Pistol Skill Acquisition and Retention: A 3-Year Longitudinal Study

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ABSTRACT

This paper will build on previous research designed to investigate the effects that pistol training, in a no-recoil synthetic environment, has on skill acquisition, the transferability of this skill in situ (Krätzig, Parker & Hyde, 2011), and the long term implications on skill retention. Krätzig et al (2011) found that live-fire training was not necessary for pistol skills acquisition nor was it needed when testing occurred in a live-fire setting. However, two areas of investigation was missing. The first was to measure performance after introducing live-fire before each Benchmark test. The second was to investigate the long term effects that this type of training has on pistol shooting skill retention (e.g., annual firearms recertification). This paper will present three follow-up lines of research. Two-hundred and fifty-six Cadets [i.e., 128 Cadets (control group) vs. 128 Cadets (experimental group)] were used for this study, with ninety-six Cadets being trained in the synthetic environment. The three lines of research are:

1) The effects of this training on skill retention in the field for three consecutive years.
2) Will adding live-fire training before each test improve performance and what effect does this have on skill retention in the field?
3) Results of a replication study.

Although evidence was found that skills transfer from a synthetic training environment to a live-fire setting (Krätzig, et al., 2011), unknown were the long term effects on skill retention, and as such results of a 3-year longitudinal study will be reported. Additionally a potential confound was identified following the Final Benchmark Test from the Krätzig et al (2011) study. Krätzig argued that because the first time these Cadets fired a live-fire weapon was during their Benchmark tests, that the unfamiliarity of the recoil, concussive blast, noise, etc resulted in lower scores and an increase in the failure rate during the Benchmark tests. In an effort to determine if overall performance could be improved, it was decided that live-fire training would occur preceding each Benchmark test. These results will be discussed in full. There is increasing evidence that supports integrating technology into the basic 24-week training program; however, it was important to replicate the Krätzig et al., (2011) study. The third area of discussion will present the results of the replication study.

ABOUT THE AUTHOR

Mr. Krätzig is responsible for investigating how simulator technology can be integrated into a police training environment, and whether the skills transfer into a real world setting. He has led several research projects, some of which have resulted in full integration into the RCMP training program. Ongoing research includes the investigation of training factors that may influence the degree to which skills are retained as well as those factors that mitigate skills from degrading. Greg is also leading the national simulation firearms research program that will see active police officers re-qualify with their pistol in the synthetic range environment for two of the next three years. He is nearing completion of his PhD which is an investigation of the effects of training in synthetic environments on skill acquisition and durability of skills depending on the amount of training received and the degree to which those skills are transferred to real world setting. Greg has been awarded ~$700,000 in research grants and scholarships in support of his work, and was awarded the Queen Elizabeth II Diamond Jubilee Medal in 2012. He has presented papers at many national and international conferences, and has 31 peer-reviewed publications and presentations.

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INTRODUCTION

Law enforcement officers have many tools at their disposal, whether it is a flashlight, OC-spray, their verbal communication skills, or their pistol. Although these are all critical tools for any police officer, they are not just given without proper training in their use. A review of the literature revealed a paucity of scientific evidence in the area of police training, which is surprising given the long history of policing in our society, not to mention the number of police agencies. Perhaps the lack of evidence investigating police training is related to how police research used to be conducted, and the negative and long term implications that this has had on relationships between academia and the police. Laycock (2014) suggested that police have long resisted academic research; and that this was due in part because scientists conducted research "on" police, rather than with or for them. This paper addresses a gap in the literature that investigates a number of domains as it relates to pistol skills acquisition and retention, as well the use of technology as a replacement to live-fire training.

