Technical Report 828

Effects of Recoil on Rifle Marksmanship Simulator Performance

Kenneth L. Evans

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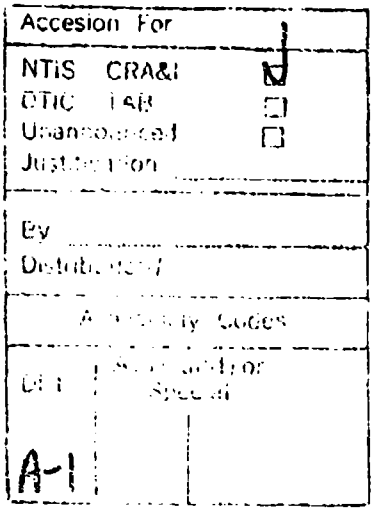

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movement by the recoil mechanism itself. Consistent with previous research in the areas of classical conditioning and simulator fidelity, these findings suggest that the accurate reproduction of recoil is unnecessary in rifle marksmanship simulation.

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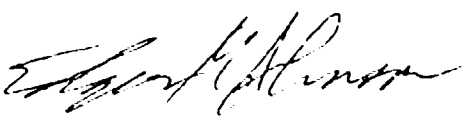
FOREWORD

Although many rifle marksmanship instructors believe the accurate reproduction of a rifle's noise and recoil is an essential characteristic of a rifle marksmanship simulator, the available evidence from research in classical conditioning and simulator fidelity suggests that noise and recoil may be unnecessary. Given the likelihood that the addition of realistic noise and recoil features to a marksmanship simulator would increase its manufacturing and maintenance costs substantially, it is prudent to consider whether such an addition would result in greater training effectiveness. The present research investigates this dilemma.

At the request of the U.S. Army Training Support Center, this research also examined whether it would be worthwhile to add a recently developed recoil feature to an existing marksmanship simulator, the Multipurpose Arcade Combat Simulator (MACS). This simulator has been evaluated extensively in the Army. The benefits associated with MACS training appear to be increased performance, fewer failures to meet performance standards, significantly lower ammunition expenditures, improved performance feedback, and greater soldier interest. Patented in 1986, MACS is a product of the U.S. Army Research Institute's Fort Benning Field Unit, which also performed the present investigation. The Fort Benning Field Unit conducts research on training and training technology with particular emphasis on individual and small-team skills in the Infantry arena. The research task that supports this mission is titled "Developing Training for Individual and Crew-Served Weapons," which is organized under the "Train the Force" program area.

Providing sponsorship for the MACS research program were the U.S. Army Infantry School under a Memorandum of Understanding (9 December 1987) and the U.S. Army Training Support Center under a Training Device Need Statement for MACS approved in 1984. The Army Training Support Center also procured the recoil mechanism used in the investigation. Preliminary results of this research have been provided to the Directorate of Training and Doctrine of the Infantry School and to the Devices Management Directorate of the Army Training Support Center. These findings are expected to have substantial impact on their decisions concerning future requirements for rifle marksmanship training devices. It should be noted that these findings may have some applicability to the simulation of other weapon systems, particularly if simulation is used in conjunction with live firing in an overall training strategy.



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EFFECTS OF RECOIL ON RIFLE MARKSMANSHIP SIMULATOR PERFORMANCE

EXECUTIVE SUMMARY

Requirement:

To determine if the accurate reproduction of a rifle's recoil is a necessary feature of a rifle marksmanship simulator, particularly the Multipurpose Arcade Combat Simulator (MACS).

Procedure:

Twenty-four adult volunteers in a military research organization each fired 12 shots at silhouette targets presented on a MACS system, whose demilitarized M16A1 rifle was equipped with a recently developed five-stage solenoid recoil mechanism. Each research participant fired six shots with recoil and six shots without recoil. In each recoil condition, three shots were fired from a supported firing position, and three were fired from an unsupported position. The order of presentation of the recoil and firing position conditions was counterbalanced across firers. Three measures of simulator performance were obtained for each firer in each experimental condition: movement before the shot, movement after the shot, and accuracy.

