focus (Loftus et al., 1987). However, only one more recent study specifically examined law enforcement gaze patterns (Vickers & Lewinski, 2012).

Vickers and Lewinski (2012) examined differences between expert and novice police officers' visual performance and decision-making while being faced with a shoot/no shoot decision. The elite officers were members of the Emergency Response Team while the novices were new law enforcement officers. During the scenario, the officers would watch a civilian become agitated with a receptionist before quickly turning around toward the officer with either a handgun or a cell phone in his or her hand. The officers wore a vision tracker, and the entire encounter was recorded. Vickers and Lewinski (2012) found that expert officers fixated their foveal vision where the firearm or cell phone could be before it was even visible (i.e., as the irritated civilian turned around, the expert officers fixated their vision on the individual's hands) while the novice officers focused their foveal vision on non weapon locations (e.g., the face of the individual, or the surrounding environment). This process allowed the expert officers to see the item faster than the novice officers did. When the cell phone was present, novice officers incorrectly identified the cell phone and fired their weapon 61.5% of the time, while the expert officers only misidentified the cellphone and fired their weapon 18.2% of the time (p. 113). These findings illustrate the importance of officers quickly fixating their foveal vision on a questionable item.

In a separate line of research, James et al. (2013) sought to understand the use of force decision differences between experts (i.e., at least 5 years of on-duty policing experience) and novices (i.e., non police officers) during use of force training scenarios designed specifically to measure use of force decision making. James et al. (2013) found that while reaction times between experts and novices were similar, experts more accurately placed their shots, fired faster follow-on shots, and attempted de-escalation techniques when feasible. Overall, Vickers and Lewinski (2012) and James et al. (2013) both show that expert officers outperformed novices. While no scholarly work has been accomplished yet, this may suggest that vision training for novice officers may help improve object identification and decision-making more dramatically than expert officers.

Race is, understandably, an important factor in the law enforcement literature. Scholars have sought to understand how race may, or may not, impact officer decision-making. James et al. (2013) found officers took longer to shoot black suspects than white or Hispanic suspects in a laboratory setting. James et al. (2013) also found officers were more likely to shoot unarmed white suspects than unarmed black or Hispanic suspects. Participants were also significantly more likely to fail to fire at armed black suspects than armed white or Hispanic suspects. James et al. (2016) replicated this study and added an Implicit Bias Test. Even though their sample showed strong implicit bias associating Black males with weapons, officers again took significantly longer to shoot and were less likely to shoot unarmed Black males than unarmed White males. Other scholarly efforts have examined the impact priming race has on individual's decision to identify weapons (Eberhardt et al., 2004; Payne, 2001), apply lethal force (Correll et al., 2002), or view people as criminogenic (Eberhardt et al., 2004). With regards to weapon identification, Eberhardt et al. (2004) sought to understand how priming individuals can impact how they identify weapons. The authors subliminally primed participants with Black or White male faces, or nothing as a control. Participants were then presented with a degraded image that slowly became clearer. Participants would indicate if the object was crime relevant (e.g., weapon) or not (e.g., camera or book). Eberhardt et al. (2004) found that participants primed with Black male faces were significantly faster at correctly identifying crime relevant items (p. 880). While the current research controls for race by holding it constant (see Intervention section below), it is possible that race may play a role in the identification of weapons and the decision-making process. However, this is not entirely clear as James et al. (2013) and James et al. (2016) found officers were less likely to apply force to minority suspects in a laboratory section. While race is outside of the scope of the current study, a first step in unpacking the complex issue of race and officer-involved shootings is to determine whether a vision training program can improve weapon identification. If the intervention is effective, then the training program may be useful in improving the identification of weapons by officers in encounters with citizens with varying demographic characteristics.

Deliberate Practice

The prior section detailed studies that examined differences between novice and expert performers from a variety of professions, even law enforcement. But, how does an individual become an expert or improve performance? While early learning models focused on genetic predisposition (Galton, 1869) or large amounts of training, such as the 10,000-hour rule (Chase & Simon, 1973; Gladwell, 2008), to explain expert performance, they did not take into consideration the manner in which individuals practice for expert performance (Ericsson & Pool, 2016, pp. 109–114). One heavily researched training method that can be viewed as the gold standard in training to develop expertise is deliberate practice. Deliberate practice harnesses what Ericsson and Pool (2016) refer to as the gift of adaptability. That is, the mind and body are designed to adapt to experiences and training much like how bodybuilders can sculpt and build their physique.

