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Development and Evaluation of a Novel Method for Basic Marksmanship Training on an Australian Army Course

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ABSTRACT

Marksmanship training simulators are widely used within the Australian Army and other defence forces to support marksmanship training. While there is much anecdotal evidence to support the training effectiveness of these devices, there is little empirical data that quantifies their effectiveness, and informs the appropriate mix of simulation and live-fire training for specific marksmanship tasks. This report documents the development and evaluation of a novel method for basic marksmanship training with the M4 weapon, as part of a follow-on study. The novel training method consisted of 70% simulation and 30% live-fire and contained practices that specifically addressed factors linked to poor qualification rates in the previous study. The outcomes were compared with those from a standard training method that was based on current marksmanship doctrine. Both training methods resulted in very high (94%) pass rates after three qualification attempts and a significant saving in the number of live rounds used when compared with the previous study. The findings support the effectiveness of the novel training method and provide additional evidence for the utility of simulation in basic marksmanship training. The report discusses the reasons for the findings and outlines recommendations for future studies.

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Executive Summary

Marksmanship training simulators are widely used within the Australian Army and other defence forces to support marksmanship training. While there have been numerous studies investigating the utility of these simulators, there remains a gap in our understanding of how to best employ these devices in marksmanship training programs, including the mix of simulation and live-fire training for specific marksmanship practices. This report documents the development and evaluation of a novel training method for basic marksmanship training. This work is a follow-on to a previous study conducted by Stephens and Temby (2014) which examined the utility of simulator training for achieving better training outcomes on an Australian Army course. The primary aims of this study were to (a) evaluate the effectiveness of a novel training method for marksmanship qualification relative to a standard training method, and (b) to compare training outcomes with those from our previous study. The study was conducted by DSTO Land Operations Division under Task ARM 07/163: Training, Learning and Performance.

Thirty-five personnel enrolled in an Australian Army training course took part in the study. As part of the course, trainees were required to undertake basic marksmanship training using the M4 weapon with iron sights and pass a qualification practice on the live-fire range. Trainees were randomly assigned to either the novel training method or a standard training method. Both groups completed simulator and live-fire training practices over four days. The novel training method comprised 70% simulator and 30% live-fire training, including specific practices to address factors negatively impacting on qualification rates. The standard training method comprised 55% simulator and 45% live-fire, and was based on the existing training program. Following training, both groups undertook qualification until all trainees qualified. The findings showed that both training methods were equally effective and resulted in high pass rates (94%) after three qualification attempts. Both training methods resulted in faster qualification and significant savings in live rounds compared with the previous study. The most likely reasons for the outcomes are: adopting a more methodical training progression, greater opportunities for practice and feedback, and the use of white target imagery in the simulator, when compared with the previous study.

Overall, the findings suggest that the novel training method is effective for basic marksmanship training and could replace the current training method. The results also provide support for the utility of simulation for basic marksmanship training. The report concludes with additional recommendations for future marksmanship training research, including investigating whether the findings generalise to other weapon systems and marksmanship practices.

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Acronyms

ADF	Australian Defence Force
DSTO	Defence Science and Technology Organisation
LF	Live-Fire
LOD	Land Operations Division
M4	M4A1 Weapon System
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
WTSS	Weapons Training Simulation System

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1. Introduction

Marksmanship training is a core component of individual training within the Australian Army (Filippidis & Puri, 1999) and other defence forces. This is because the ability to handle a weapon safely and deliver accurate and effective fire (marksmanship) is a fundamental skill required by all soldiers, especially for those in combat units. Traditional marksmanship training involving live-firing is resource intensive because of the cost of live ammunition, transport time to and from firing ranges, time to draw weapons from armouries, the requirement to have qualified personnel oversee range safety, and other administrative overheads. With diminishing training budgets defence forces are seeking more efficient and effective ways to deliver marksmanship training. The use of marksmanship training simulators can potentially result in significant cost-savings, greater training efficiency, and reduced ammunition expenditure compared with live-fire training. Consequently it is not surprising that modern armed forces, including the Australian Defence Force (ADF), have adopted these simulators[1] to support marksmanship training.

Marksmanship training simulators provide a safe and convenient environment for military personnel to practice marksmanship skills, such as weapon handling and target engagement. While there are different versions of these simulators available, they typically consist of a laser-instrumented weapon, projector for projecting the target imagery and background scenery onto a screen, camera for capturing the laser footprint when the weapon is fired, and a gas-powered system for simulating weapon recoil, along with associated computing software to support firer performance review and analysis. These simulators allow trainees to practice and confirm marksmanship principles, rehearse practices to be fired on outdoor firing ranges, and detect and correct faults in firing technique (Australian Army, 1993). In doing so, trainees can develop their confidence and competency with weapon handling and other marksmanship skills before conducting live-firing[2]. However, unless these simulators support trainee learning, and the programs are based on good training principles, the training is unlikely to be effective. While there are many published studies on marksmanship, there have been few publicly available studies which have empirically evaluated marksmanship training programs. Without such data, it is difficult to diagnose the effective and ineffective components of training programs, and hence where improvements to training may be required.

This report describes an empirical study of basic marksmanship training with the M4 weapon (using iron sights) on an Australian Army course. The study was a follow-up to a previous study conducted by the authors (Stephens & Temby, 2014) in DSTO Land Operations Division. The broad aim of the two studies was to investigate how faster qualification rates could be achieved using both simulation and live-fire training methods. In the previous study, a number of limitations in the training method were found to impact on qualification rates (e.g. simulator target imagery, training sequence, lack of

[1] These simulators have different names in different defence forces. For example, the Australian Army uses the Weapon Training Simulation System (WTSS) while the Canadian Army uses the Small Arms Trainer (SAT). For convenience we use the term 'marksmanship training simulator' to refer to these simulation systems.

[2] Army doctrine also recommends conducting 'dry shooting training' to develop shooting technique. Dry shooting was not examined as part of the current study but the technique was taught to trainees on the marksmanship course.

coaching); the current study was specifically designed to address these limitations using a novel training method. The report commences with a brief summary of previous marksmanship training research, which is followed by a description of the study aims, methods and measures, and then the key findings. The report then compares the findings from the two studies, and highlights the implications for simulation-based marksmanship training. The report concludes with key messages for the military and scientific communities, including recommendations for future marksmanship training and research.

1.1 Previous Marksmanship Training Research

There have been numerous studies conducted into marksmanship training and the use of simulators for marksmanship training. These studies can be grouped into four categories which are relevant to the current study. In the first category, studies have investigated the correlation between simulator and live-fire scores and predictors of live-fire performance. In doing so, these studies have attempted to validate the reliability of marksmanship simulators and determine useful measures of trainee readiness to commence live-firing. In general, these studies have found that firer performance is worse in the simulator compared to live-fire (Gula, 1998; Keefe & Tikuisis, 2003), and the correlation between simulator and live-fire varies from low to moderate on equivalent tasks (Chung et al., 2006; Delanghe, 2001; Filippidis & Puri, 1999; Smith & Hagman, 2000; 2003). In addition, there is some evidence that self-estimates of marksmanship ability can predict marksmanship qualification scores (e.g. Schendel, Morey, Granier, & Hall, 1983). The implication from this category of studies is that: (1) simulator scores may not be a reliable indicator of live-fire performance and hence caution should be used when comparing simulator and live-fire scores on equivalent marksmanship tasks; and (2) self-report ratings of marksmanship ability show some predictive utility.

In the second category, studies have examined the training effectiveness of marksmanship simulators by evaluating skill transfer from the simulator to live-fire (e.g. Collier, 2010; Delanghe, 2001; James, 2011; Jensen & Woodsen, 2012; Merlo et al., 2010; Stephens & Temby, 2014; Yates, 2004; see Stephens & Temby, 2014 for a summary of these studies). While the methodologies vary across these studies, typically one group will undertake marksmanship training in the simulator followed by live-firing using the equivalent weapon system (e.g. rifle or pistol). The performance of this group is then compared with a control group that has undertaken some other form of training (e.g. dry-firing, live-fire) or no training. The findings from this category of studies have been mixed; in some studies (Collier, 2010; Delanghe, 2001; Jensen & Woodsen, 2012; Stephens & Temby, 2014) simulator training has been found to produce a positive training benefit (in terms of improved performance on subsequent live-fire tasks), while in other studies (James, 2011; Merlo et al., 2010; Yates, 2004) no significant differences have been observed between groups that receive simulator training and groups that do not receive simulator training. Due to methodological differences across these studies, it is difficult to make definitive statements about the effectiveness of marksmanship simulators, beyond noting that these devices appear to have some utility for training marksmanship procedures, and that more evaluation studies are needed.

In the third category of studies, researchers have attempted to quantify the impact of differences between the simulator and live-fire environments on firer performance (e.g. Scribner, Wiley & Harper, 2007). In doing so, these studies have attempted to explain the findings from studies in the first two categories. For example, research has found that limitations in the digital target imagery (Temby, Ryder, Vozzo, & Galanis, 2005; Vozzo, 2008) and determination of the weapon aim-point (Stephens, 2012) in marksmanship simulators can degrade firer performance. The implication is that technological limitations can negatively impact on firer performance and limit the training effectiveness of these devices. If these limitations can be addressed, then firer performance in the simulator and live-range may become more equivalent.

A fourth category of studies has focused on the development, implementation and evaluation of rifle marksmanship training programs (e.g. Dyer et al., 2010; Evans & Osborne, 1988; Hagman, 2000; Hunt & Evans, 1986; Maxey, George, & Straesel, 1985; Thompson, Smith, Morey, & Osborne, 1980). This research has included: reviews of marksmanship doctrine, analysing areas for improvement in marksmanship training, development of new training programs, and evaluation of 'new' training methods (including simulator-based training). Studies in this category have generally focussed on developments in equipment, target design, marksmanship ranges, training aids, and instructor training. These studies have mostly been qualitative in nature (e.g. descriptions of factors that need to be improved) rather than quantitative evaluations of training programs (cf. Dyer et al., 2010). The implications from this category of studies are: (1) there are various factors that need to be considered when designing a marksmanship training program; (2) marksmanship simulators should not be used as 'black-box' training devices; and (3) there is still a need for quantitative studies to assess the effectiveness of different marksmanship training methods.

In summary, previous marksmanship research has highlighted factors that impact on firer performance and contribute to effective marksmanship training, and provides insights into the effectiveness of marksmanship simulators. However, there remains a gap in marksmanship training research that: (a) provides quantitative data on the effectiveness of different marksmanship training methods; (b) examines the balance of simulator and live-fire training required to achieve effective and efficient marksmanship training outcomes; and (c) investigates predictors of live-fire performance. While the current study was driven by a client request on how to achieve more efficient live-fire qualification, and to specifically address the limitations noted in our previous study, it provided an opportunity to address these gaps in the literature.

1.2 The Current Study: Rationale, Framework and Aims

The current study was conducted as part of a research program in DSTO Land Operations Division which is aimed at assisting the Australian Army achieve more efficient and effective use of simulation for training. The study was conducted in 2011 during an Australian Army training course in direct response to a request from a military client. Specifically, the client was seeking to develop a marksmanship training program using both simulator and live-fire ranges which resulted in faster qualification within the available time and resources. During the course, students receive two weeks of basic marksmanship training on the M4 weapon using iron sights (see Figure 1)[3]. In order to progress through the course, students are required to pass the LF6 practice. This practice is composed of eight serials that involve firing at static and moving targets over different ranges (100, 200, 300 m) from different firing positions (e.g. prone, standing, kneeling) under timed conditions.

Figure 1: M4 weapon with iron sights.

As mentioned, the current study was a follow-up to a previous study conducted on the course by Stephens & Temby (2014). In the previous study the effect of additional simulator training on LF6 qualification rates was investigated. Following training-as-usual, one group (n=18) conducted three LF6 practices in the simulator while another group (n=18) proceeded to conduct live-fire LF6 qualification. The results showed that LF6 qualification rates were higher for the group that received simulator training, consistent with the simulator training providing a small positive benefit. However, it took ten attempts for all students to achieve qualification, which indicated that neither training method was entirely satisfactory and that improvements were required. Further analysis highlighted that several factors impacted on LF6 qualification rates (outlined in Section 3, Table 1), which were addressed in the current study. The previous study also found a modest correlation between simulator and live-fire LF6 scores, and that self-report measures of marksmanship skill level were good predictors of LF6 qualification scores; the current study provided an opportunity to validate these findings.