Findings:

In terms of both movement before the shot and accuracy, marksmanship simulator performance did not differ significantly as a function of recoil. As expected, recoil resulted in significantly greater movement after the shot, because of the introduction of rifle movement by the recoil mechanism itself. Compared with the supported firing position, firing from an unsupported position resulted in significantly greater marksmanship error on each measure of performance. Significant relationships were found in the no-recoil condition between movement, both before and after the shot, and accuracy. Specifically, greater movement was associated with more error in accuracy. Finally, experienced firers exhibited significantly less movement and accuracy error than inexperienced firers.

Utilization of Findings:

Consistent with previous research in the areas of classical conditioning and simulator fidelity, these findings suggest that the accurate reproduction of recoil is unnecessary in rifle marksmanship simulation when that simulation is part of a training program that also includes live firing. Their implications for cost savings are substantial. Because of the greater costs associated with simulating recoil, these findings suggest that it would be more

cost-effective to use simulators without recoil in rifle marksmanship training. In addition, these findings may have some applicability to the simulation of other weapon systems, particularly if simulation is used in conjunction with live firing in an overall training strategy.

EFFECTS OF RECOIL ON RIFLE MARKSMANSHIP SIMULATOR PERFORMANCE

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EFFECTS OF RECOIL ON RIFLE MARKSMANSHIP SIMULATOR PERFORMANCE

INTRODUCTION

In order to hit a target with a rifle, the rifle must be aligned with the target and a shot must be fired without disturbing this alignment. The U.S. Army rifle marksmanship training program teaches soldiers four marksmanship fundamentals: steady position, aiming, breath control, and trigger squeeze (Osborne & Smith, 1985; U.S. Army Infantry School [USAIS], 1984). The purpose of these fundamentals is to ensure that soldiers have proper rifle-target alignment at the moment a shot is fired. If this is achieved, the target is hit. If rifle-target alignment is poor at the moment a shot is fired, the target is missed. Failure to achieve proper rifle-target alignment can be attributed to errors in the execution of one or more marksmanship fundamentals.

Teaching the first three fundamentals is relatively straightforward and most novice firers learn their execution after a short period of training. However, the fourth fundamental, trigger squeeze, is more difficult to learn. In fact, trigger squeeze errors cause more target misses than errors in the execution of any of the other fundamentals (Osborne & Smith, 1985; USAIS, 1984). Trigger squeeze is taught for two important reasons. First, any sudden movement of the finger on the trigger may disturb rifle-target alignment. Second, and more importantly, squeezing the trigger prevents the firer from knowing the exact moment of rifle firing. If this exact moment is known precisely, most firers will develop a tendency to anticipate the rifle's noise and recoil by closing their eyes, for example, or by tensing their shoulder or arm muscles a fraction of a second before the shot. These latter anticipatory behaviors transfer undesirable movement to the rifle that disrupts rifle-target alignment, often with dramatic results. For instance, a small lateral muzzle movement of a fraction of an inch just prior to firing will cause a target at 300 yards to be missed by several feet. When such behaviors occur after the shot, as a normal reaction to the rifle's firing, they are inconsequential. This is because the bullet has already exited the muzzle. Only when they occur just prior to the shot, as anticipatory behaviors, do target misses result.

Trigger squeeze errors caused by the anticipation of noise and recoil are particularly problematic because they occur in close temporal proximity to the rifle's actual firing. Hence the muzzle blast and recoiling movement of the rifle itself tend to mask any anticipatory movement of the firer. Firers are generally unaware of their error and it is difficult for an observer to detect as it happens. However, the occurrence of a trigger squeeze error can be inferred by determining the magnitude of the target miss distance after the fact. The miss distances associated with trigger squeeze errors tend to be much larger than those associated with other types of errors (Osborne & Smith, 1985; USAIS, 1984).

Most rifle marksmanship instructors know that the anticipation of rifle noise and recoil by firers is the most difficult problem they encounter in training. Largely for this reason, many instructors also believe the accurate reproduction of a rifle's noise and recoil is an essential characteristic of

any rifle marksmanship simulator. Instructor comments and questionnaire responses from simulator training effectiveness evaluations attest to this commonly held belief (Eagle Technology, Inc., 1987; U.S. Army Infantry Board [USAIB], 1986, 1987, 1988). Yet, work in two different areas of research, classical conditioning and simulator fidelity, suggest that noise and recoil are unnecessary in rifle marksmanship simulation.