There are four key components to deliberate practice (Ericsson & Lehmann, 1996). First, the task is practiced at an appropriate level of difficulty. A task that is too easy will become mundane, while a task that is too difficult may be unattainable (i.e., racing in the Indianapolis 500 is not possible without knowing how to drive). Because of this, the difficulty of the task must increase as the learner becomes accustomed to it (i.e., it must be difficult enough to foster improvement without plateauing performance). Second, the learner must be provided with informative and immediate feedback regarding his or her performance. Feedback allows the learner the opportunity to know what areas need improvement. Third, the learner must be provided with repetition of the task. Finally, the learner must be motivated to exert effort in hopes of improving future performance. These four key components make up the foundation of deliberate practice. A motivated individual who received increasingly difficult practice, repeatedly and with ample feedback, will show improvement.

Examples of deliberate practice are found in a variety of fields, including but not limited to: musical performance (Ericsson et al., 1993); development of perfect pitch in children (Sakakibara, 2014); mnemonic devices to aid in short-term memory (Chase & Ericsson, 1982); and a variety of sports-related applications such as triathlon and swim training (Hodges et al., 2004), ballet

(Hutchinson et al., 2013), bowling (Harris, 2008), and practice techniques for darts (Duffy et al., 2004).

While previous learning models posited that large amounts of training are required for expertise (e.g., 10,000-hour rule), there is evidence within deliberate practice suggesting people can achieve marked improvement with smaller amounts of training. Hunt et al. (2014) developed Rapid Cycle Deliberate Practice (RCDP) to more efficiently train pediatric residents' resuscitation skills. Participants only received two (2) hours of training under the RCDP model. Consistent with deliberate practice, the RCDP model provides repeated opportunities to practice the skills with immediate, direct feedback of their performance. The RCDP training model was associated with improved performance by pediatric residents during simulated cardiac arrest. Kutzin and Janicke (2015) replicated the RCDP training model with nursing staff. Following training, it was found that compressions were started earlier and were of better quality, the patient was positioned correctly, and all equipment was ready for the code team when they arrived. These RCDP based studies showcase how skills needed in high-stress situations (i.e., performing life-saving care for cardiac arrest patients) can be successfully improved with short amounts of training.

The primary goal of deliberate practice is to improve performance on any given task. While some scholars claim expert-level performance requires a certain amount of time, my position is that the principles of deliberate practice can improve an individual's ability to perform a task even if expert-level performance is not the goal. For example, short bursts of training based on the concepts of deliberate practice will result in marked improvement as demonstrated with the Rapid Cycle Deliberate Practice model (Hunt et al., 2014; Kutzin & Janicke, 2015).Therefore, the principal research question was: Can a vision-training program based on the concepts of deliberate practice improve an individual's ability to correctly identify a gun in a dynamic use-of-force scenario? In order to answer this question, the following hypotheses were developed and tested:

> H_1: Deliberate practicing where to place foveal vision to identify a gun will improve the accuracy of use-of-force decisions over deliberate practice in unrelated visual searches.

> H_2: Deliberate practicing where to place foveal vision to identify a gun will improve the speed of use-of-force decisions over deliberate practice in unrelated visual searches.

> H_3: Deliberate practicing where to place foveal vision to identify a gun will decrease the amount of time needed to visually fixate on the item over deliberate practice in unrelated visual searches.

Method

Design

The randomized controlled trial utilized an independent groups design with random assignment to conditions. The two conditions included: (1) a control condition, a vision-training software program void of firearm-related media; and (2) a test condition, a vision-training software program focusing on firearm-related media. Because the design incorporated random participant assignment to conditions, the participants were blind to which condition of the experiment they were assigned. Both a pre- and posttest were conducted.

Intervention

There were three levels of training presented to both the test and control group. All three levels were based on the principles of deliberate practice (i.e., the task must be increasingly complex, participants must receive performance feedback throughout training, and motivated participants must repeat the task). Each level showed the participant different types of increasingly complex media (still images or video). After making a selection, the participants were immediately informed if they were correct or not and given an unlimited amount of time to review the media (still image or video) before proceeding to the next image to repeat the process. This feedback process was designed to teach the participants where to focus their foveal vision without explicitly telling them where to look. Rather, the training was designed so participants would learn where to focus their foveal vision through repeated feedback and exposure. Furthermore, based on Hunt et al. (2014) and Kutzin and Janicke's (2015) work with small bursts of deliberate practice-based training (Rapid Cycle Deliberate Practice), the intervention was designed to be short to assess if a small amount of training based on deliberate practice could result in marked improvement. The following details the three levels of training for both the test and control group.

Level 1. In accordance with the principles of deliberate practice, the first level is the simplest. Level 1 presented participants with 30 still images, shown in a random order one at a time. The images were placed on a blank background so the focus was only on the item being presented.