1.2.1 Framework for Evaluating Training Effectiveness

The current study was conducted using Kirkpatrick's model (Kirkpatrick, 1994) of training evaluation as the framework. This model has been widely used by researchers in studies of training effectiveness (see Alliger & Janak, 1989, and Alliger, Tannenbaum, Bennett, Traver, & Shotland, 1997 for meta-analytic reviews; Salas, Milham, & Bowers, 2003). This model outlines four levels of training outcomes:

- Reaction (Level 1): Level 1 outcomes include assessment of participants' reaction to the training program (e.g. satisfaction with training content, quality of instruction, and perceived relevance of training). In the case of marksmanship training, relevant measures would include trainee feedback on the quality of training, and what they liked/disliked about simulator and live-fire training. Such data is typically collected from trainees at the end of training using surveys.

[3] This is important to note because, anecdotally, trainees on the course typically have little prior experience using iron sights.

- Learning (Level 2): Level 2 outcomes are quantifiable indicators of learning that has occurred during training (e.g. test scores). In the case of marksmanship training, relevant measures might include trainees' marksmanship scores during training[4]. Such data can be collected manually or automatically from marksmanship simulators and live-fire ranges.
- Behaviour (Level 3). Level 3 outcomes examine the extent to which knowledge and skills gained during training are applied (or transfer) to the job context. In the case of marksmanship training, if live-fire qualification is taken as a surrogate measure of job performance, then relevant measures include: pass rates on training courses and changes in marksmanship performance from pre-training levels[5].
- Results (Level 4). Level 4 outcomes, or results, are intended to provide a measure of the impact that the training has had on organisational goals (e.g. resource savings, increased competency levels). In the case of marksmanship training, relevant measures might include: reduction in training costs (e.g. from using less live ammunition), reduction in training time or number of trials to achieve required competency levels, and increased throughput (e.g. greater percentage of trainees achieving competency standards each year).

In the current study, training outcomes were evaluated at all four levels by measuring trainee reactions (Level 1), changes in marksmanship performance during training (Level 2), transfer of training to live-fire qualification (Level 3), and the resource savings (ammunition, training time) for the organisation (Level 4); in this case the Australian Army.

1.2.2 Study Aims and Hypotheses

The primary aim of the study was to evaluate the effectiveness of a novel training method for marksmanship qualification on the M4 weapon with iron sights. Specifically, the main aim was to compare LF6 qualification rates from a novel training method with those for a standard training method. It was hypothesised that the novel training method would lead to faster qualification than the standard training method. The second aim of the study was to investigate predictors of live-fire qualification. It was hypothesised that simulator LF6 scores and skill level ratings would be significant predictors of live-fire qualification scores based on the previous study findings (Stephens & Temby, 2014). The third aim of the study was to compare the outcomes with those from the previous study; it was expected that the current study would result in faster qualification and a reduction in ammunition to achieve qualification, compared with the previous study. The fourth aim of the study was to identify implications for using simulation-based marksmanship training, and any suggestions for future marksmanship research.

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[4] Another measure would be trainee knowledge levels of marksmanship principles and weapon handling procedures, which could be assessed via written and practical tests.

[5] Strictly speaking, the job context for military personnel is operations. Thus, measures of marksmanship performance on operations (e.g. number of targets hit) are likely to be more reliable.

2. Method

2.1 Study Design and Approval

The study employed a randomised allocation, between-groups design. The study methods and procedures were approved by an internal human research ethics review committee prior to data collection (Ethics Protocol Number: DSTO LOD 06/11). The study procedures were conducted in accordance with ethical principles and guidelines for the conduct of human research (NHMRC, 2007).

2.2 Participants

Thirty-five ADF personnel took part in the study; all participants were students enrolled on an Australian Army training course. The participants completed a demographic questionnaire (Appendix B) on the first day of the study; the questionnaire requested details of participants' age, length of military service, prior marksmanship experience, self-reported marksmanship skill level, health status, visual acuity, and confidence using the M4 and achieving LF6 qualification[6].

The participants' age ranged from 21 to 39 years (Mean=27.9 years, SD=4.5 years) and length of military service ranged from 6 months to 15 years (Mean=5.7 years, SD=3.8 years). Less than a third of participants (29%) had prior experience firing the M4 weapon using iron sights. All participants reported having conducted the LF6 practice at least once prior to the study (Mean=9.1 times; SD=8.0). In terms of marksmanship skill level, 34% rated themselves as "Above Average", 51% rated themselves as "Average", and 14% rated themselves as "Below Average". These responses were based on participants' recall of their typical scores on the annual weapons test.

All participants reported being in at least 'good' general health at the time of the study. The visual acuity of the participants was not objectively tested; however, the participants' eyesight had been tested within the last 12 months as part of their annual medical assessment in the Army. The majority of participants (79%) reported having 20/20 vision, while the remaining participants reported they either did not have 20/20 vision or did not answer this item. The majority of participants (63%) were 'moderately confident' of passing LF6 qualification after their first attempt. Twenty-six percent (26%) rated their confidence of passing first time as 'low'. A small percentage (11%) of participants was 'highly confident' they would qualify on their first attempt.

[6] The questionnaire was developed specifically for the purposes of this study based on consideration of demographic factors that might be important to correlate with marksmanship performance.

2.3 Procedures

2.3.1 Development of Training Methods

The training methods used in this study were developed from three main sources: marksmanship doctrine, the existing training program, and the previous study findings of Stephens and Temby (2014). Initially, the intent was to develop and implement a novel training method for all students and compare the outcomes (e.g. pass rates) with those from previous courses. However, discussions with the course staff indicated that the training program was not the same each year due to differences in instructor styles, different rates of student progress, and the availability of the simulator and live-fire ranges. Furthermore, (except for our previous study), no reliable records of the training program or trainee marksmanship performance and qualification data from previous courses were available. Consequently, it would not have been possible to reliably compare the outcomes of the novel training method with data from previous courses. This led to the development and comparison of two training methods. The first was the 'novel method' (which addressed the limitations outlined in the previous study) and the second was a 'standard method' that was representative of the marksmanship training program employed on the course. In doing so, the two training methods were able to be compared under controlled/standardised conditions. As with the previous study, the course staff indicated that the following constraints applied:

- five days are available for M4 theory lessons and weapon handling training
- five days are available for simulator and live-fire training practices
- two days are available for LF6 qualification (on the live-fire range)
- both the simulator and live-fire ranges must be used
- all trainees on the course must receive equivalent amounts of training

These constraints were taken into account when developing the training methods. The contents of the two training methods are summarised in the following sections.

2.3.1.1 Novel Training Method

The novel training method was developed by the authors in conjunction with a military subject matter expert (see Appendix C for details of specific practices) from a review of M4 marksmanship doctrine, the existing training program, and the previous study findings of Stephens and Temby (2014). In the previous study, eight factors were identified that can influence LF6 qualification rates. These factors are outlined in Table 1 along with a description of each one, and how they were addressed by the novel training method.

The training commenced with weapon zeroing and familiarisation training at 25 metres (Factor 1), before progressing to firing at 100 m with deliberate, rapid and snap serials including opportunities to repeat practices. These serials were then repeated at 200 m and 300 m ranges (addressing Factors 2 and 3). This method also involved basic coaching (Factor 4) and live-firing prior to qualification (Factor 6). The worst performing firers on the training course were previously identified to have difficulty with snap serials and serials at 200 and 300 m ranges (Stephens & Temby, 2014). The LF3 and LF4 practices do not contain snap serials and LF4 does not contain any serials at 300 m (although LF4 does focus on firing from other positions). Therefore, since poor firers have the greatest impact on qualification rates (Factor 5) these practices may not provide sufficient training at 200 m and 300 m ranges and snap serials. Consequently, this method included additional training on snap serials, and serials at 200 and 300 m ranges (addressing Factor 5). In developing the novel training method, there was insufficient time to include serials in which target range, serial type and firing position were varied.

It was hypothesised that target range and serial type would have a greater effect on performance than firing position; furthermore it was expected that participants would already be familiar with firing from other positions. As a result, it was decided that most practices in this method would be fired from the prone position to allow students to concentrate on adjusting to using the iron sight (Factor 1) without having to focus as much on changing their firing position. This method also addressed the problem with the black and yellow targets in the simulator (Factor 7) by replacing them with white targets (see Figure 1). In addition, the training was conducted over four days, and made use of both simulator and live-fire ranges to maximise the available training time (Factor 8).

2.3.1.2 Standard Training Method

The standard training method was also developed by the authors but was guided by current Australian Army doctrine for M4 marksmanship training and the existing training method used on the course. It was selected as the baseline method on which to compare the outcomes with the novel training method (see Appendix D for details of specific practices). As with the novel training method, training commenced with weapon zeroing and 25 metre practices to ensure trainees were familiar with using iron sights (Factor 1). Consistent with doctrine, the training progressed from LF1 through to LF6 prior to attempting qualification (Factors 2 and 3) and employed basic coaching (Factor 4). This method also included several opportunities to practice live-fire prior to qualification (Factor 6).

The training was conducted over four days, and made use of the simulator and live-fire ranges to maximise the available training time (Factor 8). Overall, this method was able to address all factors except 5 and 7. This training method did not specifically address natural variation in firer progress (Factor 5) and used black and yellow targets (Factor 7) for all practices in the simulator (except for the LF6 practice). White targets were used in the simulator for the LF6 practice. This modification was made as part of the development of the novel training method (as described above); however it was decided that both methods would employ white targets for the LF6 practice in the simulator to allow reliable comparison on this specific task. Therefore, the standard training method only partially addressed Factor 7 and did not address Factor 5.

Table 1: Description of factors influencing LF6 qualification rates with M4 weapon and solutions implemented in current study to address them

Factor	**Description**	**Solutions Implemented in Current Study**
1. Difficulty adjusting to firing with iron sights	Firing with iron sights is a more difficult task than firing with optical sights because of the lack of target image magnification and differences in technique required; this means that aiming at and hitting targets is more difficult with iron sights.	Following weapon theory lessons, both training programs commenced with familiarisation training on the M4 weapon at 25 metres on the live-fire range to allow trainees to become used to firing with iron sights.
2. Not following a logical progression from simpler to more advanced practices	Previous courses have progressed from simpler to more advanced practices but the number of attempts on each practice has been unsystematic; this may mean that too much time is being spent on certain practices at the expense of training other ones.	The novel training program contained practices that progressed systematically from firing at short range (100 m) to longer range targets (200 and 300 m). In addition, the amount of time allocated to training each of the practices was fairly even to maximise the use of available training time.
3. Not achieving competency on earlier practices prior to qualification	Not achieving a pass standard on earlier practices may reduce trainee proficiency and confidence levels for subsequent marksmanship practices, which in turn will reduce their likelihood of achieving qualification.	The novel training program provided opportunities for students to repeat specific practices and serials in order to develop their competency at the specific task, and increase their chances of achieving a pass standard.
4. Limited staff to provide marksmanship coaching	Limited numbers of training staff can impact on the rate at which training is delivered and learning occurs for those trainees that are experiencing more difficulty on marksmanship practices and achieving qualification.	The training programs included basic marksmanship coaching by qualified instructors to assist trainees who were having difficulty during marksmanship training (but not during qualification as this is not permitted).
5. Natural variation in marksmanship ability between firers	Marksmanship is a complex skill and performance variation between firers is natural. The worst performing firers will always be a limiting factor on qualification rates.	The novel training program contained more opportunities to practice the tasks that the worst performing firers had difficulty with in the previous study (e.g. 200 m snap serials).
6. Limited firing on live-fire range prior to qualification	There are differences between conducting marksmanship practices in the simulator and on live-fire ranges (e.g. exposure to weather, use of live ammunition); greater experience with live-fire will improve trainee's ability to cope with these differences and develop their competence/confidence on live-fire practices.	The novel training program contained a mix of simulator and live-fire training, including several opportunities for live-fire practices prior to commencing qualification.
7. Difficulty seeing standard black/yellow targets in simulator with iron sights[7]	Firer ability to see targets in the simulator will be affected by the contrast between the target and background imagery. Making the contrast more representative of the live-fire range is likely to enhance target visibility and marksmanship performance (assuming all other factors being equal).	White targets were used in the simulator for the LF6 practice and for all novel method simulator practices (instead of the standard black and yellow targets) to make it easier for trainees to see targets, particularly at longer ranges[8].
8. Limited time to develop proficiency with M4 weapon on the course	Marksmanship is a skill that requires deliberate practice to become proficient; the amount of time available for training is a limiting factor on the level of proficiency that can be achieved. This may take longer when learning to use new equipment and techniques (e.g. M4/iron sights).	The novel training program was conducted over four whole days using both simulator and live-fire ranges to maximise the available training time and develop firer proficiency levels.