Collins English Dictionary and Thesaurus (1999) defines skill as a "special ability in a sport, etc., or something requiring special ability or manual proficiency". Although this definition has evolved over time, it was Pear (1928) who first defined this term. Pear suggested that skill is dependent on habit, that it should only apply to "higher types of well-adjusted performance" (pp 611), and has clear reference to the quantity and quality of output, an important consideration when performance of a particular task is examined (Adams, 1987). Researchers argue that police training, or more specifically pistol training, is rooted in tradition, and best practices instead of science (Krätzig, Parker, and Hyde, 2011; Morrison &Vila, 1998). This argument is supported even further following an exhaustive review of the literature in the area of skills acquisition and retention as it relates to pistol training. There is a great deal of skill acquisition research in areas such as athletics training (e.g., Guadagnoli, Dornier, & Tandy, 1996; Summers, 2006), typing (e.g., Baddeley & Longman, 1978), and medical training (e.g., Seymour et al., 2002; Stefanidis, Korndorffer, Sierra, Touchard, Dunne, & Scott, 2005; Wik, Myklebust, Helge, Auestad, & Steen, 2002)[1]. However, the extant literature indicates a significant gap examining the role of overlearning and duration of the retention interval as it pertains to skill retention. The author was unable to find any scientific evidence to suggest what the optimal number of training sessions should be, how many trigger pulls are required, nor was their evidence to support re-certifying pistol skills every 3, 6, 12 or more months.

Consider, for example, a person who plays golf once per month. It is unlikely that this amount of effort would have them qualify for any professional tournament, although it may be enough to allow them to be competitive at their company golf tournament. In northern climates where year-round outdoor golfing is often not possible, many golfers take a hiatus during the winter months. Once the weather improves and golf courses re-open, many golfers need to practice their skills before achieving the same level of competence they had before the previous season had concluded. The same can also be said for professions that require a minimum skill level to be achieved in order to continue employment; those who do not meet the minimum (and often arbitrarily assigned) standard may require remedial training whereas those who demonstrate superior skills are often recognized with promotions or other rewards (Ericsson, 1996; Ericsson et al., 1993).

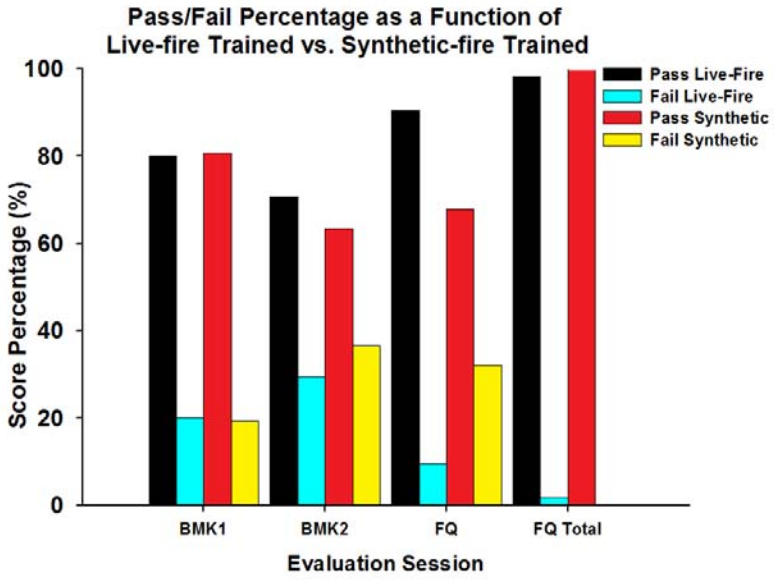
In 2008 the Royal Canadian Mounted Police (RCMP) began the first of several studies designed to determine if pistol shooting skills could be acquired in a synthetic training environment (i.e., in the absence of both live-fire and recoil training), and the extent that these skills were transferable to a real-world setting. Although technological advances have improved the effectiveness of many of these tools, including the revolver vs. pistol, one of the most

[1] The current direction of research investigating the retention of surgical skills may be a result of a paradigm shift from training in situ to training in a synthetic environment (Seymore et al., 2002; Stefanidis et al., 2005; Wik et al., 2002).

significant advancements in the area of police training has been the development of simulation technology as an instructional tool; however, adoption of this technology has been slow (Krätzig & Hudy, 2012).