Control Group. The control group was shown individual images of letters, either consonants or vowels. Their task was to identify the presence of a vowel by pressing the number 1 if the image was a vowel and the number 3 if the image was not a vowel (i.e., a consonant).

Test Group. The test group was shown images of firearms or unrelated objects (e.g., wallet, hairbrush). Their task was to press the number 1 if the image was a firearm and the number 3 if the image was any object other than a firearm.

Level 2. The second level of training increased the complexity of the still image; thus, the difficulty of the training was also increased in accordance with deliberate practice. Both the control and test conditions contained 30 still images, shown in a random order one at a time.

Control Group. The control group was once again shown images of letters. However, instead of a single letter, the participants were shown a 4x4 matrix containing random letters and symbols (see Appendix A for an example). Their task was once again to identify the presence of a vowel by pressing the number 1 if the image contained a vowel and the number 3 if the image did not contain a vowel. This task required the participant to scan the entire image and attempt to find the vowel.

Test Group. The test group was once again shown images with or without firearms. However, in order to increase the complexity of the training image, an actor had the object somewhere on his body (Appendix A). The test group would press the number 1 if the image contained a firearm or the number 3 if the image contained an object other than a firearm. The participants were not explicitly told where to look. This task also required the participant to scan the entire image and try to find the object. It should be noted that all the actors were Caucasian males wearing blue shirts and blue jeans (see Appendix A for an example of the test and control group media). Methodologically, this choice reduces contextual variance and focuses on the presence of the item. As with much experimental research, small incremental steps are taken. The race and clothing of the actors, as well as the background in the media, were held constant to reduce as much variation as possible.

Level 3. The third level of training further increased the complexity by moving away from still images in favor of video. Video-based media required participants to identify the item while in motion; thus, the task was more difficult in accordance with deliberate practice. Both the control and test conditions contained 30 videos, shown in a random order one at a time. As with Level 2, the participants were not told where to look, only to find the object in question.

Control Group. The control group was required to identify if a video contained a vowel. An additional 30 4x4 matrix cards were created following the same format as Level 2 (see Appendix A). A camera panned over the card from different angles and at different speeds for each card. The participants were once again required to press 1 if the card contained a vowel and 3 if it did not contain a vowel.

Test Group. The test group was shown 30 videos of actors either turning around with an object in their hand or pulling an object out of their pocket. The videos used the same actors in the same location as Level 2. The participants were tasked with pressing 1 if the actor presented a firearm and 3 if the actor presented an object other than a firearm.

While this research is concerned with improving participants' ability to visually locate and correctly identify the presence of a gun, I wanted to ensure the control group also received an equal level of training albeit not related to identifying a weapon. I did not want this research to be training versus no training. Both the control and test condition training looked and functioned identically. The only difference was the media presented in each condition (the test condition media was related to identifying the presence or absence of a firearm, while the control condition media was related to identifying the presence or absence of a vowel).

Participants completed the training using the E-Prime Studio platform. The training was developed to perform like a game. At the start of each level of training, the software presented instructions for the participant. After reading the instructions, each participant pressed a button to start the selected level of training. The software would then present a single piece of visual media after a random amount of time longer than three seconds (i.e., the participant was unable to guess when it would appear). The participant would make a selection based on the specific level's requirements. The software would then display the response time, inform the participant if his or her selection was correct or not, and allow the participant to review the media again. The participant would press any key to move to the next image. Participants finished all of the training in approximately 20 total minutes. Participants were unaware of the purpose of the intervention. They were not explicitly told what they were being trained to do.

Pre- and Posttest Media

Participants completed a pretest to ensure both groups were comparable and to establish baseline data. A posttest was utilized to examine if the intervention was successful at improving weapon identification. Both the pre- and posttest videos were provided by MILO Training Systems. MILO Training produces advanced use-of-force simulators to train law enforcement officers and military personnel on the proper application of force. The simulator videos used for both the pre- and posttest are not the same videos or images used in the intervention. In fact, the simulator videos did not look like the test group intervention. The simulator videos are much more complex with multiple actors, varying backgrounds and environments, and varying light conditions. However, as with the test group intervention, all suspects in the MILO videos were Caucasian to hold the race variable constant. The simulator videos are utilized to assess if the simple training intervention results in improved performance during a complex use of force simulation. The videos were projected on a large wall approximately six feet in front of the participants. The projector was positioned so the images were life-sized and encompassed the participants' field of view.

Pre-Test Simulations. Four videos were chosen for the pre-test. There were two videos where the perpetrator was armed with a gun and two videos where the perpetrator was "armed" with something other than a gun (e.g., cell phone). Each participant was required to virtually move through each scenario and verbalize if they saw a gun at any point.