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[7] This is largely due to poor contrast between background and target images in the simulator. However, poor vision is another factor which cannot be ruled out.

[8] Standard black and yellow targets were used for all shoots on the live-fire range.

2.3.1.3 Comparison of rounds used in each training method

The total number of rounds fired was similar for both training methods (Standard=329 rounds per student, Novel=364 rounds per student). However, the novel method involved greater use of the simulator so was more cost-effective in terms of live rounds used (Standard=148 live rounds per trainee; Novel=119 live rounds per trainee, i.e. a saving of 29 live rounds per student). The reader is referred to Appendix C and D for a breakdown of the number of rounds associated with each training method.

Figure 2: Images of the standard black and yellow target imagery (left side) and modified white targets (right side) used in the simulator training.

2.3.1.4 Coaching and Feedback

In the previous study (Stephens & Temby, 2014), there was limited coaching provided to students. This was a deliberate condition of the study methodology to control for coaching being a potential confound. Australian Army doctrine emphasises that marksmanship coaching is essential to improve shooting standards (Australian Army, 1993; pg.37). In the current study, basic marksmanship coaching was provided to trainees who were consistently missing targets and having obvious difficulty using iron sights. In addition, the training instructors prompted all the trainees to apply the marksmanship principles during practices and to adjust their point-of-aim at the target if required. When conducting LF6 in the simulator, trainees were able to see their fall-of-shot after each serial, which is the default condition for this practice in the simulator. However, the trainees were not provided with any corrective action from training staff based on this information. When conducting LF6 qualification on the live-fire range, each trainee is allowed two sighting rounds at the start of Serial 1 to see their fall-of-shot on the target and adjust their point-of-aim if necessary. In addition, targets fall when hit for all snap and moving target serials, which provides trainees with performance feedback.

2.3.2 Study Schedule and Activities

The study was conducted over the period 21-28 October 2011 at an Australian Army base. On the first day, the study team briefed the training staff and participants on the study aims and procedures. The participants then completed the demographic questionnaire (Appendix B). Participants were then randomly allocated into two groups which either received novel training or standard training, where they remained for the study duration. The training schedule for both groups is summarised in Table 2. Initially, both groups conducted zeroing and familiarisation practices at 25 metres to gain experience and confidence with using iron sights. A baseline LF6 practice was conducted on Day 2 (not shown in Table) in the simulator by both groups to establish each group's initial level of proficiency. This assessment was not part of the training program, although it is acknowledged that it would have provided some degree of training on this task. On completion of their respective training, both groups conducted LF6 qualification on the live-fire range.

All participants conducted at least two qualification attempts and continued until they had all qualified. The weather conditions were mostly fine for all live-firing practices, with the exception of the afternoon of Day 3 when poor weather meant that Practice 3 for the novel training group had to be aborted and conducted the next day. Marksmanship scores for each practice were recorded for all participants. The pass mark for all practices was 70%, except for the grouping and zeroing practices. During the study, participants wore the Australian Army camouflage pattern uniform and webbing as per the course requirements.

Table 2: Schedule of Marksmanship Training and Qualification

Day	Standard Training	Novel Training
1	25 m zeroing/familiarisation (live-fire)	25 m zeroing/familiarisation (live-fire)
2	LF1 (simulator)	Practice 1 (simulator)
3	LF3 (live-fire)	Practice 2 (simulator)
	LF4 (simulator)	Practice 3 (live-fire)*
4	LF4 (live-fire)	Practice 3 (live-fire)
	LF5, LF6 (simulator)	LF5, LF6 (simulator)
5	LF6 Qualification (live-fire)	LF6 Qualification (live-fire)
6	LF6 Qualification (live-fire)	LF6 Qualification (live-fire)

*Practice 3 was aborted on day 3 due to inclement weather and conducted the next day.

2.4 Measures

2.4.1 Marksmanship performance

The primary measure of marksmanship performance was the total number of points scored on each practice. For the LF6 practice, five points are allocated for each hit on target; the highest possible score is 235 points and a pass score is 165 points (i.e. 70% of maximum score). For grouping practices (e.g. LF1) marksmanship performance was measured by the distance (in millimetres) between the two furthest shots in a group of shots; in such cases, lower values indicate better performance.

2.4.2 Training effectiveness

Several measures were used to assess training effectiveness; these measures are outlined below along with their corresponding level in Kirkpatrick's model.

- **Pass rates** (Level 3): the difference in LF6 qualification rates achieved for each group after each qualification attempt.
- **Number of qualification attempts** (Level 3): the difference in mean number of qualification attempts for both groups.
- **Mean qualification scores** (Level 3): the difference in mean LF6 scores from the first three qualification attempts for both groups.
- **Live rounds used for qualification** (Level 3 and 4): the difference in the number of live rounds used to achieve qualification by both groups (and compared with previous study).
- **Total number of rounds fired** (Level 3 and 4): the difference in the total number of rounds fired during training and qualification by both groups (and compared with previous study).
- **Mean LF6 simulator scores** (Level 2): the mean scores for the LF6 simulator practices conducted by each group (and compared with previous study).
- **Mean scores for training practices** (Level 2): the mean scores for the training practices conducted by each group; this measure provided an assessment of each group's progress during training prior to attempting qualification.
- **Hit ratios** (Level 2): the number of targets hits divided by the maximum number of hits possible on each training practice; this measure provided another assessment of each group's progress during training prior to attempting qualification.
- **Participant reactions** (Level 1): the comments made by trainees regarding their opinions of the training.

2.4.3 Predictors of LF6 qualification

The following measures were used to investigate their utility as predictors of LF6 qualification, consistent with the second aim of the study. The selection of these variables was guided by previous marksmanship research (e.g. Chung et al., 2006) and consideration of individual factors likely to influence marksmanship performance.

- baseline LF6 simulator scores
- final LF6 simulator scores
- number of times fired in past 12 months
- number of times conducted LF6 practice (prior to study)
- time since last fired LF6 practice (months)
- amount of prior experience with M4 (months)
- marksmanship skill level (1 = below average, 2 = average, 3 = above average)
- confidence level in using M4 (low = 1, moderate = 2, high = 3)
- confidence level in passing LF6 first time (low = 1, moderate = 2, high = 3)

- general health level at time of study (1 = well below average, 2 = below average, 3 = average, 4 = good, 5 = excellent).

2.5 Data Analysis

All quantitative data was analysed using SPSS Version 17.0 (SPSS, 2008). The data was checked for any missing or extreme values that may have unduly affected the data analysis. One participant missed some of the marksmanship training during the study; hence the sample size was reduced to thirty-four in some cases. The following protocols and statistical tests were used:

- Mean scores and standard deviations were calculated for all training practices and qualification shoots.
- Independent samples t-tests were conducted to compare mean scores, and chi-square tests were conducted to compare pass rates.
- Pearson correlation coefficients were calculated to measure the co-variation between scores on marksmanship practices.
- Non-parametric tests (e.g. Mann-Whitney) were used to analyse data where the criteria for normality were not met.
- Normality testing of the data was conducted using the Shapiro-Wilk test.
- Pass rates for LF6 qualification were calculated using 165 points as the cut-off score.
- Multiple linear regression analysis was conducted using the stepwise (or forward) entry method.
- All significance testing was conducted using p=0.05 as the cut-off value.

3. Results

3.1 Sample Characteristics

Descriptive statistics based on demographic data for the novel and standard training groups are presented in Table 3. The results show there were no significant differences between the two groups on any of the demographic variables (p>0.05 for all analyses). This confirms that the two groups were similarly matched on key demographic variables prior to undertaking marksmanship training.

Table 3: Demographic data for the novel and standard training groups

Variable	Novel (n=18)	Standard (n=17)	Statistic (*p* value)	Total
	Mean (SD)	Mean (SD)		Mean (SD)
Age (years)	27.2 (3.9)	28.8 (5.2)	U=124.5 (0.50)	28.0 (4.5)
Years of Service	5.4 (3.7)	6.0 (3.9)	U=128.5 (0.59)	5.6 (3.8)
Skill Level	2.2 (0.7)	2.2 (0.7)	U=145.5 (0.79)	2.2 (0.7)
Confidence Level	1.9 (0.6)	1.8 (0.6)	U=144.0 (0.73)	1.86 (0.6)
General Health	4.3 (1.0)	4.1 (0.6)	U=118.5 (0.79)	4.2 (0.6)
Times shot LF6	10.2 (9.1)	7.9 (6.8)	U=131.5 (0.48)	9.1 (8.0)
	Frequency	*Frequency*	*Statistic (p value)*	*Frequency*
M4 Experience	9 (50%)	7 (41%)	χ^2 (1) = 0.27 (0.60)	16 (46%)

3.2 Effectiveness of Training Methods

3.2.1 Pass Rates

The pass rates for the novel and standard training groups after first, second and third qualification attempt are shown in Table 4. The standard training group had slightly higher pass rates than the novel training group after first and second attempt but these differences were not statistically significant (p>0.05). Both groups achieved almost the same pass rate (94%) after the third attempt. It took six attempts for all trainees to pass; the average for all participants in this study was 1.9 attempts. The difference in mean number of attempts to pass for the two groups was not statistically significant (p>0.05). These findings indicate that the two training methods were of similar effectiveness for LF6 qualification.

Table 4: Pass rates for the novel and standard training groups after first, second and third attempt.

Group	Pass Rates			
	First Attempt (%)	Second Attempt (%)	Third Attempt (%)	Mean number of attempts to pass
Novel (n=18)	50.0	61.1	94.4	1.9
Standard (n=17)	58.8	76.5	94.1	1.8
Statistics	χ^2 (df=1)=0.27 p=0.60	χ^2 (df=1)=0.96 p=0.33	χ^2 (df=1) =0.02 p=0.97	t=0.30 p=0.77

3.2.2 LF6 Qualification Scores

The mean qualification scores for the novel and standard training groups are shown in Table 5. Mean scores were slightly higher for the standard training group than the novel training group after first, second and third attempt, but none of the differences in mean scores between the two groups were statistically significant (p>0.05). As with pass rates, these results indicate that the two training methods were of similar effectiveness for LF6 qualification.

Table 5: Mean qualification scores for novel and standard training groups after first, second and third attempts. The pass score is 165 points and the maximum possible score is 235 points.

Group	**Qualification Score**			
	First Attempt	Second Attempt	Third Attempt	Average of first two attempts
Novel	152.2	157.2	175.0	155.3
(n=18)	(39.8)	(33.4)	(20.8)	(31.4)
Standard	165.0	175.0	187.1	170.0
(n=17)	(42.7)	(29.4)	(22.4)	(31.9)
	t=0.92	*t*=1.67	*t*=1.35	*t*=1.38
Statistics	*p*=0.37	*p*=0.11	*p*=0.19	*p*=0.18
	d=0.31	*d*=0.56	*d*=0.56	*d*=0.46

The mean scores for each LF6 serial are shown in Table 6 for the novel and standard training groups. The scores are the average of the first two qualification attempts. When comparing the same serial, the majority of scores for the two groups were similar; none of the differences in serial scores were statistically significant ($p>0.05$), although the differences approached significance for Serials 1 and 8. These results provide further evidence that the two training methods were of similar effectiveness.

Table 6: Mean LF6 serial scores for novel and standard training groups. Scores are the average of first two qualification attempts. Highest possible score is 30 points. Standard deviations are shown in brackets.