Classical Conditioning

Classical, or Pavlovian, conditioning has a rich history of psychological research spanning more than 60 years. The traditional classical conditioning model involves the pairing of two stimuli, an **unconditioned stimulus** (UCS) and a **conditioned stimulus** (CS). An unconditioned stimulus is one that naturally and consistently produces a particular response, called the **unconditioned response** (UCR). A conditioned stimulus is one that is neutral initially, in that it produces no such response. Through a process of conditioning, in which the CS is paired repeatedly with the US, the previously neutral CS eventually begins to produce the response alone. Then the response is called the **conditioned response** (CR). After the CR has been learned, it also can be eliminated through an extinction process, in which the CS continues to be presented without the UCS. Although classical conditioning currently is viewed as the learning of relations among events (Rescorla, 1988), the traditional model remains useful in understanding the process that causes trigger squeeze, or anticipatory, errors in rifle marksmanship. Not only is the classical conditioning model consistent with conventional wisdom in rifle marksmanship training, but more importantly, it suggests additional methods that might prove effective in preventing or eliminating anticipatory errors.

Consider how the process of firing a rifle could be viewed in terms of the classical conditioning model. The noise and recoil associated with firing live ammunition is the UCS. It naturally and consistently results in an eyeblink or shoulder movement response, the UCR. Pulling the trigger can be viewed as the CS. It is a neutral stimulus initially, in that it does not cause one to blink their eyes or move their shoulder in the absence of noise and recoil. For example, eyeblinks and shoulder movements normally do not occur when the trigger on an unloaded rifle is pulled, because it does not produce noise and recoil. Only after pulling the trigger (CS) has been paired with noise and recoil (UCS) does pulling the trigger by itself result in eyeblink or shoulder movement responses just prior to the shot (CR). Elimination, or extinction, of the CR occurs following a period during which pulling the trigger repeatedly fails to produce noise and recoil.

The classical conditioning model is remarkably consistent with what is routinely observed in rifle marksmanship training. First, many novice firers initially experience a brief phase during which anticipatory errors do not occur. This can be considered a conditioning phase that precedes the development of the CR. Although the conditioning model predicts that this should happen with all firers, some firers nevertheless exhibit anticipatory errors at the onset of live firing. This may be due to the likelihood of these firers already having learned the CS-UCS relationship between trigger pull and the rifle's noise and recoil, perhaps through watching television, movies, or

live-fire demonstrations before training. Second, the model states that anticipatory errors can be extinguished by pulling the trigger repeatedly without the usual noise and recoil. In fact, the two methods most often used in rifle marksmanship training to eliminate anticipatory errors both involve pulling the trigger without noise and recoil (Osborne & Smith, 1985; USAIS, 1984). One method consists of alternating periods of live firing and dry firing. Dry firing is identical to live firing, except no live ammunition is used. An even more effective method is to randomly alternate the firing of live and inert rounds, without the firer knowing which type of ammunition will be the next fired. This is accomplished by having the instructor load the firer's magazine with a random mixture of live and inert rounds. When the unsuspecting firer first pulls the trigger with an inert round loaded, any anticipatory movement can be seen easily by both the firer and instructor because it is no longer masked by noise and recoil.

In rifle marksmanship training, interest lies not only in those techniques that can be used to eliminate anticipatory errors after they have been conditioned, but also in techniques that may help to prevent such errors from ever becoming conditioned. A number of consistent findings from classical conditioning research suggest additional procedures that might be used to prevent or eliminate anticipation. Rescorla (1988) has noted that conditioning in a variety of situations is a function of the likelihood of the UCS during the CS. If the likelihood of the UCS is zero in the absence of the CS, as happens normally in rifle marksmanship training, then conditioning decreases as the probability of the UCS decreases in the presence of the CS. Consistent with the two methods of eliminating anticipation previously described, this finding suggests that increased amounts of dry firing, relative to the amount of live firing, should reduce anticipatory errors because it lowers the overall probability of noise and recoil during the trigger pull. Rescorla (1988) also has noted that conditioning is an inverse function of the base rate of UCS occurrence in the absence of the CS. Thus, attempts to increase the incidence of noise and recoil in the absence of a trigger pull also should reduce the number of anticipatory errors. Although a firer can be exposed easily to the noise of others firing on a rifle range, it is more difficult to imagine how a firer could experience recoil without pulling the trigger. Perhaps the effects of recoil could be simulated by having firers deliver slight shoulder punches to one another unpredictably, both before and after each training session. Finally, Rescorla (1988) has reported that conditioning is almost nonexistent when the probability of the UCS in the presence of the CS is equal to the probability of the UCS in the absence of the CS. This ideal situation, in which pulling the trigger provides the firer with no information about noise and recoil likelihood, could be expected to prevent conditioned anticipatory responses almost completely.