In an effort to determine the efficacy of simulation training, the Royal Canadian Mounted Police (RCMP) developed a line of research studies designed to provide the empirical evidence needed to determine 1) if synthetic firearms training could be conducted in lieu of live-fire training, 2) whether the skills acquired in this environment could be transferred to a live-fire setting, and 3) what are the economic implications of utilizing this technology. The first study was completed in early 2011 (Figure 1), and the results provided evidence that pistol skills can be acquired in a synthetic training environment using only dry-fire weapons (i.e., no recoil and no live-fire training; Krätzig, et. al., 2011).

This paper significantly adds to the research conducted by Krätzig, et al., (2011), and is designed to investigate what effects integrating live-fire has on pistol skill acquisition, and the longitudinal effects on pistol skill retention following three years of active duty in the field.



Krätzig, Parker, and Hyde, (2011).

Figure 1.
Note. BMK1 = Benchmarks 1, BMK2 = Benchmark 2, FQ = Final Qualification First Attempt, FQ Total = Final Qualification Second Attempt.

METHODS

Participants

In order to measure the effectiveness of this type of training one troop of Cadets (N = 32) was studied; however, the training methods variable was manipulated and they were not trained exclusively in the synthetic environment. In the Krätzig, (2011) study, the Cadets who were trained entirely in the synthetic environment had their first exposure to a live-fire weapon during their first benchmark test. However, it could be argued that performance was negatively affected because recoil concussive blast, etc., was not present during the initial training. The hypothesis was that if the Cadets were exposed to live-fire feedback (i.e., recoil, concussive blast, etc.) before each of their three benchmark tests that there would be both a score improvement, as well as an improvement in the pass rate. In order to achieve this the troop of Cadets received live-fire practice in each of the three sessions prior to their benchmark tests. Their performance was compared to the data collected in the Krätzig, et al., (2011) study (Troop A; N = 32).

Materials

Every Cadet is required to successfully complete an intensive 24-week training program (e.g., pistol training occurs over eighteen sessions). Although this training traditionally occurs on a live-fire range environment, the experimental group of Cadets would receive the majority of their pistol training in a synthetic range environment, shooting live rounds during six sessions (i.e., each training session before their benchmark tests, as well as the three benchmark tests). The pistol training they received was identical in every respect to live-fire training; however, they did the majority of their training with dry-fire laser-based pistols[2]. The training system that was used was the PRISim trainer (CUBIC, 2013). This computerized system projects a digital 25 m range complete with 16 lanes of fire (Figure 2 and 3). Photos of our firearms range were taken and digitized to replicate, as close as possible, what the Cadet would see if they were on the 25 m live-fire range at the RCMP Training Academy (e.g., target carrier system, lighting, shadows, etc.). The targets used were jpeg images that were digitized to resemble the targets Cadets use in training, but were resized to represent how they would appear when placed at distances of 3, 5, 7, 15 or 25 m. Cadets used the RCMP standard Smith & Wesson issue pistol (model 5946) but it was modified to emit a laser beam (i.e., all pistols were dry-fire weapons only). Additionally the synthetic environment was always treated as if it was a live-fire range and Cadets and Instructors adhered to all safety protocols including requiring the Cadets to wear their duty belt, ear and eye protection, as well as body armor. These data were analyzed using SPSS 19.0 (IBM, 2011) statistical software, and the results are considered significant at $p < .05$.

Figure 2. Photo of 12 lanes of fire at the RCMP Training Academy with Cadets training in the synthetic environment.

Figure 3. Close-up photo of the synthetic range environment

Design

One of the many training requirements for Cadets is to pass the Final Benchmark exam; however, they first must participate in two preceding evaluation sessions (i.e., Benchmark Test 1 and 2). Cadets who fail the first attempt during any of the three Benchmark exams, are allowed a re-test following remedial training. Although a second failure at Benchmark 1 or 2 would not initiate termination procedures, if a Cadet fails their second attempt at the Final Benchmark exam, termination procedures would begin.