	Serial Score							
Group	1 deliberate 300 m HPS=30	2 snap 300 m HPS=30	3 rapid 200 m HPS=30	4 snap 200 m HPS=30	5 rapid 200 m HPS=30	6 snap 100 m HPS=30	7 snap 100 m HPS=30	8 moving 100 m HPS=25
Novel	15.6	17.9	17.5	21.3	16.8	25.1	23.8	17.4
(n=18)	(6.5)	(7.7)	(7.8)	(6.7)	(7.1)	(4.9)	(5.3)	(5.7)
Standard	20.0	19.3	18.4	20.6	19.7	27.1	24.0	21.0
(n=17)	(6.8)	(8.6)	(7.2)	(7.5)	(7.0)	(2.7)	(3.9)	(5.1)
	t=1.97	*t*=0.49	*t*=0.35	*t*=0.28	*t*=1.21	*t*=1.43	*t*=0.14	*t*=2.00
Statistics	*p*=0.06	*p*=0.63	*p*=0.73	*p*=0.78	*p*=0.23	*p*=0.16	*p*=0.89	*p*=0.054
	d=0.66	*d*=0.33	*d*=0.12	*d*=0.10	*d*=0.41	*d*=0.50	*d*=0.04	*d*=0.66

3.3 Predictors of LF6 qualification

3.3.1 Linear Regression Analysis

The ability to predict marksmanship performance can be useful for identifying those trainees who are likely to qualify and those who may require remedial training. In both cases, such information can help inform training delivery and reduce resource wastage. In this study, a number of measures were investigated for their utility as predictors of LF6 qualification. The primary measure of interest was the correlation between LF6 simulator scores and LF6 live-fire qualification scores.

Results showed that there was a moderately positive correlation between final LF6 simulator scores and LF6 qualification first attempt scores (r=0.44; p=0.005). Using the average of the two simulator scores and the average of the first two qualification attempt scores, the correlation increased to r=0.59 (p<0.001). The correlation between first and second attempt LF6 qualification scores was r=0.52 (p=0.002); the correlation between baseline and final LF6 simulator scores was r=0.56 (p=0.001). These results indicate that marksmanship performance can be quite variable across a sample of trainees even when conducting the same task in succession. Overall, these results indicate that LF6 simulator scores were modest predictors of live-fire qualification scores and that using repeated measures can give better prediction levels, and that variance in marksmanship performance is a limiting factor to obtaining high levels of prediction.

The correlation between LF6 scores and other practice scores for the two groups was also examined. This was done in order to examine whether specific practices conducted by the different groups were correlated with their qualification scores. This data is presented in Appendix E; the key findings were as follows:

- Baseline and final LF6 simulator scores for both groups were moderately correlated with LF6 qualification scores.
- For the novel training group, the scores for Practice 1 (r=0.57, p<0.05) and Practice 2 (r=0.68, p<0.01) were moderately correlated with their LF6 qualification scores. Scores for Practice 3 (which reflect live-fire performance at 200 and 300 metre targets) were not significantly correlated with any of the other practice scores.
- For the standard training group, LF3 and LF4 live-fire scores were moderately correlated with LF6 qualification scores (r=0.51, p<0.05 and r=0.55, p<0.05 respectively).
- LF5 scores (which reflect performance at 100 m moving targets from a kneeling position) were not correlated with scores for any other practices conducted by the standard training group.

Overall, the correlation data indicates that there was substantial commonality in scores for the different training practices (as we would expect for different marksmanship tasks having common components). Hence the correlation data provide evidence that the novel training practices were suitable preparation for LF6 qualification.

Additional analysis was conducted to determine whether a usable cut-off value for LF6 simulator scores could be used to reliably predict LF6 qualification first time. Referring to Figure 3, a visual scan of the spread of scores indicates that no reliable cut-off score can be determined. For example, if 140 points was used as a cut-off for simulator scores (i.e. 85% of pass score), 11 of 32 (34%) could be expected to pass live-fire qualification first time, however 3 of 32 (9%) would also be expected to pass but actually fail (i.e. false positives). While three students is a low number of false positives, the number of true positives (34%) is too low to have practical utility.

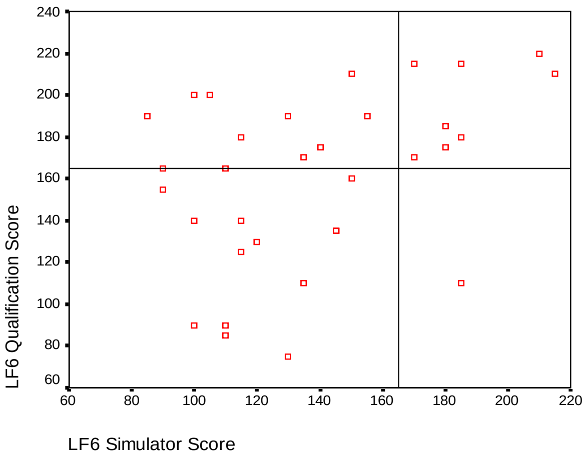

Figure 3: Scatterplot of baseline simulator LF6 scores and live-fire LF6 qualification scores for first attempt. Reference lines indicate pass score of 165 points.

3.3.2 Multiple Linear Regression Analysis

As noted in Section 2.4.3, the predictive utility of other measures in this study were of interest. Consequently, multiple regression analyses were conducted to examine whether these other measures provided additional utility for predicting qualification scores. Multiple linear regression was conducted using the forward method to test whether baseline LF6 simulator scores, final LF6 simulator scores, years of service, skill level ratings, confidence level ratings, self-reported health, and previous marksmanship experience (i.e. number of times shot LF6 in previous 12 months, months since last LF6 practice), were predictors of LF6 qualification scores.

The results showed that the regression model was highly significant (r=0.65, F(2, 27)=9.92, p=0.001) and skill level ratings (β=0.41, t=2.65, p=0.013) and baseline LF6 simulator scores (β=0.40, t=2.59, p=0.02) were the only significant predictors of LF6 qualification scores (first attempt). When using second attempt qualification scores, the only variable in the model that significantly predicted LF6 qualification scores was skill level ratings (r=0.62, F(1, 28)=17.04, p<0.001, β=0.62, t=4.13, p<0.001). These results show that while these variables are statistically significant predictors of qualification scores, they have limited practical utility as predictors of readiness for qualification.

3.4 Comparison of Outcomes with Previous Study

The following paragraphs compare pass rates, mean qualification scores, ammunition usage and predictors of LF6 qualification for the current and previous studies. Across all measures of effectiveness, outcomes from the current study were superior to the previous study, demonstrating the effectiveness of the training methods employed in the current study, and the utility of collecting and analysing training data.

Pass rates: As shown in Table 7, the pass rates in the current study were significantly higher after first, second and third attempt compared with the previous study (Stephens & Temby, 2014). Notably, the pass rate after three attempts was markedly higher in the current study than in the previous study (i.e. 94% vs. 58%). In the previous study, the average number of attempts to qualify was 3.4; in this study the average was 1.9. The difference in mean number of attempts to qualify between the two studies was statistically significant. These findings clearly demonstrate the greater effectiveness of the training methods in this study for improving pass rates, compared with the previous study.

Table 7: Pass rates for participants in current and previous study. Asterisks indicate statistically significant difference.

Group	**Pass Rates**			
	First Attempt (%)	Second Attempt (%)	Third Attempt (%)	Mean number of attempts to pass
All (n=35) (current)	54.3*	68.6*	94.3*	1.9*
All (n=36) (previous)	25.0	38.9	58.3	3.4
Statistics	χ^2 (df=1)=6.37 *p*=0.01 ϕ =0.30	χ^2 (df=1)=6.29 *p*=0.01 ϕ =0.30	χ^2 (df=1)=12.60 *p*<0.001 ϕ =0.42	*U*=360.0, Z=3.23 *p*=0.001 r= 0.38

LF6 simulator scores: The mean scores and pass rates for the LF6 simulator practice for participants in the current and previous study are presented in Table 8. The results show that LF6 simulator scores were significantly higher in the current study based on the mean scores for all simulator practices (i.e. two in current study; three in previous study). In addition, it can be seen that the percentage of students that passed LF6 simulator practices was significantly higher in the current study. These results support the effectiveness of the white targets in the current study because the standard black and yellow targets were used for the LF6 simulator practice in the previous study. They also provide additional support for the effectiveness of the novel training method in the current study because the participants achieved a higher standard of performance on the LF6 practice by the end of the simulator training, compared with the previous study.

Table 8: Mean scores and pass rates for LF6 simulator practices in current and previous study. Numbers in brackets are standard deviations[9].

Study	Mean LF6 Score	*t* value, *p* value and Cohen's *d*	% Passed	Chi-square, *p*, and phi values
Current (n=35)	155.6 (28.7)	*t*=2.91 *p*=0.005	80%	χ^2 (1)=7.156 p=0.007
Previous (n=36)	137.1 (24.6)	*d*=0.69	50%	ϕ =0.31

[9] The values are based on two LF6 simulator practices in the current study and three LF6 simulator practices in the previous study, consistent with the different training methods.

LF6 qualification scores: As shown in Table 9, the mean qualification scores for all participants in the current study were significantly higher (better) than those for participants in the previous study ($p<0.05$), and the effect size was large. The comparison is based on the average scores for the first two qualification attempts scores as not all participants needed three attempts in the current study. These findings provide further evidence that the training methods were effective in improving qualification scores and addressing the limitations with the training method employed in the previous study.

Table 9: Mean scores for LF6 qualification in current and previous study. Scores are the average of first two qualification attempts. Numbers in brackets are standard deviations.

Study	Mean Score	Statistics
Current (n=35)	162.4	t=2.56
	(32.0)	p=0.013
Previous (n=36)	144.2	d=0.60
	(27.9)	

When comparing LF6 serial scores for all participants in the current and previous study (see Table 10), there were statistically significant differences for Serials 2 and 4 (snap serials at 200 m and 300 m) and Serial 5 (rapid serial at 200 m). In these three cases, the effect size based on Cohen's *d* was large. These findings provide additional evidence for the effectiveness of the novel training method; in particular, for improving performance on snap serials at 200 m and 300 m (which we identified as being problematic for trainees in the previous study and specifically addressed in Practices 1, 2 and 3 of the novel training method; see Appendix C).

Table 10: Mean serial scores for LF6 qualification in the current and previous study. Scores are the average of the first two qualification attempts. Numbers in brackets are standard deviations. Asterisk indicates statistically significant difference.

	Serial Score							
Study	1 deliberate 300 m HPS=30	2 snap 300 m HPS=30	3 rapid 200 m HPS=30	4 snap 200 m HPS=30	5 rapid 200 m HPS=30	6 snap 100 m HPS=30	7 snap 100 m HPS=30	8 moving 100 m HPS=25
All (n=35)	17.7	18.6*	17.9	20.9*	18.2*	26.1	23.9	19.1
(current)	(6.9)	(8.1)	(7.4)	(7.0)	(7.1)	(4.0)	(4.6)	(5.7)
All (n=36)	16.3	13.1	15.6	15.4	13.4	26.3	22.8	21.2
(previous)	(7.2)	(6.3)	(7.8)	(7.1)	(5.5)	(3.8)	(4.1)	(4.2)
Statistics	t=0.83	t=3.22	t=1.27	t=3.30	t=3.20	t=0.27	t=0.98	t=1.72
(p-value)	(0.41)	(0.002)	(0.21)	(0.002)	(0.002)	(0.79)	(0.33)	(0.09)
	d=0.20	d=0.76	d=0.30	d=0.78	d=0.76	d=0.05	d=0.25	d=0.42

Ammunition Use: The number of simulator and live rounds used in the current and previous study are presented in Table 11. The calculations do not include the rounds fired for the baseline LF6 practice in the simulator because it was included for assessment purposes only and not for training. As can be seen, the total number of simulator rounds fired in the two studies was similar. There were a similar number of live rounds fired during the training practices in both studies, but much fewer live rounds were used in the current study to achieve qualification. This is because it took participants less attempts to qualify in this study, compared with the previous study. Consequently, the current study achieved a significant saving in the total number of live rounds used (3361 rounds) compared with the previous study; this equated to a saving of 87 live rounds per trainee when normalising for the different sample sizes or 1.5 fewer attempts when expressed as the number of rounds used for the LF6 practice.

Table 11: Number of simulator and live rounds used in current and previous study. Numbers in bracket indicate the number of rounds per trainee.