These findings of classical conditioning research suggest noise and recoil are unnecessary in rifle marksmanship simulation, when that simulation is part of a training program that also includes live firing. In this situation, simulation without noise and recoil should result in fewer anticipatory errors, because it reduces the overall probability of noise and recoil during the trigger pull. Classical conditioning research also suggests that when simulators having noise and recoil are used, its noise and recoil should be presented in a random or unpredictable fashion.

Simulator Fidelity

Simulator fidelity, or realism, refers to the degree of similarity between the simulator and the equipment being simulated. Thus, rifle marksmanship simulators having noise and recoil are considered to be higher in fidelity than those without noise and recoil. Because greater fidelity in a simulator usually increases its cost, a simulator that includes only those features necessaary for training has the highest potential for cost-effectiveness (Yuan-Liang, 1984). Although many assume greater simulator fidelity results in more effective training, a review of simulator fidelity research has concluded that "increased fidelity does not guarantee better training" (Yuan-Liang, 1984, p.2).

Research investigating those conditions warranting greater simulator fidelity has been inconclusive. Though psychomotor coordination tasks have been found to require higher fidelity than procedural tasks (Yuan-Liang, 1984), those psychomotor tasks typically investigated, such as aircraft flight operation and equipment maintenance tasks, have been generally more complex than the comparatively simple psychomotor tasks involved in rifle marksmanship. In contrast, Osgood (1949) proposed that the amount of learning that transfers from an original situation to a new one depends on the degree of similarity between the stimuli in the two situations and the similarity between the responses in those situations. He concluded that when stimuli are varied and responses are functionally identical, positive transfer of learning is obtained; when stimuli are functionally identical and responses are varied, negative transfer of learning is obtained. The notion that noise and recoil are unnecessary in rifle marksmanship simulation is consistent with the findings of Osgood (1984), because the firer's task remains the same whether or not noise and recoil stimuli are present.

Two investigations have examined issues related to the role of noise and recoil in rifle marksmanship simulation. In the first investigation, the training effectiveness of five rifle marksmanship simulators was evaluated in U.S. Army basic training (USAIB, 1986). One of the simulators had realistic noise and recoil features; four did not. The five simulators were generally equivalent in terms of their overall training effectiveness and each substituted effectively for some live firing with no significant decrease in subsequent marksmanship performance. Thus, those simulators without noise and recoil were as effective in training as the one having noise and recoil. The second investigation used another rifle marksmanship simulator to examine the effects of fidelity and performance feedback on both simulator performance and live firing performance (Torre, Maxey, Cuddeback, & Piper, 1986). In a comparison of fidelity and feedback extremes, 52 sailors inexperienced in rifle marksmanship were assigned to one of two experimental groups. One group received simulator training that involved noise, recoil, and a maximum level of performance feedback. The other group received an equivalent amount of training on the same simulator, but with minimum performance feedback and without noise and recoil. The average performance of sailors in the two groups did not differ significantly, either during simulator training or during subsequent live firing. In summary, these two investigations offer additional support to the position that noise and recoil are unnecessary in marksmanship simulation.

Statement of the Problem

Although many rifle marksmanship instructors believe the accurate reproduction of a rifle's noise and recoil is an essential characteristic of a rifle marksmanship simulator, the available evidence from research in classical conditioning and simulator fidelity suggests noise and recoil are unnecessary. Given the likelihood that the addition of realistic noise and recoil features to a marksmanship simulator would increase its manufacturing and maintenance costs substantially, it is prudent to consider whether such an addition would result in greater training effectiveness.