Benchmark 1. Targets are placed at 15 m, and the Cadets are instructed during five-50 min sessions. Cadets are tested during the sixth session (Benchmark 1) and must achieve a minimum of 15/18 rounds centre of the mass.

Benchmark 2. This test consists of four stages (i.e., Stage 1, Stage 2, Stage 3, Stage 4), and each stage must be completed in sequence. Cadets must achieve a score of at least 168/210 to pass this test.

Final Benchmark Test. This test is the last time the Cadets will be evaluated on the range before they leave the training academy. This test includes each of the four stages that make up Benchmark 2 plus an additional stage (i.e., Stage 5).

[2] Cadets who trained in the combined synthetic/live range environment shot on average 396 live rounds during their training compared to 2300 live rounds for their live-fire trained peers, and 200 live rounds fired in the Krätzig, et al., (2011) study.

Stage 1. Cadets must shoot 14 rounds at a target set at 25 m. The Cadet must achieve a score of at least 46/70 in 120 s or less. This stage includes shooting in the standing kneeling, and prone positions. Cadets must also successfully clear a stoppage.

Stage 2. Cadets shoot 8 rounds at a target placed at a distance of 15 m with the first 4 rounds fired from the standing position followed by 4 rounds from the kneeling position. Cadets have 20 s to complete this stage and must achieve a score of at least 26/40.

Stage 3. Cadets begin this Stage with their pistol out of their holster (i.e., low ready). Eight rounds are shot at a distance of 7 m. Four target facings are presented for 2 s each, and Cadets are given 2 s to fire 2 rounds in each of the four facings. They must score at least 26/40 to pass this stage.

Stage 4. Cadets shoot this stage at a distance of 5 m and they must fire 12 rounds (i.e., 3 rounds for 5 s per facing). They need to achieve a minimum score of 40/60 to pass.

Stage 5. Cadets shoot a target that is placed 3 m away, and is the only test of one-handed shooting. Cadets must first fire 4 rounds with their dominant hand, reload, and then additional 4 rounds with their support hand. Cadets have 15 s to complete this stage and must achieve a minimum score of 26/40.

RESULTS

In order to draw comparisons, data obtained from the Krätzig, et al., (2011) study (N = 32) was collapsed with the data from this study (N = 32). This approach was used because it was important to measure performance differences between the Cadets who were trained without live-fire (i.e., Troop A; Krätzig, et al., 2011), with those Cadets who were given live-fire practice before each of the three Benchmark tests (Troop B). The pass/fail rates across the three Benchmark Tests were calculated, and a chi-squared analysis was conducted and there were no pass/fail differences between Troop A and Troop B for Benchmark 1, Benchmark 2 or the Final Benchmark Test, with 100% of the Cadets from both Troops passing their final Benchmark Test (Table 1). Pass/fail rates for the live-fire trained (Control) Cadets (N = 96). A chi-squared analysis found that there were significant pass/fail differences between the two experimental Troops (Troop A and B) and the live-fire Control Cadets, with 97% of the Control Cadets vs. 100% of the Experimental Troops passing the Final Benchmark Test ($p < .05$).

Table 1. χ^2 Analysis for Each Evaluation Session

Evaluation Session	χ^2	*df*	*p*	ϕ2
BMK1	.268	1	.605	.067
BMK2	.000	1	.986	.002
FQ	-.042	1	.752	.100

Note. BMK1 = Benchmarks 1, BMK2 = Benchmark 2,
FQ = Final Benchmark Test.