Study	Simulator Rounds Training	Live Rounds Training	Live Rounds Qualification	Live Rounds Total
Current	7595	4658	3894	8552
(n=35)	(217)	(133)	(111)	(244)
Previous	7578	4656	7257	11913
(n=36)	(211)	(129)	(202)	(331)
Difference	+17	+2	- 3363	- 3361
(per trainee)	(+6)	(+4)	(-91)	(87)

Predictors of LF6 qualification scores: In the current study, the correlation between LF6 simulator scores and LF6 qualification scores was r=0.59 for all participants, whereas the correlation was r=0.40 in the previous study. The higher correlation observed in the current study is likely due to the effect of the white targets (which were not used in the previous study) and the tailored training practices undertaken by the novel training group. Indeed additional analysis showed that there was a moderately large positive correlation between scores on Practices 1 and 2 and LF6 qualification scores (Appendix E). In both studies, the results of regression analysis demonstrated that LF6 simulator scores and skill level ratings were statistically significant predictors of live-fire LF6 qualification scores. However, when attempting to identify reliable cut-off values, LF6 simulator scores had little practical utility as predictors of LF6 qualification.

3.5 Observations

We noted several observations during the study which highlighted factors that may have impacted, positively and negatively, on LF6 qualification rates. These observations are outlined below along with recommendations for addressing them in future studies.

- **Zeroing of weapons**. Training staff noted that some live-fire weapons were not correctly zeroed. This resulted in some students having to 'aim-off' in order to hit targets, even during qualification shoots. **Recommendation**: Ensure weapons are correctly zeroed prior to conducting all range practices.
- **Difficulty with iron sights**. During the early training practices some students were not using the iron sight correctly. Some students appeared to not fully understand the requirement to adjust the iron sights according to target distance (relates to Factor 1). **Recommendation**: Provide coaching and use training aids (e.g. photos of correct sight pictures) to assist trainees having difficulty with using iron sights.

- **White simulator targets**. The contrast of the black iron sight against white targets seemed to make it easier for students to align the iron sight correctly and engage targets[10]. The use of white targets was commented on favourably by a trainee who took part in the current and previous study. **Recommendation**: Ensure target imagery is clearly visible to trainees when they are conducting practices in the simulator.
- **Not achieving competency on practices**. During the training practices a few participants did not achieve the pass standard on some practices prior to progressing to subsequent practices and qualification. While the majority of students achieved the standards on all training practices prior to qualification, this was not always possible within the time available (relates to Factor 3). **Recommendation**: Allow students to repeat training practices and achieve the pass standard prior to progressing to more complex practices, preferably achieving the pass standard more than once.
- **Range time**. During the study, training practices did not always start on time resulting in lost training opportunities. Had all the available time been utilised, students may have been able to conduct each practice twice rather than once only. If this cannot be achieved then ranges should be booked for longer periods. This would provide more opportunities for live-firing and training beyond competency levels. **Recommendation**: Maximise the use of available range time during marksmanship training.
- **Student eyesight**. Five students reported not having 20/20 vision and did not wear corrective eyewear. While eyesight is regularly tested in the Australian Army[11], the possibility exists that some students had difficulty hitting targets due to poor eyesight. **Recommendation**: Test the visual acuity of trainees to ensure it is not a major limiting factor to their marksmanship performance.

3.6 Additional Analyses

Consistent with the Kirkpatrick model, we conducted additional analyses that allowed a more detailed evaluation of the training methods. The results of these analyses are summarised in the following sections with more details provided in Appendix E.

3.6.1 Mean Scores and Hit Ratios for Training Practices

To examine student progress during training (Level 2 measures) we calculated and compared mean scores and hit ratios for each training practice for both groups (see Appendix E.1). The results of these analyses showed that:

- LF6 simulator scores for the two groups were similar prior to attempting live-fire qualification and the difference was not statistically significant.

[10] Target visibility on the live-fire range was not identified to be a problem in the previous study; hence the standard black and yellow targets were used for all live-fire practices, including LF6 qualification. There was no evidence of negative training associated with using different colour targets in the simulator and live-fire range.

[11] The medical classification system used by the Australian Army (including eyesight/visual acuity standards for different employment categories) are outlined in Defence Instruction (Army) PERS 159-1 (Department of Defence, 2011).

- There was a statistically significant increase in mean LF6 simulator scores from baseline levels for both groups by the end of training.
- Both groups were hitting about 85% of targets at 100 m, 65% of targets at 200 m, and 60% of targets at 300 m. Based on these hit ratios, we would predict a score of 166.75 points[12] for the LF6 practice, which is above the pass score of 165 points.

Overall, the training data indicates that both groups were improving (i.e. learning) over subsequent practices, and the two groups were at a similar competency level prior to undertaking LF6 qualification. These findings also indicate that both training methods were effective and that a reasonable proportion of students might be expected to qualify after first attempt, as was found to be the case (see Section 3.1). The implication of these findings is that instructional staff can be confident in using training data to predict qualification and should use data to inform their assessment of trainee readiness levels.

3.6.2 Simulator versus live-fire LF6 scores

In this study, we modified the target imagery in the simulator for the LF6 practice by changing the targets from black and yellow to white. This modification was done to make it easier for firers to see and aim at the targets. In doing so, we expected that LF6 simulator and live-fire scores would be more similar on this practice over the different ranges. To examine whether this was the case, we compared simulator and live-fire LF6 scores at the equivalent target ranges (i.e. 100, 200 and 300 m; see Appendix E3). The results showed that simulator and live-fire LF6 scores were similar for 100 m and 300 m serials, with no significant differences in mean scores ($p>0.05$), but were significantly different for 200 m serials. There is no apparent reason for the significant difference at 200 m; it would be worth investigating as part of future research. Overall, these findings provide additional evidence for the effectiveness of the white targets on trainees' marksmanship performance in the simulator.

3.6.3 Participant Feedback

We collected qualitative feedback from participants regarding their opinions about the effectiveness of the simulator training during the study. Due to time constraints we collected this feedback informally throughout the study based on discussions with the participants and training staff. The study team took notes from their discussions and compared them at the end of the study. The most significant feedback from the participants was that they found it easier to see (and acquire) the white targets in the simulator, compared with the standard black and yellow targets, especially at longer ranges (i.e. 200 and 300 m).

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[12] The maximum possible scores at each range are: 85 points (100 m); 90 points (200 m) and 60 points (300 m). Thus, the predicted score is 0.85*85 + 0.65*90 + 0.60*60 = 166.75 points.

4. Discussion

In the following sections we discuss the study findings in the context of the study aims, hypotheses and previous research. Potential reasons for the outcomes are also outlined along with considerations for future research.

4.1 Comparison of Training Methods

The primary aim of the study was to evaluate the effectiveness of a novel training method for LF6 qualification with the M4 weapon using iron sights. It was hypothesised that the novel training method would lead to faster LF6 qualification compared with a standard training method. The results demonstrated that the novel training method produced comparable qualification rates to the standard method, suggesting that the two methods were of similar effectiveness. Consequently, the hypothesis was not supported. The most likely reason for this outcome is the fact that both training methods addressed the majority of factors (outlined in Table 1) that can influence LF6 qualification rates. Specifically, both methods involved familiarisation training at 25 metres, progression from basic to more advanced practices prior to qualification, simulator and live-fire training, similar amounts of training time, opportunities for live-fire training, and both methods allowed time for repeated practices to improve students' chances of qualifying.

The main differences were that the novel training method used 12% more rounds overall and the standard training method used 24% more live rounds. Also, the novel training method included more practices at 300 metres (2.1 times more rounds fired) and the standard training method involved more firing from other positions. While both training methods incorporated white targets for the LF6 simulator practice, the novel method used white targets for all simulator practices. Overall, it is plausible that the net effect of these differences in training methods cancelled out each other in their contribution to overall training effectiveness. The novel training method was developed on the basis that focusing on longer target ranges and on different serial types would have a greater effect on LF6 scores than focussing on different firing positions. The fact that there was no difference in pass rates for the two training methods suggests that all three factors may have had a roughly equivalent effect on firer performance. Notwithstanding this, the findings demonstrate the two training methods were of similar effectiveness, and either method could be utilised on future courses.

The standard training method may be preferable because staff and trainees will be familiar with the training practices. However, the novel training method is more efficient in terms of live rounds required, so is likely to be more attractive from a resource perspective. However, training staff need to be mindful that seeking greater efficiency through increased use of simulator training may be at the expense of training effectiveness. There is likely to be a minimum amount of live-fire training that is required to achieve pass rates that are deemed to be acceptable[13]. Additional studies would need to be conducted to identify the point at which this occurs for specific marksmanship practices. Overall, however, whichever method is used on future courses, it is recommended that white targets (or highly visible targets) be used for all simulator practices, especially for those at longer ranges (e.g. 300 m).

4.2 Predictors of Live-Fire Qualification

The second aim of the study was to investigate predictors of live-fire qualification. Based on our previous study findings, we hypothesised that LF6 simulator scores and skill level ratings would be significant predictors of LF6 qualification scores. The results of multiple regression analyses showed that skill level ratings and baseline LF6 simulator scores were the only predictors of LF6 qualification scores. These findings support our hypothesis and are consistent with our previous study (Stephens & Temby, 2014) and with other studies which have investigated predictors of live-fire scores (e.g. Chung et al., 2006; Schendel et al., 1983). Consequently, these outcomes provide further evidence that self-report ratings of skill level are useful to collect from trainees prior to commencing training in order to identify trainees who may require more assistance during training. Where possible, however, it is recommended that more objective data (e.g. recent marksmanship scores) are used to inform such decisions.

The results of simple linear regression analyses demonstrated that simulator LF6 scores were moderate predictors of live-fire LF6 scores; the magnitude of the correlation increased (from 0.47 to 0.59) when using the average of two simulator practices and the average of the first two qualification attempts. This highlights the limitation of using single scores as predictors of training outcomes, and that higher correlations can be achieved when using repeated measures. These findings are in agreement with previous studies which have found small to moderate correlations between simulator and live-fire scores (Chung et al., 2011; Gula, 1998), including the previous study (Stephens & Temby, 2014). Given the moderate correlations and variability in scores observed in the current study, no cut-off values could be found for LF6 simulator scores that would provide a reliable indication of the likelihood of passing LF6 qualification first time without incurring high numbers of false positives. Overall these findings imply that (1) while marksmanship simulator scores have some utility, caution is still needed when using them to make inferences about firer proficiency and readiness levels, and (2) repeated practices should be conducted where possible to obtain more reliable measures of marksmanship performance.

[13] What constitutes an acceptable number of attempts to pass would need to be based on a consideration of the amount of training conducted prior to attempting qualification, the complexity of the task, and the resources available. In the current case, we would suggest that taking three or less attempts to qualify is probably acceptable; ideally all trainees would pass after first or second attempt.

4.3 Comparison of Outcomes with Previous Study

The third aim of the study was to compare the outcomes with those of the previous study (Stephens & Temby, 2014) and, where possible, with other marksmanship studies. The current study produced a significant improvement in qualification rates compared with the previous study (94% vs. 58% after three attempts). As a consequence, this study achieved significant savings in live ammunition (87 rounds per trainee) as well as a reduction in time to achieve qualification compared with the previous study. Given that the sample of trainees in the current and previous study were similar on key demographic variables, it is likely that the differences in outcomes are due to the different training methods employed in the two studies. More specifically, we believe the improved outcomes can be attributed to the following factors.

- **More methodical training:** The current study contained serials that provided graduated exposure to the qualification task over four days by systematically increasing the difficulty of training, including: familiarisation at 25 m, followed by firing on tasks that were representative of the qualification practice (i.e. firing at 100, 200 and 300 metres from different firing positions and with deliberate, rapid & snap serials). There was also opportunity for live-firing prior to qualification, as well as time for coaching, feedback and repetition of practices. This contrasted with the previous study in which training was shorter, less methodical, and involved less live-firing before qualification.
- **White targets:** The use of white targets in the simulator is also likely to have contributed to the improved pass rates. While it is not possible to isolate the effect of this factor, LF6 pass rates in the simulator were significantly higher in this study (79%) compared with the previous study (50%) which used black and yellow targets for the LF6 practice. Having more students pass LF6 in the simulator prior to attempting qualification is likely to have increased their confidence level prior to qualification.
- **Coaching:** In the previous study there was limited coaching provided to students; this was a deliberate condition of the study. In the current study there was more marksmanship coaching provided to students, in particular, to those students that had difficulty using iron sights and were consistently missing targets. This coaching is likely to have made a significant contribution to the improved pass rates.
- **Range Feedback**: In this study the classification range was used for all live firing. The classification range proved to be conducive to a tempo that allowed opportunities for coaching and for students to reflect on their performance and correct any faults. Additional feedback was provided through the use of marking wands to highlight fall-of-shot locations. In contrast, the previous study used the Marksmanship Training Range (MTR) for all live firing and utilised automated targetry and fall-of-shot feedback. While the use of these technologies allows for faster throughput, it may create fewer opportunities for students to correct any faults. If the MTR is used on future courses, it is recommended that sufficient opportunities for coaching and feedback are provided.