The purpose of the present investigation was threefold. First, it examined whether rifle marksmanship simulator performance differs as a function of recoil. Second, the present investigation, unlike the two previous investigations of rifle marksmanship simulator fidelity, used a research design that controlled for the initial marksmanship ability of firers. This variable has been found to influence the results of previous rifle marksmanship research; in fact, Evans (1988) has reported that rifle marksmanship simulator training may be more effective for those individuals with lower levels of initial ability. Third, the present investigation examined whether or not it would be worthwhile to add a recently developed recoil feature to an existing marksmanship simulator, the Multipurpose Arcade Combat Simulator (MACS). In this specific case, it was estimated that the addition of recoil would at least double the cost of the simulator.

METHOD

Subjects

Twenty-four adult workers in a military research organization served as voluntary research participants. Four participants were female and 20 were male. The rifle marksmanship experience of the participants varied widely. Seven participants were considered to be inexperienced because they never had received any formal marksmanship instruction. The remainder were considered to be experienced because they had received either military or law enforcement marksmanship training previously, though most had not fired a rifle within the past year.

Apparatus

Developed by the U.S. Army Research Institute and patented in 1986, the Multipurpose Arcade Combat Simulator (MACS) was the rifle marksmanship simulator used in the present investigation (Evans, 1988). Its basic hardware consists of a long-distance light pen mounted to a demilitarized M16A1 rifle, a Commodore 64 microcomputer, a Commodore 1702 color monitor, and a program cartridge. A Commodore 1541 disk drive and 1526 printer were added to the basic system in order to store and retrieve performance data. As computer-generated targets are presented on the monitor, the light pen determines the firer's point of aim and a switch mechanism attached to the rifle's trigger sends an electrical signal to the microcomputer when each shot is fired. Because many of its components are available as commercial off-the-shelf items,

the MACS system is relatively inexpensive to produce when compared with other rifle marksmanship simulators.

The MACS software used in this investigation presented each firer with a series of 12 U.S. Army E-type silhouette targets scaled to represent a target range of 250 m when viewed at a distance of 3 m from the monitor. Each target appeared individually at a random screen location and remained exposed until a shot was fired. After a shot was fired, the target disappeared and the next target appeared. Performance data, consisting of the target location and a series of aiming points across time, were collected for each shot. Vertical and horizontal light pen aiming coordinates, measured in pixel units, were collected at a rate of 60/s, from 1 s before trigger switch closure to .5 s after switch closure.

Simulated recoil was added to a MACS demilitarized M16A1 rifle by Larson Lectronics, Inc. All components of their five-stage solenoid recoil mechanism (patent pending) were mounted within the stock and upper receiver of the MACS rifle, with the exception of an ON/OFF switch mounted in the pistol grip and an external power supply. Whenever the power switch to the recoil mechanism was in the ON position, pulling the trigger resulted in an almost instantaneous rearward movement of the rifle.

Procedure

Four experimental firing conditions were presented to each research participant. Three shots were fired in each condition for a total of 12 shots. Recoil was presented in two conditions. One of these involved firing from a supported firing position and the other involved firing from an unsupported position. Recoil was absent in the two remaining conditions. Likewise, one of these involved supported firing and the other involved unsupported firing. A table with two sandbags was placed 3 m in front of the monitor. Firers stood behind this table while firing. In the supported firing conditions, the rifle was placed on top of the sandbags to obtain maximum stability. In the unsupported conditions, no sandbags were used and firers held the rifle with their elbows touching the table surface.

The presentation of recoil and firing position conditions was counterbalanced across firers. Four different sequences of presentation were used and six firers were assigned randomly to each presentation sequence. The first sequence presented the four experimental conditions in the following order: recoil-supported (RS), recoil-unsupported (RU), no recoil-supported (NRS), and no recoil-unsupported (NRU). The other three sequences were RU-RS-NRU-NRS, NRS-NRU-RS-RU, and NRU-NRS-RU-RS. Thus, half of the firers received recoil before no recoil and the other half received no recoil before recoil. Further, half fired supported before they fired unsupported and the other half fired unsupported before they fired supported.