Mean Scores

Shooting performance differences were measured between Training Condition (Control; Live-fire vs. Troop A; Synthetic-fire vs. Troop B; Synthetic/Live-fire) and each Benchmark Test using a Oneway ANOVA with Training Condition as the between subjects factor. There were score differences in Benchmark 1 Test with those Cadets who were trained in the Synthetic/Live-fire (Troop B) condition scoring lower than the other two training conditions $F(2,138) = 14.569$, $p < .001$. Cadets who were trained in the live-fire environment (Control) scored better in Benchmark 2 than those Cadets who were trained in either the Synthetic-fire (Troop A) or the Synthetic/Live-fire

(Troop B) condition $F(2,138) = 5.724$, $p = .004$. There were no differences found following the Final Benchmark test $p = .114$ (Figure 4).

Mean Scores for Those Cadets who Failed a Benchmark Test

Benchmark 1
Data between all three groups were analyzed using a 2 (Test; First Test vs Re-test) x 3 (Training Condition; Live-fire vs. Synthetic vs. Synthetic/Live) repeated measures ANOVA. There was a main effect of Training Condition with scores higher for those who were trained in the live-fire condition than those Cadets in the other two conditions $F(2,41) = 10.15$, $MSE = 253.47$, $p < .001$. There was no Training Condition x Test interaction ($p > .05$); however, a Bonferroni PostHoc test was conducted and the Cadets who were trained in the synthetic/live-fire condition scored significantly lower than the Live-fire training condition $p < .001$, and the synthetic-fire training condition $p < .009$ (Table 2).

Benchmark 2
Data between all three groups were analyzed using a 2 (Test; First Test vs Re-test) x 3 (Training Condition; Live-fire vs. Synthetic vs. Synthetic/Live) repeated measures ANOVA. There was an effect of Test with scores higher for all groups in during the re-test $F(2,45) = 9.45$, $MSE = 40.82$, $p = .004$, all other effects were $p > .05$ (Table 2).

Final Benchmark
Data between all three groups were also analyzed using a 2 (Test; First Test vs Re-test) x 3 (Training Condition; Live-fire vs. Synthetic vs. Synthetic/Live) repeated measures ANOVA. There was an effect of Test with scores higher for all groups during the re-test $F(2,24) = 41.14$, $MSE = 27.04$, $p < .001$, all other effects were $p > .05$ (Table 2, Figure 5).

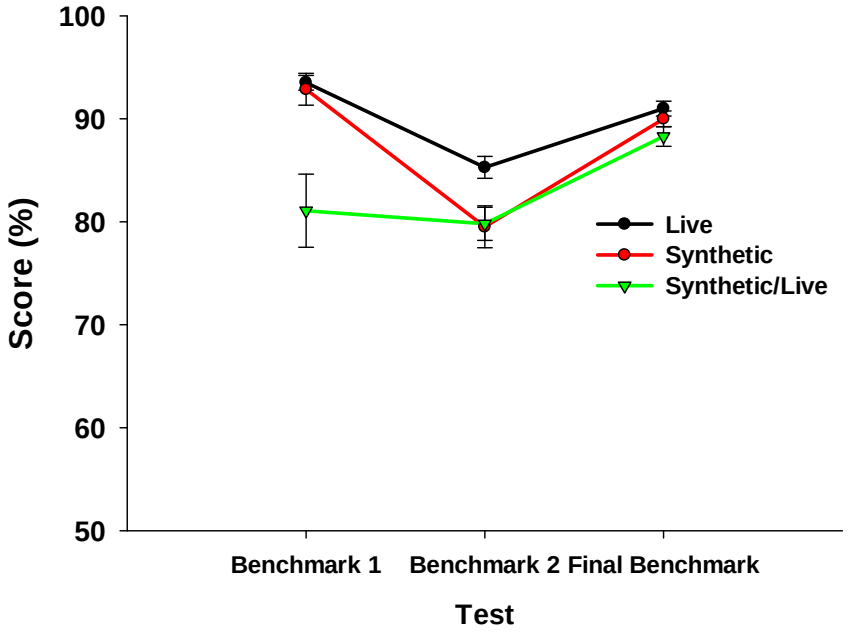


Figure 4. Benchmark Test Scores as a Function of Training Condition
Note. Live = Live-fire trained, Synthetic = No live-fire training, Synthetic/Live = Live-fire training before each Benchmark Test

Table 2. Total Mean Percentage Scores, only for Cadets who Failed an Evaluation Session.