Post-Test Simulations. Ten different videos were chosen for the post-test (i.e., the four pre-test videos were not repeated). There were four videos where the perpetrator was armed with a firearm, four videos where the perpetrator was armed with something other than a gun, and two videos where no item was present. The two videos with no item present were utilized as a control. The videos were randomized to remove any order effect.

Procedure

All procedures used in the study were reviewed and approved by an Institutional Review Board. Following the signing of the consent form, all participants completed the pretest. In order to measure visual performance, a vision tracker was first placed on the participant and calibrated. The vision tracker (version: Mobile Eye-Tracking Laboratory) was procured from Positive Science, LLC. The cameras record at 30 frames per second (fps) (0.03 seconds of data specificity, meaning a new frame is visible every 0.03 seconds).

Vision Tracker. The vision tracker consists of an eyeglasses frame with two small cameras. One camera faced the participant's eye and captured pupil movement. The second camera faced forward and captured the participant's point of view. The cameras were connected to a laptop on the participant's back by a cable. The included software (Yarbus) synced the video from both cameras and superimposed a small dot where the participant was looking based on pupil orientation in relation to the forward-facing camera (i.e., the participant's foveal vision).

Participants were told the study was focused on improving decision-making speed. Participants were told to vocalize if they saw a gun in the scenario. Participants completed the four pre-test scenarios and then the vision tracker was removed. After the vision tracker was removed, participants were shown to the computer lab to complete all three levels of the training program with which they were randomly assigned to the control or test condition. Participants were then dismissed and came back the next day to complete the study. Participants first completed a different level 3 training (utilizing different videos from the previous day) and then went on to complete the post-test. Participants wore the vision tracker again for the posttest to gather foveal vision data. After completing all 10 post-test scenarios, the vision tracker was removed, and participants were dismissed.

Participants

Participants were recruited from criminal justice classes at a large southwestern university. Criminal justice students were used instead of law enforcement officers because this was an initial test of a novel training model. Law enforcement resources (e.g., staffing levels) are limited, and I did not want to draw on these limited resources before the training model was empirically tested. The target sample was 50 participants per condition for a total sample of 100. This would give an approximate power of 0.80 to detect effects of a moderate size within the t-distribution ($d = 0.50$; Cohen, 1988, p. 30).

As seen in Table 1 – a total of 87 people completed the experiment (control condition $n = 44$; test condition $n = 43$). Participants were of equal age in both conditions ($t_{(85)} = 0.59$, $p = 0.56$). There was no observed difference between conditions in terms of participant sex ($^2_{(1)} = 0.05$, $p = 0.83$). There was also no observed difference between conditions in terms of participant race (Fisher's exact: $p = 0.82$). This sample, while slightly smaller than 100, results in a power of 0.75 to detect effects of a moderate size within the *t*-distribution (Cohen, 1988, p. 30).

Primary Variables

There were three primary variables utilized to test the hypotheses: error rate, decision speed, and the speed in which participants visually fixated on the item. All these data are derived from the pre- and post-tests simulation videos only. The intervention training was not included in these variables or subsequent analysis.

Decision Error Rate. To determine the decision error rate, each time a participant incorrectly identified an object as a gun he or she was given a score of 1 for that video. Alternatively, if a participant did not verbally identify a gun if present, he or she was given a score of 1. The cumulative errors were computed for each individual and divided by the number of videos in the pre-/post-test to determine the respective error rate (i.e., error per person). A high degree of interrater reliability was found for this variable (intraclass correlation coefficient (ICC) = .98, 95% CI [.97, .99], $p < .001$).

Decision Speed. Each pre- and post-test video was coded to capture the speed of the participants' decisions. The vision tracker captured video at 30 fps. The number of frames was counted from the moment the item in question was visible until the participant verbalized the presence of the gun. The number of frames was converted to seconds for easier comprehension (i.e., decision in seconds = frames/30). Unless the participants made an error on a nongun video, the decision was only verbalized when a gun was present. As such, the decision speed variable was composed of videos where a gun was present (two videos in the pretest and four videos in the posttest). A high degree of interrater reliability was found for this variable (ICC = .95, 95% CI [.90, .97], $p < .001$).

Fixation Speed. The fixation variable measures the amount of time, in seconds, it took a participant to visually fixate on an item once it was present. As with the decision speed variable, these data were calculated by counting the number of frames that passed from the time the item was present. However, in the fixation variable, the counting stopped once the participant visually fixated on the item. A visual fixation occurred when the individual's superimposed gaze point stopped on an item for two or more frames. A high degree of interrater reliability was found for this variable (ICC = .94, 95% CI [.90, .96], $p < .001$).

Results

The following results come from the pre- and post-test simulation videos. The vision tracker video was coded for each participant to gather these data.