4.4 Implications for Simulator-Based Marksmanship Training

The fourth aim of the study was to identity implications for simulator-based marksmanship training and future marksmanship research.

Amount of Simulator Training: The results from this study showed that two different training methods produced almost identical pass rates after three qualification attempts. While it is not possible to isolate the effectiveness of the simulator training on pass rates from overall training effectiveness, we can make some inferences. In the standard method, simulator training accounted for 55% of the total training. In the novel method, simulator training accounted for 68% of the total training. Therefore, given that each method was found to be equally effective after three qualification attempts, it seems that increasing the amount of simulator-based training from 55% to 68% had no detrimental impact on training outcomes.

Training Effectiveness: It would be interesting to know whether a higher percentage of simulator training could be used to achieve even greater training efficiencies (i.e. cost-savings) while still achieving comparable pass rates. It should be noted that in the previous study, the training method utilised 62% simulator training without achieving the same pass rates as the current study. Consequently, these findings imply that (1) the training content is critical to marksmanship training outcomes, and (2) a marksmanship training program that consists of a moderately high percentage of simulator training can produce effective outcomes, provided it also contains live-fire practices and training principles are followed. In the current study both training methods met these criteria. Future research would need to be conducted to determine whether the outcomes generalise to other marksmanship tasks and weapon systems (i.e. not just for LF6 qualification with M4/iron sights).

Mix of Simulation and Live Training: Another implication of these findings is that the notion of an optimal mix of simulator and live-fire training may be overly simplistic. Given that the previous study and the novel training method in the current study both employed similar amounts of simulator training (~60%) but resulted in very different pass rates, this highlights that other factors, such as training content, are crucial to achieving good training outcomes. Consequently, discussions on the optimal mix of simulator and live-fire training need to consider other factors effecting training transfer, such as trainee ability levels, training content, and skill acquisition rates.

Simulator Realism: Finally, another implication for simulation-based marksmanship training is that when the task in the simulator is more representative of the real-world (live-fire) task (e.g. by modifying target contrast), there is likely to be a higher correlation between simulator and live-fire scores, as was found in this study.

4.4.1 Suggestions for Future Research

A final aim of the study was to identify suggestions for future marksmanship research. The outcomes of this trial, where 69% of all students passed after two qualifications attempts and 94% of all students passed after three qualification attempts, could be improved, but probably only by a small amount in the time available. This is because in any course there are likely to be students with low marksmanship ability who struggle to qualify; a pass rate of 100% after first or second attempt may not be achievable. Some recommendations for researchers to consider in future trials have already been highlighted based on observational data collected in this study (Section 3.5); it is likely that these recommendations could help achieve even more efficient marksmanship qualification. In the following points, suggestions for future marksmanship research are outlined based on the findings and limitations associated with the current study.

- The current findings are based on small sample sizes; therefore it is recommended that future research replicate the current study to validate the outcomes for the novel training method using larger samples.
- The current findings are specific to using the M4 weapon with iron sights for basic marksmanship tasks. Therefore, it is recommended that future research replicate this study with other weapon systems (e.g. F88 Steyr with optical sights) and other marksmanship tasks to examine the generalisability of the outcomes.
- The current study has found evidence for the effectiveness of using white targets for specific simulator practices; future research could examine whether using white targets for all simulator practices leads to better performance on those practices compared with the standard simulator targets.
- In the novel training method all practices were conducted from the prone position whereas the standard training method involved firing from different positions. Therefore firing position was a confounding variable when comparing the two training methods; it may be worthwhile investigating the impact of different firing positions on training performance as part of future studies.
- The current study focused on marksmanship performance both during and immediately following training; however, the retention of marksmanship skills over longer periods is an important consideration for training designers. It is therefore recommended that longitudinal studies be conducted to investigate skill retention levels associated with different training methods and marksmanship tasks.
- At the time of this study, training policy required that students on the course achieve LF6 qualification with the M4 weapon using iron sights. The training policy has now been changed and students are required to qualify on LF6 practice using the F88 Steyr weapon with optical sights. It is recommended that LF6 qualification data from these courses is collected and analysed as part of future research to see whether there has been any significant change in pass rates since this policy change.
- Finally, if the standard training method continues to be used on future courses, it is suggested that white targets be used for all simulator practices, and more live-firing is conducted, as these factors appear to have had significant benefit in this study compared with our previous study.

4.5 Study Limitations

There were two main limitations with this study. Firstly, the sample size was quite small (N=35), with only small numbers of participants in each training group (n=18 and n=17 respectively); however it did represent 100% of the students on the course. In addition, the course is only run annually, which means there is infrequent opportunity to build upon the outcomes of the current study. The second limitation was the requirement to fit the study design within the constraints of the training course, in particular, the requirement for both groups to receive (roughly) equivalent amounts of training. While this had minimal impact on the study outcomes, it constrained the options for the study design.

5. Conclusion and Recommendations

The current study has shown that a novel training method that employs 70% simulator and 30% live-fire training, can achieve high qualification rates for a basic marksmanship task. Furthermore, this study resulted in significantly higher qualification rates after fewer attempts, along with significant savings in live ammunition, compared with previous studies (Stephens & Temby, 2014); the effect sizes for the difference in pass rates were large between the studies. These outcomes provide empirical support for the training methods used in this study and showed that the limitations in the previous study were successfully addressed. In addition, the outcomes provide evidence for the utility of simulation for marksmanship training.

The novel training method was found to be as effective as a standard training method, but more efficient in terms of live rounds used. Consequently, implementing the novel training method on future courses would be warranted on cost effectiveness grounds. The findings also showed that simulator scores and trainee skill level ratings were predictive of live-fire qualification scores; however, their utility for determining trainee readiness levels for qualification may be limited due to the variance in scores and false acceptance rates. Further studies are recommended to validate the current findings and address areas identified for future research in the report, including investigating whether the findings generalise to other weapon systems and marksmanship tasks.

The key lessons for the military community from this study are as follows:

- Marksmanship training is effective when it follows doctrine and training principles.
- Use marksmanship training data (e.g. hit ratios) to inform assessments of trainee readiness levels for qualification; where possible use repeated measures of performance to obtain more reliable assessments.
- There are many factors that contribute to effective training (e.g. trainee ability levels, simulator environment, opportunities to practice, coaching and feedback); addressing each of these factors when developing training programs is more important than focussing on the 'optimum' mix of simulator and live-fire training.

- Allow sufficient time for trainees to learn new techniques (e.g. learning to use iron sights) during the training program; do not assume trainees will be able to achieve competency quickly just because they have conducted the task before.
- Modifying the simulator may lead to better training outcomes; do not assume the default simulator settings will always meet the training requirements.

Overall, this study has made a significant contribution to the literature on marksmanship training for several reasons:

- The study has provided quantitative evidence regarding the effectiveness of different marksmanship training methods, which is currently lacking in the published literature.
- The study has evaluated training effectiveness at all four levels of Kirkpatrick's model, thereby providing a comprehensive evaluation of training.
- The findings challenge the notion of an 'optimal' mix of simulator and live-fire training by highlighting differences in training outcomes with a previous study which employed similar amounts of simulator training.
- The study has demonstrated that military training units can achieve more efficient and effective marksmanship training by adherence to a systematic process of data collection, analysis, refinement and re-testing.

In summary, the following recommendations are made for future research:

- Replicate the current study to validate the outcomes for the novel training method on future Australian Army training courses.
- Replicate the current study for other weapon systems (e.g. F88 Steyr rifle) including investigating whether the mix of simulator and live-fire training is effective for other marksmanship tasks.
- Replicate the current study using white targets for all simulator practices to examine whether this leads to even better performance on those practices.
- Conduct longitudinal studies to investigate levels of skill retention associated with different training methods for specific marksmanship practices and qualification.
- Conduct studies to investigate the impact of different firing positions on training performance and qualification outcomes.

6. References

Alliger, G.M., & Janak, E.A. (1989). Kirkpatrick's levels of training criteria: thirty years later. *Personnel Psychology, 42,* 331–342.

Alliger, G.M., Tannenbaum, S.I., Bennett, W., Traver, H., & Shotland, A. (1997). A meta-analysis of the relations among training criteria. *Personnel Psychology, 50,* 341–358.

Australian Army (1993). Manual of Land Warfare Part 2 Infantry, Volume 9, Pamphlet 1: Training the Battle Shot (MLW 2-9-1). Headquarters Training Command: Commonwealth of Australia.

Blume, B.D., Ford, J.K., Baldwin, T.T., & Huang, J.L. (2010). Transfer of Training: A Meta-Analytic Review. *Journal of Management, 36,* 1065-1105.

Chung, G.K.W.K, Delacruz, G.C., deVries, L.F., Kim, J., Bewley, W.L., de Souza e Silva, A.A., Sylvester, R.M., & Baker, E. (2006). *Determinants of Rifle Marksmanship Performance: Predicting Shooting Performance With Advanced Distributed Learning Assessments. Report for Office of Naval Research.* National Center for Research on Evaluation, Standards, and Student Testing (CRESST): University of California, Los Angeles.

Collier, G. (2010). Simulation: Shortening the Learning Loop. *Australian Infantry Magazine, April/October 2010.*

Delanghe, F. (2001). Validating Small Arms Simulation. Military Simulation and Training Magazine, Issue 6/2001. Halldale Media Group, Lake Mary, Florida USA.

Department of Defence (2011). The Application of the Medical Employment Classification System and PULHEEMS Employment Standards in the Australian Army. DI(A) PERS 159-1 Amendment 4. Canberra, ACT: Army Headquarters.

Dyer, J.L., Schaefer, P.S., Bink, M.L., James, D.R., Wampler, D.R., & Dlubac, M.D. (2010). *Soldier Performance on a New Marksmanship Course of Fire. Research Report 1924.* Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Evans, K.L. & Osborne, A.D. (1988). *The Development and Implementation of Basic, Advanced, and Unit M16A1 Rifle Marksmanship Training Programs. Research Report 1491.* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Filippidis, D., & Puri, V. (1999). *Development of Training Methodology for F-88 Austeyr using an Optimum Combination of Sim/Live Training.* Proceedings of the Land Weapons Systems Conference. Defence Science and Technology Organisation: Salisbury, South Australia.

Gula, C. A. (1998). *FATS III Combat Firing Simulator Validation Study. Report No. 98-CR-26.* Defence and Civil Institute of Environmental Medicine (DCIEM). Ontario: Canada.

Hagman, J.D. (1998). Using the Engagement Skills Trainer to Predict Rifle Marksmanship Performance. *Military Psychology, 10,* 215-224.

Hagman, J.D. (2000). *Basic Rifle Marksmanship Training with the Laser Marksmanship Training System. Research Report 1761.* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hunt, J.P., & Evans, K.L. (1986). *The Development and Evaluation of a Moving Target Engagement Training Program with the M16A1 Rifle.* Proceedings of the Human Factors and Ergonomics Society Annual Meeting, September 1986, 30: 285-289.

James, S. (2011). *Evaluation of a Marksmanship Training Simulator: Effects of Feedback on Training and Transfer.* Unpublished Masters Thesis. School of Psychology, Faculty of Health, Griffith University, QLD.

Jensen, T., & Woodson, J. (2012). *A Naval Marksmanship Training Transfer Study: The Use of Indoor Simulated Marksmanship Trainers to Train for Live Fire.* Unpublished Masters Thesis. Monterey, California: Naval Postgraduate School.

Keefe, A.A., & Tikuisis, P. (2003). *A comparison of target detection and rifle marksmanship during live and simulator firing with and without caffeine consumption. Technical Report 2003-003.* Defence R&D Canada (DRDC), Toronto.