Prior to firing, the experimenter told each research participant that the present investigation was an evaluation of a new recoil mechanism in the MACS system. Participants unfamiliar with the process of rifle firing were either told or shown how to aim at a target using the sights and how to hold the rifle in each firing position. Firers also were told they had unlimited time to

fire each shot. After the third, sixth, and ninth shots were fired, the experimenter instructed the firers to change their firing position. After the first six shots were fired, the experimenter repositioned the ON/OFF switch of the recoil mechanism to change the recoil condition. This clued most firers to the fact that the recoil condition was changing.

Three performance measures were computed: movement before the shot, movement after the shot, and accuracy of the shot. These performance measures were based on similar diagnostic scores used in MACS training software (Evans, 1988). Movement before the shot was computed by adding the vertical and horizontal standard deviations of the 10 aiming coordinates collected during the last sixth of a second before trigger switch closure. Likewise, movement after the shot was the sum of the vertical and horizontal standard deviations of the 10 coordinates collected during the first sixth of a second after switch closure. Accuracy of the shot was determined by measuring the radial distance, in pixels, between the center of the target and the last aiming coordinate before trigger switch closure. Each of the three performance measures represents error in the firing process, with lower scores denoting better performance than higher scores. After scores on each performance measure were calculated for each shot, mean scores on each measure were calculated for the three shots fired in each of the four experimental conditions. Thus, 12 mean scores were calculated for each firer.

RESULTS

Three dependent variables were employed in the present investigation: movement before the shot, movement after the shot, and accuracy. For each of these dependent variables a separate three-way mixed factorial analysis of variance (ANOVA) was performed with recoil (two levels: recoil and no recoil) and firing position (two levels: supported and unsupported) as within-subjects factors and with presentation sequence (four levels: RS-RU-NRS-NRU, RU-RS-NRU-NRS, NRS-NRU-RS-RU, and NRU-NRS-RU-RS) as a between-subjects factor.

Movement Before the Shot

The results of the ANOVA for movement before the shot are reported in Table 1. Recoil did not influence marksmanship performance on this measure. In fact, the position main effect was the only source of variance found to be statistically significant in this analysis. As expected, firers exhibited significantly more movement before the shot when they fired from an unsupported firing position (M = 2.54) than when they fired from a supported position (M = 1.72), $F(1, 20) = 26.75$, $p < .0001$.

Movement After the Shot

The results of the ANOVA for movement after the shot are reported in Table 2. Highly significant main effects for recoil and position were found. Due to the recoil mechanism itself causing movement after the shot, it was not surprising to find that firers exhibited significantly more movement after the shot when the rifle recoiled (M = 14.50) than when it did not (M = 2.62), $F(1, 20) = 214.65$, $p < .0001$. Like the results obtained for movement before the shot,

Table 1

Analysis of Variance Results of Movement Before the Shot

Source	SS	df	MS	F	p
Presentation Sequence (PS)	1.32	3	0.44	0.61	.6188
Subjects within PS	14.51	20	0.73		
Recoil (R)	0.49	1	0.49	1.50	.2348
PS X R	0.49	3	0.16	0.50	.6892
R X Subjects within PS	6.53	20	0.33		
Firing Position (FP)	16.19	1	16.19	26.75	.0001
PS X FP	2.59	3	0.86	1.42	.2651
FP X Subjects within PS	12.10	20	0.61		
R X FP	0.10	1	0.10	0.32	.5775
PS X R X FP	0.21	3	0.07	0.24	.8669
R X FP X Subjects within PS	5.92	20	0.30		
Total	60.44	95			

Table 2

Analysis of Variance Results of Movement After the Shot

Source	SS	df	MS	F	p
Presentation Sequence (PS)	42.47	3	14.16	0.83	.4925
Subjects within PS	340.79	20	17.04		
Recoil (R)	3387.82	1	3387.82	214.65	.0001
PS X R	30.65	3	10.22	0.65	.5937
R X Subjects within PS	315.66	20	15.78		
Firing Position (FP)	380.21	1	380.21	46.62	.0001
PS X FP	16.34	3	5.45	0.67	.5816
FP X Subjects within PS	163.09	20	8.15		
R X FP	190.15	1	190.15	23.26	.0001
PS X R X FP	20.40	3	6.80	0.83	.4920
R X FP X Subjects within PS	163.46	20	8.17		
Total	5054.06	95			

firers were found to exhibit significantly more movement after the shot when they fired from an unsupported firing position (M = 10.55) than when they fired from a supported position (M = 6.57), $F(1, 20) = 46.62$, $p < .0001$.