Analysis Plan

A Bayesian framework was utilized for data analysis. Bayesian analysis begins with an initial belief about the distribution of the phenomenon in question, known as a

Table 1. Sample Descriptive Statistics.

	Control	Test
Age	22.66 (5.83)	22.05 (3.63)
Sex		
Male	18	20
Female	26	23
Race		
African American	8	9
Asian	4	2
Caucasian	18	18
Latino	14	14

Standard deviations are shown in parentheses.

prior distribution. The program then updates this prior distribution based on new data. In an experimental design, these new data are the data collected to test the research hypotheses. The updated distribution is known as a posterior distribution. The posterior distribution represents credible parameter estimates based on the combination of the observed data and the prior distribution.

Researchers are able to select the prior distribution based on prior knowledge of the phenomenon. In the case of the analyses reported here, I utilized the data derived from the pre-test as the prior distribution. By utilizing the pre-test results as informed priors, the post-test data differences must be strong enough to influence the prior data and show any changes.

The Bayesian approach also allowed the use of models that were appropriate to the data structure. Using an appropriate data structure avoids many of the assumptions of traditional frequentist models (such as normal distributions and equal variance) or the kludges that are used when these assumptions are violated.

Unlike traditional frequentist statistics which produce p values that are used as part of the Null Hypothesis Significance Testing paradigm, Bayesian analysis does not produce p values. In the place of p values, I report 95% credible intervals for means and effect sizes. These intervals represent the 95% most likely values for the relevant parameter (mean or effect size) given the prior and the data. Ninety-five percent credible intervals of effect sizes that do not contain 0 are considered indicative that it is unlikely that the observed differences between means is 0 in the population. This is quite similar to how frequentist confidence intervals are interpreted. While there are distinctions between Bayesian credible intervals and frequentist confidence intervals, discussing these differences is beyond the scope of this paper (see Kruschke, 2014 for a detailed discussion). For readers who prefer more traditional analyses, frequentist tests for each of the Bayesian models are included in the endnotes.

Decision Error Rate

Pre-Test Results. The pre-test control group made 16 total errors, while the test group made 13 total errors. This corresponds with a control group mean of .37 (95% CI [.18, .56]) and a test group mean of .30 (95% CI [.16, .44]). The difference in means (.07 errors per person) ranged from -0.16 to .30, suggesting that any observed difference may be a product of random assignment error. In essence, there was no difference.

Post-Test Results. The average group mean for the pre-test control and test group was utilized for the informed prior ($\mu = .335$). The average group standard deviation for the pre-test control and test group was utilized for the informed prior standard deviation ($\sigma = .545$).

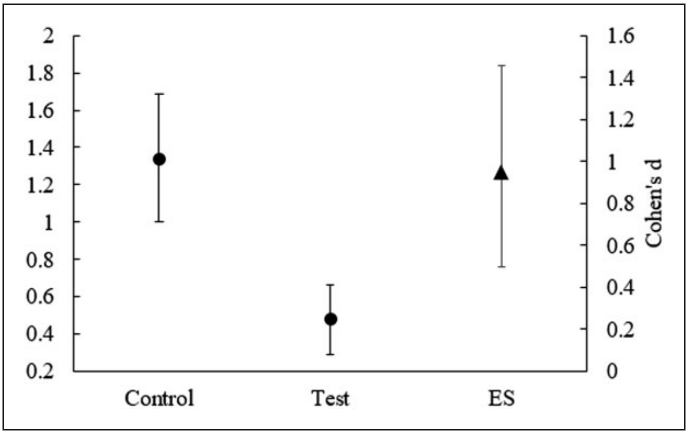

Figure 2. Decision Error Rate by Condition and Effect Size.

The control group made 61 total errors, while the test group made 22 total errors during the posttest (see Figure 2). This corresponds with a control group mean of 1.34 errors per person (95% CI [1.0, 1.69]) and a test group mean of .48 errors per person (95% CI [.29, .66]). The 95% CI for the difference in means (.86 errors) ranged from .48 to 1.25. This suggests that the observed difference was not a product of random assignment error. The effect size of this difference is considered large (Cohen's $d = .95$, 95% CI [.50, 1.46]). These data suggest the test intervention was more effective at training participants to make accurate decisions regarding the presence of a gun. *Hypothesis 1* was supported by these data.[2]

Decision Speed

Pre-Test Results. It took the control group .64 seconds (95% HDI [.57, .72]), on average, to verbalize the presence of a gun. The test group required .68 seconds (95% HDI [.61, .76]) to verbalize the presence of a gun. The difference in means (-.04 seconds) ranged from -.15 to .06, suggesting any observed difference may be a product of random assignment error. No differences were found between the test and control groups.