Evaluation Session	Live-fire Mean	SE	Synthetic-fire Mean	SE	Synthetic/Live Mean	SE
BMK1	81.19	2.42	71.28	2.52	62.42	2.20
BMK1a	86.91	4.49	88.29	4.66	70.91	4.08
BMK2	67.38	1.79	70.48	2.64	71.47	2.43
BMK2a	74.94	2.11	72.55	3.12	74.54	2.87
FQ	76.89	2.18	77.82	1.98	76.70	2.48
FQa	82.58	2.56	90.98	2.32	85.54	2.90

Note. BMK1 = Benchmark 1 first attempt, BMK1a = Benchmark 1 Reshoot, BMK2 = Benchmark 2 first attempt, BMK2a = Benchmark 2 Reshoot, FQ = Final Benchmark Test First Attempt, FQa = Final Benchmark Test Re-shoot.
* $p < .05$

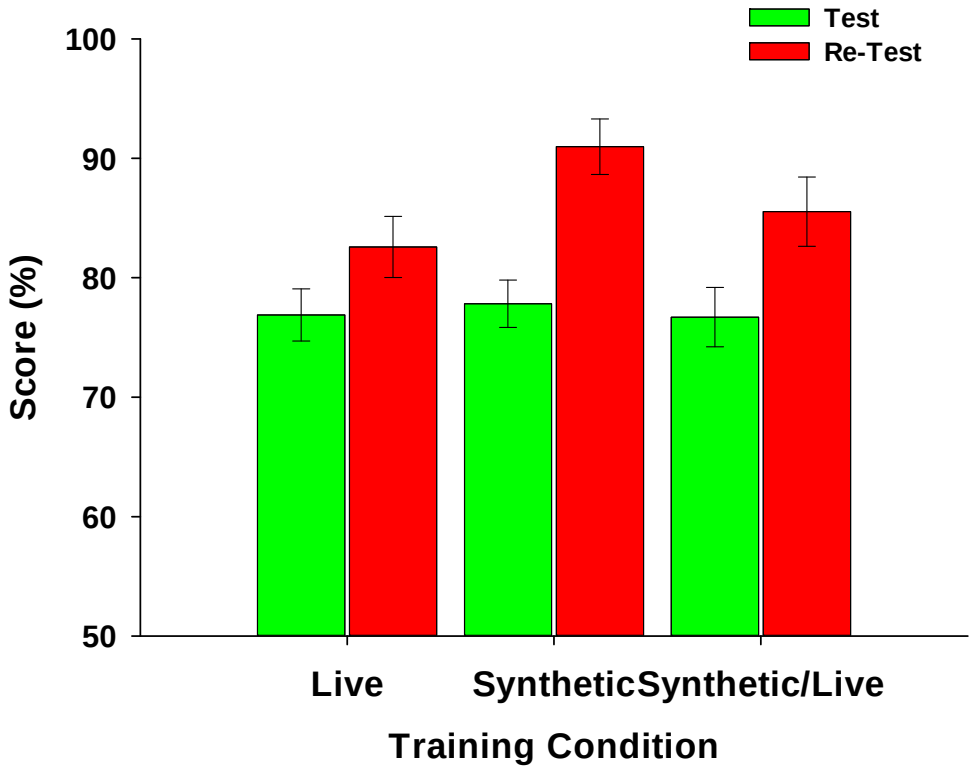


Figure 5. Final Benchmark Test, Re-test Scores as a Function of Training Condition
Note. Live = Live-fire trained, Synthetic = No live-fire training, Synthetic/Live = Live-fire training before each Benchmark Test

Retention

Following the Final Benchmark Test and successful completion of the rest of the Cadet Training Program, Cadets are engaged to the field. As part of their job requirements they must pass an Annual Pistol Qualification (AFQ).