In addition, a highly significant recoil X position interaction was found, $F(1, 20) = 23.26$, $p < .0001$. The results of a simple effects analysis of this interaction are reported in Table 3. In the no recoil condition, firers displayed slightly more movement after the shot in the unsupported position (M = 3.20) than in the supported position (M = 2.03), $F(1, 20) = 1.99$, n.s. In the recoil condition, however, firers displayed significantly more movement after the shot in the unsupported position (M = 17.89) than in the supported position (M = 11.10), $F(1, 20) = 67.78$, $p < .0001$. The interactive relationship between the effects of recoil and firing position on movement after the shot is shown in Figure 1.

Table 3

Simple Effects Analysis Results of the Interaction Between Recoil and Firing Position on Movement After the Shot

Source	SS	df	MS	F	p
Firing Position (FP) for Recoil	554.06	1	554.06	67.78	.0001
FP for No Recoil	16.30	1	16.30	1.99	>.10
Recoil X FP X Subjects within Presentation Sequence	163.48	20	8.17		

Accuracy

The results of the ANOVA for accuracy are reported in Table 4. Like the results obtained for movement before the shot, recoil did not influence accuracy of the shot. Again, the position main effect was the only source of variance found to be statistically significant in this analysis. As expected, firers were significantly more accurate when they fired from a supported firing position (M = 2.38) than when they fired from an unsupported position (M = 3.00), $F(1, 20) = 9.99$, $p = .0049$.

Relationships Among the Dependent Variables

The relationships among mean scores on movement before the shot, movement after the shot, and accuracy were found to differ as a function of recoil. In the no recoil condition, mean scores on the dependent variables were found to be interrelated. Highly significant Pearson product-moment correlations were obtained between movement before the shot and accuracy error (r = .78,

$p < .0001$), between movement after the shot and accuracy error ($r = .76$, $p < .0001$), and between movement before the shot and movement after the shot ($r = .67$, $p = .0003$). As expected, greater movement before the shot and greater movement after the shot were found to be associated with more accuracy error in the no recoil condition.

In contrast, no significant correlations were obtained in the recoil condition, despite greater variation in these mean scores. There was no substantial relationship found between movement before the shot and accuracy error ($r = .25$, $p = .2402$), between movement after the shot and accuracy error ($r = .10$, $p = .6557$), or between movement before the shot and movement after the shot ($r = -.09$, $p = .6631$). However, movement after the shot was not expected to be related to the other two variables, because most of this movement was probably caused by the recoil mechanism itself and not by the firer. Although a more substantial relationship was expected between movement before the shot and accuracy error in the recoil condition, a highly significant correlation was obtained between these two variables when scores across the two recoil conditions were combined, $r = .75$, $p < .0001$.