Post-Test Results. The average group mean for the pre-test control and test group was utilized for the informed decision speed prior ($\mu = .66$). The average group standard deviation for the pre-test control and test group was utilized for the informed decision speed prior standard deviation ($\sigma = .23$).

The control group took .4 seconds (95% HDI [.34, .46]), on average, to verbalize the presence of a gun across the four post-test videos with a gun present (see Figure 3). The test group took .36 seconds (95% HDI [.30, .42]), on average,

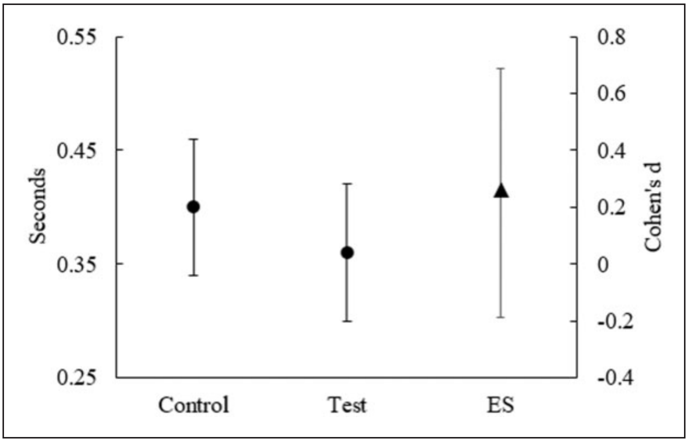

Figure 3. Decision Speed by Condition and Effect Size.

to verbalize the presence of a gun. The difference of means HDI (.04 seconds, 95% HDI [−.04, .12]) crossed zero as a possible parameter value estimate. This suggests any observed difference may have been a product of random assignment error. However, over 84% of the credible values were positive (i.e., the test group made a faster decision than the control group). The effect size of this difference was small and crossed zero (Cohen's $d = .26$, 95% HDI [−.21, .69]). This suggests the observed effect could be attributed to random assignment error. *Hypothesis 2* was not supported by these data.[3]

Fixation Speed

Pre-Test Results. It took the control group .55 seconds (95% CI [.52, .59]) to visually fixate on the item. The test group required .54 seconds (95% CI [.51, .58]) to visually fixate on the item. The difference in means (.01 seconds) ranged from −.04 to .06, suggesting any observed difference may be a product of random assignment error. In essence, there was no difference between the control and test group.

Post-Test Results. The average group mean for the pre-test control and test group was utilized for the informed fixation speed prior ($\mu = .55$). The average group standard deviation for the pre-test control and test group was utilized for the informed fixation speed prior standard deviation ($\sigma = .13$).

The control group took .46 seconds, on average, to fixate on the items (95% CI [.44, .48]; see Figure 4). Alternatively, the test group required .39 seconds, on average, to fixate on the items (95% CI [.36, .42]). The difference of means for the two conditions was .07 seconds. The difference of means CI ranged from .04 to .11, suggesting the observed difference is not a product of random assignment

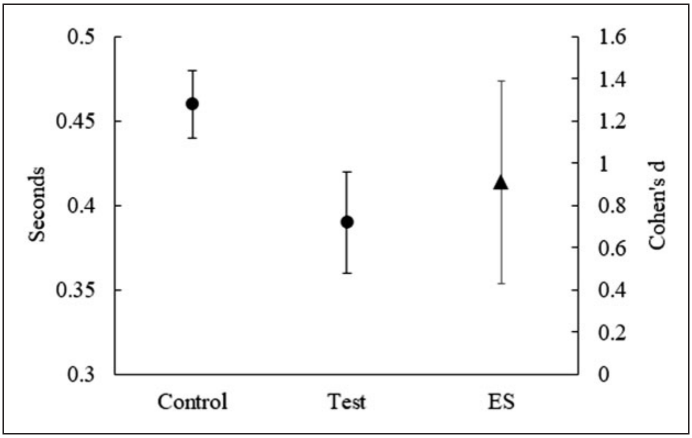

Figure 4. Fixation Speed by Condition and Effect Size.

error. The effect size for the observed difference is large while the CI ranges from a medium effect to large (Cohen's $d = .91$, 95% CI [.43, 1.39]). This suggests the test intervention was more effective at improving the participants' search strategy by reducing the amount of time required to fixate on the item. *Hypothesis 3* was supported by these data.[4]

Discussion

Improving the ability of law enforcement officers to correctly identify the presence of a firearm in a dynamic use-of-force situation is an important step toward correctly applying force and ultimately protecting the public and law enforcement officers. This study found that a simple vision-training program based on the concepts of deliberate practice can significantly improve participants' ability to correctly identify the presence of a firearm in a dynamic use-of-force scenario. In fact, participants in the test condition made approximately one-third the total number of errors of the control group while making the decision in the same amount of time. Ultimately, the participant's visual gaze data illustrate why this training was successful.