Kirkpatrick, D. L. (1994). *Evaluating training programs: the four levels.* San Francisco: Berrett-Koehler.

Maxey, J.L., George, J.D., & Straesel, H.C. (1985). *Analysis of M16A1 Basic Rifle Marksmanship Training. Research Note 85-10.* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Merlo, J. L., Frechette, J., & Banks, S. J. (2010). *Modeling Transfer of Training and Training Effectiveness in Simulated Marksmanship Training.* Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting 2010.

NHMRC (2007). *National Statement on Ethical Conduct in Human Research.* Canberra, ACT.

Salas, E., & Cannon-Bowers, J.A. (2001). The Science of Training: A Decade of Progress. *Annual Review of Psychology, 52,* 471-499.

Salas, E., Milham, L.M., & Bowers, C.A. (2003). Training Evaluation in the Military: Misconceptions, Opportunities, and Challenges. *Military Psychology, 15,* 3-16.

Schendel, J.D., Morey, J.C., Granier, M.J., & Hall, S. (1983). *Use of Self Assessments in Estimating Levels of Skill Retention. Research Report 1341.* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Scribner, D.R., Wiley, P.H., & Harper, W.H. (2007). *A Comparison of Live and Simulated Fire Soldier Shooting Performance. ARL-TR-4243.* U.S. Army Research Laboratory Human Research and Engineering Directorate. Aberdeen Proving Ground, MD.

Smith, M.D., & Hagman, J. D. (2000). *Predicting Rifle and Pistol Marksmanship Performance with the Laser Marksmanship Training System (Technical Report 1106).* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Smith, M.D., & Hagman, J. D. (2003). *Using the Laser Marksmanship Training System to Predict Rifle Marksmanship Qualification (Research Report 1804).* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

SPSS Inc (2008). SPSS for Windows, Version 17.0. Chicago, SPSS Inc.

Stephens, A. K. W. (2012). *Modelling the Laser Hit-Detection Accuracy of the Weapons Training Simulation System. DSTO-TN-1110.* Defence Science and Technology Organisation: Edinburgh, South Australia.

Stephens, A., & Temby, P. (2014). *Evaluation of the Effectiveness of Simulation for M4 Basic Marksmanship Training*. DSTO-TR-2950. Defence Science and Technology Organisation: Edinburgh, South Australia.

Temby, P., Ryder, C., Vozzo, A., & Galanis, G. (2005). *Sharp Shooting in Fuzzy Fields: Effects of Image Clarity in Virtual Environments.* Proceedings of the Simulation, Technology and Training (SimTecT) Conference, Sydney, Australia.

Thompson, T.J., Smith, S., Morey, J.C., Osborne, A.D. (1980). *Effectiveness of Improved Basic Rifle Marksmanship Training Programs. Research Report 1255.* Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Vozzo, A. (2008). *The Effect of Target Pixelation on Marksmanship Performance.* Unpublished Masters Thesis. University of Queensland, Australia.

Yates, W.W. (2004). *A Training Transfer Study of the Indoor Simulated Marksmanship Trainer.* Unpublished Masters Thesis. Monterey, California: Naval Postgraduate School.

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Appendix A: M4 Marksmanship Practices

The range practices used for basic M4 marksmanship training are (in order of increasing difficulty): 25 metre zeroing practice, LF1, LF2, LF3, LF4, LF5 and LF6. LF6 is described in detail in Table 12.

- The 25 metre zeroing practice involves firing at static targets at 25 metres to confirm weapon zeroing and to make sight adjustments to the weapon as required.
- The LF1 and LF2 practices involve engaging static targets at 100 metres from the prone position.
- The LF3 practice involves engaging static targets at 200 metres and 300 metres from the prone position.
- The LF4 practice involves engaging static targets at 100 metres and 200 metres from different firing positions.
- The LF5 practice involves engaging moving targets at 100 metres from the kneeling position; the targets move in different directions and at different speeds.
- The LF6 practice involves engaging static and moving targets from different firing positions at 100, 200 and 300 metre ranges under timed conditions.

Table 12. The LF6 practice. Scoring is five points per hit on target. HPS = highest possible score. Practice reproduced with permission from the Australian Army.

Serial	Type	Range (m)	Rounds	Target Type	Firing Position	Description and Timings	HPS
1	Deliberate Timed	300	8	Figure 11	Standing Supported (Weapon Pit)	Two sighting rounds (in firers own time) are fired at a Figure 11 target followed by six rounds to score in two minutes.	30
2	Snap	300	6	Figure 11	Prone Unsupported	One round is fired at each of six exposures of a Figure 11 target. Targets are exposed for 3 seconds with an interval of 5 to 10 seconds between exposures.	30
3	Rapid	200	6	Figure 12	Sitting Supported	6 rounds are fired at one 24 second exposure of a Figure 12 target.	30
4	Snap	200	6	Figure 12	Kneeling or Squatting Supported	1 round is fired at each of six exposures of a Figure 12 target. Targets are exposed for 3 seconds with an interval of 5 to 10 seconds between exposures.	30
5	Rapid	200	6	Figure 12	Sitting Unsupported	6 rounds are fired at one 30 second exposure of a Figure 12 target.	30
6	Snap	100	6	Figure 11	Kneeling or Squatting Unsupported	1 round is fired at each of six exposures of a Figure 11 target. Targets are exposed for 3 seconds with an interval of 5 to 10 seconds between exposures.	30
7	Snap	100	6	Figure 11	Standing Unsupported then Kneeling or Squatting Unsupported	1 round is fired at each of six exposures of a Figure 11 target. Targets come in 3 sets of 2 targets; in each set targets are engaged from a different position. Target exposures are for 3 seconds, with a 3 second interval between sets.	30
8	Moving Target	100	15	Figure 11	Kneeling or Squatting Supported	A maximum of 3 rounds are fired at each of 5 exposures of a moving Figure 11 target. Target speeds are random (1, 2 or 3 ms^{-1}). Targets move either right to left or left to right over 10 metres.	25
Total			59				235

Appendix B: Demographic Questionnaire

Rank……………………………………. …… Age……………………………………….

First Name……………………………… …... Surname…...………………………………

Previous Unit…………………………… …... Years of ADF Service…………………....

Branch of Service……………………………. Corp/Mustering…………………………

1. How many times have you fired a rifle in the past 12 months (including WTSS and live-fire)?

2. Prior to the course, how would you have rated your marksmanship skill level?

   ☐ Below average (do not consistently pass Annual Weapons Test first time)
   ☐ Average (usually pass Annual Weapons Test first time)
   ☐ Above average (always pass Annual Weapons Test first time and score well below pass mark)

3. How many times have you conducted the LF6 practice in your career?

4. When was last time you shot LF6? Specify month and year.

5. Prior to this course, have you ever used the M4 weapon? ☐ Yes ☐ No

   a. If yes, how much experience (in months or years) have you had with the M4 weapon?

6. Prior to this course, have you ever used a weapon with iron sights? ☐ Yes ☐ No

   a. If yes, please specify weapon system……………………………………………
   b. How much experience have you had with that weapon (in months or years)?

7. Based on your current level of training, how would you rate your confidence in using the M4?

   ☐ Low ☐ Moderate ☐ High

8. How confident are you of passing LF6 first time with the M4 weapon?

   ☐ Low ☐ Moderate ☐ High

9. Do you wear corrective glasses/eyewear? ☐ Yes ☐ No

10. Do you have 20/20 vision? ☐ Yes ☐ No

11. How would you rate your general health today? (please tick)

    ☐ Well Below Average
    ☐ Below Average
    ☐ Average
    ☐ Good
    ☐ Excellent

12. Are there any factors (e.g. illness, injury) that you believe may affect your marksmanship performance in this trial?

    ☐ Yes → please describe: ……………………………………………………………….
    ☐ No ………………………………………………………………………………...

Appendix C: Novel Training Method

Practice	Serial	Type	Range	Firing Position	Rounds
Zeroing (Live)	1	Deliberate	25 m	Prone Unsupported	3
	2				20
Famil (Live)	1	Deliberate	25 m	Sitting Unsupported	5
	2				5
	3			Kneeling Unsupported	5
	4				5
	5			Standing Unsupported	5
	6				5
Practice 1 (Sim)	1	Deliberate	100 m	Prone Unsupported	6
	2				6
	3	Rapid			6
	4				6
	5	Snap			6
	6				6
	7	Deliberate	200 m		6
	8				6
	9	Rapid			6
	10				6
	11	Snap			6
	12				6
Practice 2 (Sim)	1	Deliberate	200 m	Prone Unsupported	6
	2				6
	3	Rapid			6
	4				6
	5	Snap			6
	6				6
	7	Deliberate	300 m		6
	8				6
	9	Rapid			6
	10				6
	11	Snap			6
	12				6
Practice 3 (Live)	1	Snap	100 m	Prone Unsupported	8*
	2				6
	3	Rapid	200 m		8*
	4				6
	5	Snap	200 m		6
	6				6
	7	Deliberate	300 m		8*
	8				6
	9	Snap	300 m		6
	10				6
LF5 (Sim)	As for LF5 in Appendix D				48
LF6 (Sim)	As for LF6 in Appendix D				59
All					370
Total Live Rounds					119

Appendix D: Standard Training Method

Practice	Serial	Type	Range	Firing Position	Rounds
Zeroing (Live)	1	Deliberate	25 m	Prone Unsupported	3
	2				20
Famil (Live)	1	Deliberate	25 m	Sitting Unsupported	5
	2				5
	3	Deliberate	25 m	Kneeling Unsupported	5
	4				5
	5	Deliberate	25 m	Standing Unsupported	5
	6				5
LF1 (Sim)	1	Bold Adjust	100 m	Prone Unsupported	3
	2	Grouping	100 m		20
LF3 (Live)	1	Deliberate	200 m	Prone Unsupported	12
	2	Rapid	200 m		5
	3	Rapid	200 m		5
	4	Deliberate	300 m		12
	5	Rapid	300 m		5
	6	Rapid	300 m		5
LF4 (Sim)	1	Deliberate	200 m	Sitting Supported	7
	2	Rapid	200 m		5
	3	Deliberate	100 m	Sitting Unsupported	5
	4	Deliberate	200 m	Kneeling Supported	7
	5	Rapid	200 m		5
	6	Deliberate	100 m	Kneeling Unsupported	5
	7	Deliberate	200 m	Standing Supported	7
	8	Rapid	200 m		5
	9	Deliberate	100 m	Standing Unsupported	5
LF4 (Live)	1	Deliberate	200 m	Sitting Supported	7*
	2	Rapid	200 m		5
	3	Deliberate	100 m	Sitting Unsupported	5
	4	Deliberate	200 m	Kneeling Supported	7
	5	Rapid	200 m		5
	6	Deliberate	100 m	Kneeling Unsupported	5
	7	Deliberate	200 m	Standing Supported	7
	8	Rapid	200 m		5
	9	Deliberate	100 m	Standing Unsupported	5
LF5 (Sim)	1	Moving	100 m	Kneeling Supported	18
	2				30
LF6 (Sim)	1	Deliberate Timed	300 m	Standing Supported	8
	2	Snap	300 m	Prone Unsupported	6
	3	Rapid	200 m	Sitting Supported	6
	4	Snap	200 m	Kneeling or Squatting Supported	6
	5	Rapid	200 m	Sitting Unsupported	6
	6	Snap	100 m	Kneeling or Squatting Unsupported	6
	7	Deliberate Timed	100 m	Standing Supported	6
	8	Snap	100 m	Prone Unsupported	15
All					329
Total Live Rounds					148

Appendix E: Additional Data

E.1. Training Practices

E.1.1 Mean Scores and Pass Rates

Mean scores and pass rates for all training practices are presented in Table 13. Pass rates ranged from 24% to 100% for all practices. As expected, low pass rates were observed on the baseline LF6 practice. Low pass rates were also observed on the live-fire practices for the standard training group (LF3, LF4)[14] and the novel training group (Practice 3), consistent with students having limited live-fire experience with the M4 weapon. Mean scores and pass rates for the two groups were similar on the baseline LF6 practice; the difference in mean scores was compared using an independent samples t-test and was found to be not significant (t=0.38, p=0.71). This result is consistent with the two groups being at similar levels of proficiency on the LF6 practice prior to training.