AFQ scores were collected for all of the Cadets in this and the previous study and were analyzed over a three-year period. A 2 (Training Condition; Live-fire vs. Synthetic-fire) x 4 (Test; Final Benchmark vs. AFQ 1 vs. AFQ 2 vs AFQ 3) repeated measures ANOVA, with Training Condition as the Between Subjects factor was conducted. There were no score differences found $p < .05$ (Figure 6).

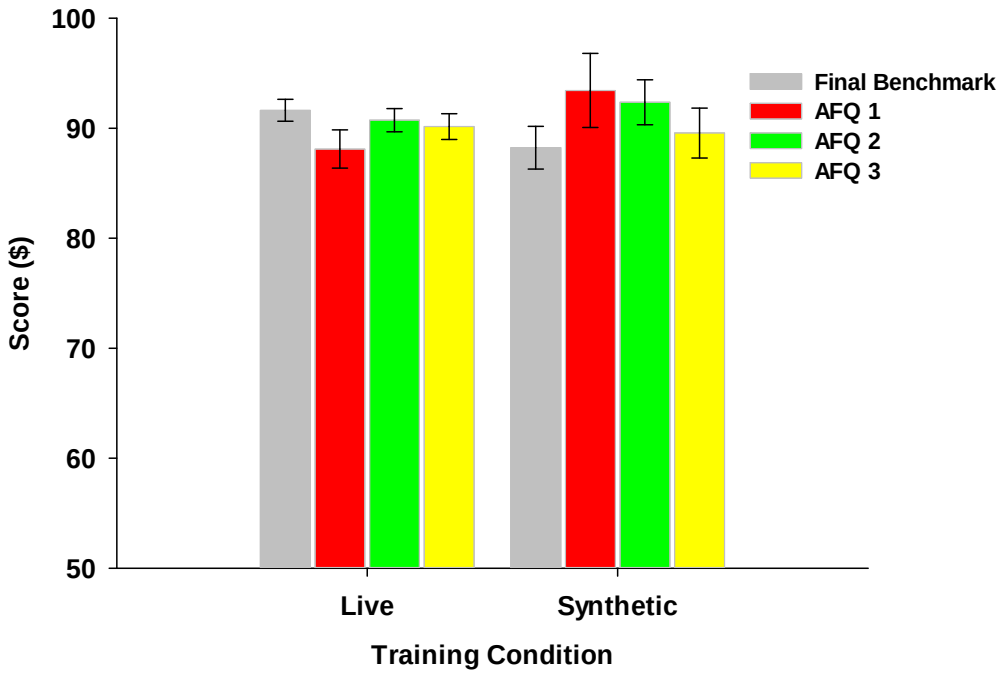


Figure 6. Test and AFQ Scores as a Function of Live vs. Synthetic-Fire Training
Note. Live = Live-fire trained, Synthetic = Synthetic-fire trained, Final Benchmark = Final Benchmark Test, AFQ 1 = First Pistol Requalification in the field, AFQ 2 = Second Pistol Requalification in the field, AFQ 3 = Third Pistol Requalification in the field.

Replication

Although the results of the Krätzig et al., (2011) study suggested that training in a synthetic environment was possible (Troop A), findings from the Federal Law Enforcement Training Center (Hawthorne, Wollert, Burnett, & Erdmier, 2011) in the United States and the Singapore Police, who conducted similar research, also found similar results. However, the RCMP made a decision to replicate their earlier 2011 study. Because of the recency of this research, there is no retention data to consider, there is; however, data from a Troop of Cadets (Troop C) who were trained in the same fashion as Troop A. An Oneway ANOVA was conducted with Troop as the between subjects factor. The results of the replication research found no score differences between Troop A and Troop C at Benchmark 1 Test ($p = .054$), Benchmark 2 Test ($p = .402$), or the Final Benchmark Test ($p = .416$), nor were there any pass/fail differences when a chi-squared analysis was conducted ($p > .05$).