It is important to recall the discussion regarding the relationship between visual acuity and foveal vision in the literature review. Foveal vision makes up the approximately 2 degrees of arc in the visual field where an individual is focusing his or her gaze. Items located within the foveal vision are the clearest and contain the most visual information. The brain can use this clear information to accurately identify the items. However, visual acuity drops precipitously as one moves away from this focal point. So, items outside of the foveal vision are still visible, but the individual's visual acuity isn't high enough to process as many distinct features to accurately identify the items. If an item does not enter an individual's more accurate foveal vision, the brain interprets what the item may be based on available information, and false positives are more likely to occur (Otten et al., 2017).

Because the vision tracker was utilized during this study, I was able to see exactly where each participant's foveal vision was focused and could decipher what items each person was actively looking at. Additionally, the vision tracker allowed for the amount of time it took each participant to visually find the item in question to be recorded. The test group visually fixated on the items in question significantly faster than the control group. In fact, the test group was about 16% faster than the control group at visually finding the object in the suspect's hand and determining if it was a gun or not. However, there was no difference between the amount of time it took the groups to verbalize the presence of the firearm. This intuitively makes sense. Participants in the test condition were more likely to visually fixate on the item prior to verbalizing their decision, whereas participants in the control condition were likely to not visually fixate on the item before deciding. It appears as if participants in the control condition were relying on the less accurate peripheral vision to make their decision. Without the accurate foveal vision to guide their decisions, the control condition's decisions were based on incomplete information.

Consider the following use-of-force scenario: The participant is presented with an individual who has his or her back to the participant. The individual quickly turns around with a black object in his hand (in this case a wallet). If the participant was unable to place her foveal vision on the black object, she is forced to make her determination based on the individual's fast movements and a fuzzy black object in his hand. This illustrates how easy it is to falsely identify the black object as a firearm without focusing on the item with accurate foveal vision.

These findings suggest that training law enforcement officers to utilize their foveal vision can greatly improve their decision-making when identifying the presence of a firearm. The most important thing to consider when assessing the results of the study is that participants received only a small amount of training. The participants completed each level of training only one time, and most of the participants finished with less than 20 minutes of training in total. Future research endeavors could examine these short bursts of training over a longer period. For instance, law enforcement officers could receive five or 10 minutes of training once a week for several weeks.

It is also important to note that the participants were never told what they were training for. Never were the participants in either condition told where to look or given search strategies. They were simply told to press 1 if an item was present or 3 if it was not present. Through the deliberate practice model of increasingly complex training with ample feedback, the participants in the test condition intuitively learned not only where to look for a firearm, but they also subconsciously learned what firearms looked like from different angles. While they made their initial decision quickly, each participant was given an unlimited amount of time to study the image after they made their decision. This feedback process intuitively taught participants where to look without having to be directly told. The control condition received strenuous visual training as well. However, the media was not related to the task, so the control condition did not intuitively learn where to look. This factor was important to the overall project. I did not simply want to have a training vs no training experiment. Instead, by having the control group complete similarly complex visual training with unrelated media, this experiment allowed the control group to be trained as well.

Additionally, it is worth noting that the differences observed in this study involved fractions of seconds. For instance, the test group visually fixated on the item .07 seconds faster than the control group, on average. While these differences are short in terms of speed, use-of-force encounters unfold quickly. The smallest of differences could result in an encounter changing from an erroneous use of too much force to the proper application of force necessary to control a dynamic situation. Overall, these findings are extremely exciting and bode well for future research endeavors.