LF6 scores and pass rates for both groups increased significantly from baseline levels to the final LF6 practice. For the standard training group, the mean score increased 35.9 points, which was statistically significant using a paired samples t-test (t=4.29, p=0.001). For the novel training group, the mean score increased 50.3 points which was also statistically significant based on a paired samples t-test (t=6.26, p<0.001). These results indicate the marksmanship training conducted between the first and second LF6 practices was effective for both groups. The mean scores for the two groups were also similar on the final LF6; the difference in mean scores was not significantly different based on an independent samples t-test (t=1.06, p=0.30). This result indicates that the two groups were at a similar standard on LF6 prior to conducting qualification on the live-fire range.

Table 13: Mean scores, standard deviations, and pass rates for both groups for all training practices

Standard Training				Novel Training			
Practice	Mean (SD)	% Pass	Pass Score	Practice	Mean (SD)	% Pass	Pass Score
25 m (l)	93.7 (19.4)	n/a	n/a	25 m (l)	91.1 (19.6)	n/a	n/a
LF6b (s)	138.2 (34.5)	24	165	LF6b (s)	133.2 (42.4)	29	165
LF1 (s)	176.7[a] (55.4)	88	< 200 mm	Prac 1 (s)	64.5 (5.6)	100	50
LF3	128.5 (18.5)	29	140	Prac 2 (s)	54.4 (7.7)	78	50
LF4 (s)	165.4 (18.9)	65	157	Prac 3 (l)	42.1 (8.2)	50	40
LF4 (l)	99.1 (8.8)	25	105				
LF5 (s)	42.4 (6.2)	88	35	LF5 (s)	42.6 (8.3)	88	35
LF6f (s)	174.1 (31.4)	71	165	LF6f (s)	183.5 (19.0)	88	165

Legend: b=baseline; f=final; n/a=not applicable; s= simulator; l=live-fire

[a] This mean score is based on 11 out of 16 students as the scores were accidentally deleted from the simulator system before they could be recorded.

[14] During the LF4 practice, only the 200 m serials were conducted due to time constraints. The inability of students to fire at 100 m targets in this practice may have decreased their chances of qualifying first time.

E.1.2 Hit Ratios

Hit ratios were calculated at each range to gauge whether students were ready to attempt qualification (Table 14)[15]. Empty cells in the table indicate the practice did not contain any serials at that range. Hit ratios of 85% for 100 m, 60% for 200 m and 60% for 300 m were used as benchmark values to assess readiness for qualification. These values were derived from the previous study (Stephens and Temby, 2014) wherein it was found that these hit ratios were required at these ranges in order to achieve a pass score of 70% for the LF6 practice.

The hit ratio does not take into account different firing positions and serial type, so simply provides an indication of the number of targets hit at each range. Overall, students were hitting about 85% of targets at 100 m, 65% of targets at 200 m, and about 60% of targets at 300 m; this indicates both groups were close to being ready to progress to qualification by the end of training.

Table 14: Hit ratios for all practices at 100 m, 200 m, and 300 m ranges for both groups

	Standard Training				Novel Training		
Practice	**100 m**	**200 m**	**300 m**	**Practice**	**100 m**	**200 m**	**300 m**
LF6b (s)	0.78	0.45	0.46	LF6b (s)	0.77	0.38	0.52
LF3 (l)	---	0.64	0.63	Prac 1 (s)	0.95	0.83	---
LF4 (s)	0.83	0.74	---	Prac 2 (s)	---	0.85	0.67
LF4 (l)	---	0.65	---	Prac 3 (l)	0.96	0.68	0.60
LF5 (s)	0.85	---	---	LF5 (s)	0.81	---	---
LF6f (s)	0.85	0.64	0.66	LF6f (s)	0.78	0.57	0.73
All	**0.83**	**0.62**	**0.58**	**All**	**0.85**	**0.66**	**0.63**

Legend: b=baseline; f=final; s= simulator; l=live-fire

Overall, the training data shows that: (1) students were generally improving (i.e. learning) over subsequent practices, (2) students were capable of hitting targets at 200 and 300 m on the classification range, and (3) the two groups were at a similar standard on LF6 prior to attempting qualification. The implication of these findings is that the training was effective and a reasonable proportion of students could have been expected to achieve qualification; this was subsequently found to be the case (see Section 3.2). Ideally, all students would have achieved the pass standard on all practices to maximise the likelihood of achieving qualification; this is a recommendation for future courses.

E.2. Correlations between all practice scores and qualification

The correlations between all practice and qualification scores for the two groups are shown in Tables 15 and 16. The results show that baseline and final LF6 simulator scores and LF5 scores were moderately correlated with LF6 qualification scores, as were scores

[15] Hit ratio data was not able to be calculated for the LF1 practice as the number of target hits was not recorded; only the grouping scores for the LF1 practice were collected.

for Practice 1 and Practice 2 which were two practices developed specifically for the novel training method. The highest correlation for the novel training group was observed between Practice 2 and LF6 qualification scores (*r*=0.68). Interestingly Practice 3 scores (which reflect live-fire performance at 200 and 300 m targets) were not correlated with any of the other practice scores for the novel training group. There is no obvious explanation for this latter finding; it would be worthwhile investigating as part of future research. For the standard training group, a similar set of results was observed: Baseline and final LF6 simulator scores were moderately correlated with LF6 qualification scores. In addition, LF3 and LF4 (live-fire) scores were moderately correlated with LF6 qualification scores. Interestingly LF5 scores (which indicate performance at hitting 100 m moving targets from a kneeling position) were not correlated with scores for the other practices conducted by the standard training group; however, LF5 scores were significantly correlated with LF6 qualification scores for the novel training group.

Table 15: Correlation coefficients for practices conducted by novel training group

	Prac 1 (s)	**Prac 2 (s)**	**Prac 3 (l)**	**LF5 (s)**	**LF6f (s)**	**LF6 Q1**	**LF6 Q2**
LF6b (s)	.42	.43	.10	.01	.59*	.31	.52*
Practice 1 (s)	1	.68**	.38	.40	.56*	.57*	.54*
Practice 2 (s)	.68**	1	.28	.50*	.65*	.68*	.65*
Practice 3 (l)	.38	.28	1	.07	.24	.35	.31
LF5 (s)	.40	.50*	.07	1	.36	.60*	.27
LF6f (s)	.59*	.65**	.24	.36	1	.54*	.38
LF6 Qual 1	.57*	.68**	.35	.60*	.54*	1	.46
LF6 Qual 2	.54*	.65**	.31	.27	.38	.46	1

Legend: b=baseline, f=final, s=simulator, l=live-fire, qual=qualification
** = significant at *p*=0.01 level (2-tailed); * = significant at *p*=0.05 level (2=tailed)

Table 16: Correlation coefficients for practices conducted by standard training group

	LF3	**LF4 (s)**	**LF4 (l)**	**LF5 (s)**	**LF6f (s)**	**LF6 Q1**	**LF6 Q2**
LF6b (s)	.43	.20	.12	.22	.45	.60**	.69*
LF3 (l)	1	.28	.21	-.06	.04	.45*	.44
LF4 (s)	.28	1	-.01	-.32	.49*	.28	.45
LF4 (l)	.21	-.01	1	.24	.40	.53*	.41
LF5 (s)	-.06	-.32	.24	1	.08	.18	-.27
LF6f (s)	.04	.49*	.40	.08	1	.53*	.51*
LF6 Qual 1	.45	.28	.53*	.18	.53*	1	.55*
LF6 Qual 2	.44	.45	.41	-.27	.51*	.55*	1

Legend: b=baseline, f=final, s=simulator, l=live-fire
** = significant at *p*=0.01 level (2-tailed); * = significant at *p*=0.05 level (2=tailed)

E.3. Differences in Simulator and Live-Fire LF6 scores

As highlighted in the introduction of the report, previous studies have found that firer performance in the simulator is generally worse compared to live-fire and that this effect can be partly explained by the simulator target imagery. In this study, the colour of the targets in the simulator was modified for the LF6 practice. In doing so, it was expected that the participants would find it easier to aim and acquire the targets, compared with participants in the previous study. It was also expected that the simulator and live-fire scores for the LF6 practice would be more similar.

The mean scores for LF6 serials at 100 m, 200 m and 300 m in the simulator (average of two practices in the current study; average of three practices in previous study) and for live-fire qualification (average of first two attempts in both studies) are shown in Table 17. As can be seen, there was no statistically significant differences between scores for the 100 m and 300 m serials, but there was for 200 m serials. In the previous study, there was a significant difference for 300 m serial scores, and the difference in 200 m serial scores was statistically significant at the p=0.05 level. There is no obvious explanation for the significant difference; it would be worthwhile investigating as part of future research

Table 17: Mean scores for 100 m, 200 m, and 300 m LF6 serials in simulator and for live-fire for both studies. Standard deviations are shown in brackets. Asterisks indicate statistically significant difference.

Serials	**Range (m)**	**Current**			**Previous**		
		Simulator	**Live-fire**	**Statistics**	**Simulator**	**Live-fire**	**Statistics**
6, 7 and 8 (HPS=28.3)	100	24.1 (2.8)	23.0 (3.9)	t=1.80 p=0.08 d=0.32	22.8 (2.6)	23.5 (2.7)	t=1.21 p=0.24 d=0.26
3, 4 and 5 (HPS=30)	200	15.6 (5.6)	19.0* (5.9)	t=3.59 p=0.001 d=0.59	13.8 (4.3)	15.4 (5.0)	Z=1.96 p=0.05 d=0.34
1 and 2 (HPS=30)	300	17.6 (5.0)	18.1 (6.2)	t=0.46 p=0.65 d=0.09	13.1 (4.5)	15.6* (5.0)	t=2.57 p=0.02 d=0.53

Legend: HPS= Highest Possible Score. Note that at 100 m, the HPS of 28.3 is the average of Serials 6 (30 points), 7 (30 points) and 8 (25 points).

The results for simulator and live-fire LF6 serials in both studies are reproduced in Table 18. The results show that simulator and live-fire scores were significantly higher in the current study (in nearly all cases) compared with the previous study. Overall, these results provide further evidence to support the effectiveness of the training methods in the current study compared with the previous study training method.

Table 18: Mean scores for 100 m, 200 m, and 300 m LF6 serials in simulator and for live-fire for both studies. Standard deviations are shown in brackets. The highest possible score at each range is 30 points (200 m and 300 m) and 28.3 points (100 m). Asterisks indicate statistically significant difference.

Practice	Current (n=35)	Previous (n=36)	Mean Difference	Statistics
Simulator 100 m	24.1* (2.8)	22.8 (2.6)	+ 1.3	t=2.09, p=0.04, d=0.48
Simulator 200 m	15.6 (5.6)	13.8 (4.3)	+ 1.8	t=1.54, p=0.13, d=0.36
Simulator 300 m	17.6* (5.0)	13.1 (4.5)	+ 4.5	t=3.99, p<.001, d=0.95
Live-Fire 100 m	23.0 (3.9)	23.5 (2.7)	- 0.5	t=0.59, p=0.56, d=0.15
Live-Fire 200 m	19.0* (5.9)	15.4 (5.0)	+ 3.6	t=2.78, p=0.007, d=0.66
Live-Fire 300 m	18.1 (6.2)	15.6 (5.0)	+ 2.5	t=1.87, p=0.07, d=0.44

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19. ABSTRACT

Marksmanship training simulators are widely used within the Australian Army and other defence forces to support marksmanship training. While there is much anecdotal evidence to support the training effectiveness of these devices, there is little empirical data that quantifies their effectiveness, and informs the appropriate mix of simulation and live-fire training for specific marksmanship tasks. This report documents the development and evaluation of a novel method for basic marksmanship training with the M4 weapon, as part of a follow-on study. The novel training method consisted of 70% simulation and 30% live-fire and contained practices that specifically addressed factors linked to poor qualification rates in the previous study. The outcomes were compared with those from a standard training method that was based on current marksmanship doctrine. Both training methods resulted in very high (94%) pass rates after three qualification attempts and a significant saving in the number of live rounds used when compared with the previous study. The findings support the effectiveness of the novel training method and provide additional evidence for the utility of simulation in basic marksmanship training. The report discusses the reasons for the findings and outlines recommendations for future studies.

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