DISCUSSION

Although the results of the Krätzig et al., (2011) study provided conclusive evidence that pistol training can be completed in a synthetic range environment, and that these skills can be acquired in the absence of live-fire using only dry-fire laser-based pistols, two questions remained. The first question centered on the first Benchmark Test. Cadets began their pistol training in the simulated range environment, and the first time they were exposed to live-fire was during this first Benchmark Test. Although the results were encouraging, it was posited that if Cadets were exposed to live-fire training before each of their three Benchmark Tests, then would this increase the pass rate as well as increase scores? It was assumed that the unfamiliarity of the concussive blast and the recoil of the pistol might have "surprised" some Cadets, eroding their confidence in their skills. The second question that could not be

answered immediately was what effect does training without recoil, noise, etc., have on later retention in the field? Even though it was agreed that Cadets could learn to shoot in this environment, it was still unclear what the effects that this training has after a year. As for all RCMP officers, they are required to demonstrate annually that they can pass the pistol course-of-fire.

The first question was answered first, rather than wait a year to measure the retention of the pistol skills of the first experimental troop (Krätzig, et al., 2011; Troop A). Using a second troop of Cadets they were trained in an identical manner as evidenced with Troop A with one exception. In the training session immediately preceding their three Benchmark Tests, the Cadets completed this training in a live-fire environment instead of the synthetic environment. It was assumed that if Cadets were exposed to recoil, and the concussive blast before their Benchmark Tests that they would be better prepared for their tests thereby improving the pass rates and overall scores. Following the conclusion of their training it was found that their results mirrored those that were found with Troop A (Krätzig et al., 2011). As was found with Troop A, 100% of the Cadets in this current study passed their Final Benchmark Test, and no score differences were found. In fact being exposed to live-fire before each of the benchmark tests did not appear to affect performance either positively or negatively.

The second question took three years to answer. All the requalification scores for both the experimental and control troops in the Krätzig et al., (2011) study were collected and the results found were unexpected. Historically when Cadets leave the training academy for the field their requalification scores decrease in each of the two years following graduation (N = 6,429). When scores for the control troops were examined it was discovered that their scores from their AFQ in the field followed that trend and were lower than their scores achieved in the training academy. However, when the scores for the experimental troop were examined they not only maintained their skills, but in fact their scores were marginally higher than their training academy scores (Figure 4). Although not empirically studied, it could be argued that the increased number of trigger pulls (i.e., at least twice as many as those receiving live-fire training) for those Cadets who were trained in the simulated range environment further strengthened their muscle memory. A second compelling argument is that training in a dry-fire environment allowed the Cadet and instructor to focus on the skill itself (e.g., trigger control, sight alignment, grip, etc) instead of having to worry about the recoil feedback and the associated psychological implications. Planned follow-up studies will examine this issue.

CONCLUSION

The evidence is clear that this technology has proven to be a safe and reliable way in which to train Cadets how to acquire pistol shooting skills. However, the lack of any scientific evidence necessitated the need for the RCMP to begin this investigation that would start to provide information which would be defendable if and when the technology was integrated into the Cadet training program.

The research discussed in this paper revealed that a police officer can acquire all of their pistol skills in the absence of live-fire using only dry-fire pistols, that the skills are transferable to a real world setting, and that the skills are better maintained than their live-fire trained peers. It is also important to note that these studies examined only the acquisition and retention of the skill, and did not look at the decision making process (i.e., when and if to shoot). Although we are not trying to replace live-fire, we are looking for opportunities to train police officers in a more dynamic setting. One of our long term projects is to develop a course for Cadets that would be more dynamic in nature instead of the current practice. It is believed that this type of high intensity training will better prepare our police officers if they should ever find themselves in a deadly use-of-force encounter, and it is simulation technology that will help us achieve our goals.

ACKNOWLEDGEMENTS

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