Limitations

As with all data, the data collected during this study are not without limitations. First, students, not law enforcement officers, were used as research participants. While the student participants are similar to newly hired law enforcement officers in terms of age, education, and race, they are not reflective of law enforcement as a whole. Future iterations of this research will utilize law enforcement officers as research participants. It is possible the between group variation will be reduced by having law enforcement participants. Not only have law enforcement officers undergone a base level of training, they are also older, more demographically homogeneous, and have been exposed to more real-life encounters, scenarios, and training throughout their careers. However, with the large effect presented after such a short amount of training, I believe the training could also be successful for the law enforcement community as a whole. Recall that James et al., (2013) found experts outperformed novices with use of force decisions and follow up actions. It is possible that this training program may have a larger impact on younger, less experienced officers. If true, the student sample would be more reflective of the newest generation of law enforcement officers. Furthermore, the student sample allowed me to test this novel training method before using limited law enforcement staffing resources. Second, the test condition training media was limited to white males who were dressed the same (e.g., blue shirts and jeans). While this was used as a control, it is not reflective of the diverse populace law enforcement officers are exposed to every day. There are conflicting results in other, related, research endeavors in regards to race. Specifically, James et al. (2013) and James et al. (2016) found officers were less likely to shoot unarmed Black suspects than they were White suspects, and officers took significantly longer to shoot armed Black suspects than White suspects. Other research (Correll et al., 2002) suggests minority populations have force disproportionately applied during weapon identification scenarios. As such, future iterations of this training will include a more diverse pool of actors to add additional data to the important race related use of force research. Third, this experiment was not able to give us an understanding of how long these improvements may last. It is possible this training would need to be repeated, but it is not clear how often it would need to be repeated. The training program was designed to be completed in short bursts so law enforcement officers could continually train throughout the year. Lastly, the vision tracker records data at 30 fps. This results in a 0.03 second level of data specificity. Higher-speed camera systems would allow for a more precise level of measurement; however, the current vision tracking technology does not allow for the increased speeds. Even when limited to 30 fps, the difference between visual fixation times was great enough to show a large effect.

Future Research

While this study showed promise in vision training and deliberate practice, future research into both vision training for law enforcement and implementing the concepts of deliberate practice into law enforcement training are clearly needed. For instance, future endeavors should focus on extending the current training model by (1) introducing variation with the actors beyond Caucasian males, and (2) increasing the complexity of the training media by adding in additional factors (e.g., presence of bystanders, different lighting conditions, varying the background). The method in which the training is delivered could also be varied to include computer programs, virtual reality, or augmented reality-based training. These new technologies may improve the way participants retain training. In addition to improving the training media, future samples should include law enforcement officers. There may be inherent differences between student-aged participants and law enforcement officers. Finally, while this study adds to the small body of use-of-force skills studies (see Blair & Martaindale, 2017; Blair et al., 2019), use-of-force skill-retention studies should be undertaken to examine how use-of-force decision-making skills degrade. This knowledge would allow trainers to develop follow-on training to best serve law enforcement.

Specifically, how long do these improvements last? While this experiment showed improvement with a short burst of training, future research must examine how often these skills need to be reinforced.

Appendix A. Example of Training Media

✪	F	§	Ψ
ς	A	➘	⏎
Ξ	Σ	α	N
¢	ϑ	G	Ŵ

Note. The control group example is on the left, and it does contain a vowel. The test group example is on the right, and it does contain a firearm.

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Notes

1. The *Washington Post* data only considers a suspect unarmed if the suspect does not have anything resembling a weapon. A suspect with a toy or replica firearm would be considered armed. For those who prefer traditional (frequentist) statistical testing, the following analyses are included.
2. Decision Error Rate. A Shapiro-Wilk normality test indicated that the decision error rate data violated the normality assumption ($W = 0.78$, $p < 0.001$). Many prefer to deal with non-normality using a non-parametric test. A Mann-Whitney U-test was utilized to assess the decision error rate data. The test was significant ($U = 1436$, $p < 0.001$) and suggestive of a large effect size (Cohen's $d = 1.1$; 95% CI 0.65, 1.55). All the frequentist tests presented here are consistent with the Bayesian results. If anything, the Bayesian results are somewhat more conservative. The Bayesian results also have the added benefit of being derived from a logically consistent framework and providing an answer to the question that was actually asked, as opposed to proof that the always false null point estimate was in fact false and then committing the logical fallacy of transposing the conditional to claim that the research hypothesis is true.
3. Decision Speed. A Shapiro-Wilk normality test indicated that the decision time data were normally distributed ($W = 0.98$, $p = 0.19$). A t-test was conducted to examine the differences between means. Levene's Test for Homogeneity of Variance was not significant, so equal variances were assumed. As with the Bayesian analysis, the t-test showed there likely is no difference between the groups and was not significant ($t_{(83)} = 1.08$, $p = 0.28$, 95% CI -0.03, 0.18) and suggestive of a small effect size for the effect of intervention on participants' decision speed (Cohen's $d = 0.23$, 95% CI -0.19, 0.66).
4. Fixation Speed. A Shapiro-Wilk normality test indicated that the fixation time data were normally distributed ($W = 0.98$, $p = 0.14$). A t-test was conducted to examine the differences between means. Levene's Test for Homogeneity of Variance was not significant, so equal variances were assumed. The t-test was significant ($t_{(83)} = 3.29$, $p < .01$, 95% CI 0.03, 0.10) and suggestive of a medium effect size for the effect of the intervention on participants' time to fixate on the item (Cohen's $d = 0.71$, 95% CI 0.27, 1.14).

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