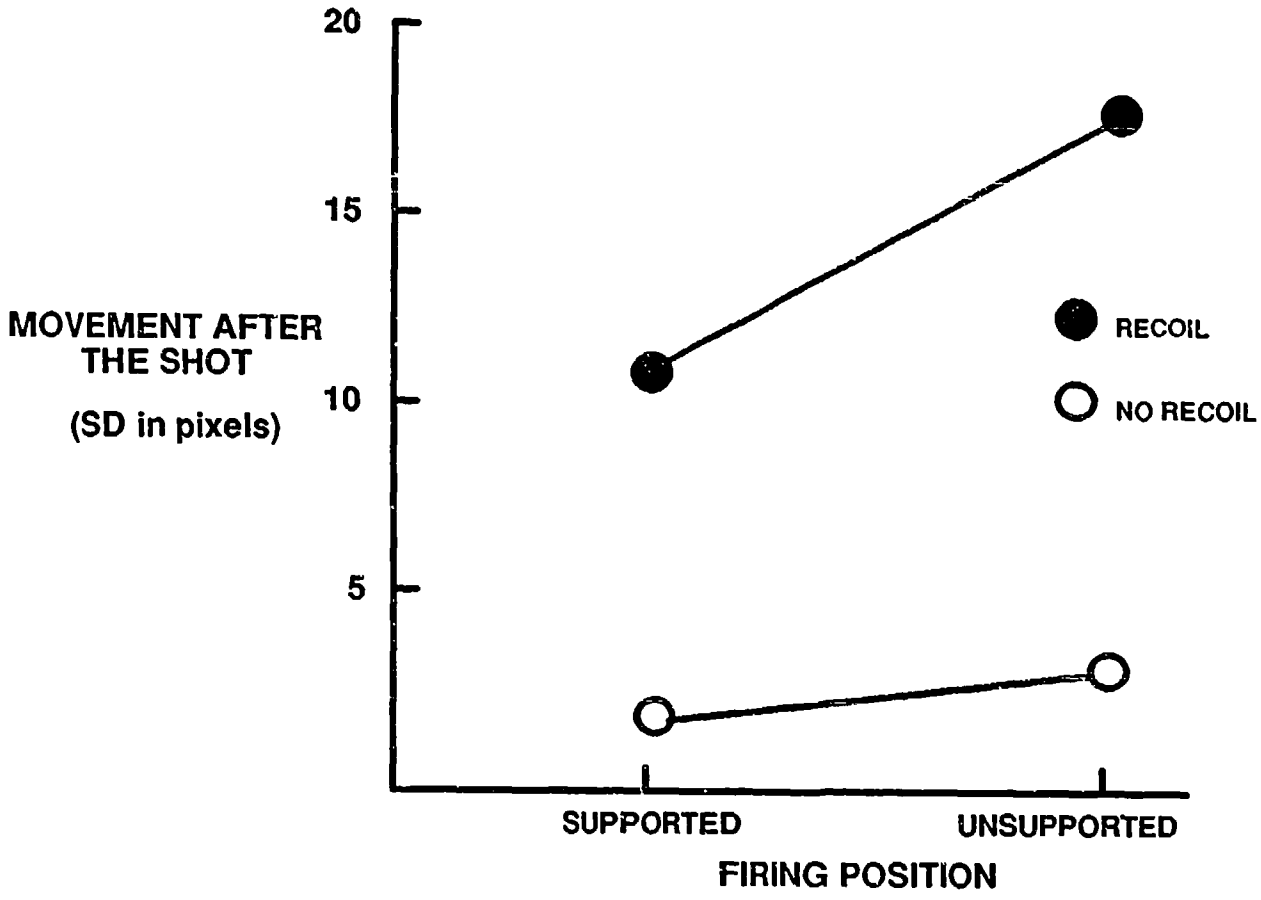

Figure 1. The interactive relationship between the effects of recoil and firing position on movement after the shot.

Table 4

Analysis of Variance Results of Accuracy

Source	SS	df	MS	F	p
Presentation Sequence (PS)	10.93	3	3.64	1.18	.3418
Subjects within PS	61.65	20	3.08		
Recoil (R)	1.53	1	1.53	1.31	.2656
PS X R	1.74	3	0.58	0.50	.6885
R X Subjects within PS	23.33	20	1.17		
Firing Position (FP)	9.25	1	9.25	9.99	.0049
PS X FP	4.28	3	1.43	1.54	.2346
FP X Subjects within PS	18.52	20	0.93		
R X FP	1.37	1	1.37	1.02	.3255
PS X R X FP	2.71	3	0.90	0.67	.5797
R X FP X Subjects within PS	26.93	20	1.35		
Total	162.24	95			

Effects of Experience on Marksmanship Performance

For each dependent variable, the performance of the 7 inexperienced firers in the sample was compared with the performance of the 17 more experienced firers. As expected, the experienced firers were found to have significantly better scores than the inexperienced firers on each marksmanship performance measure. Experienced firers had significantly less movement before the shot (M = 1.95) than inexperienced firers (M = 2.58), $t(22) = 4.57$, $p < .0001$. Experienced firers also had less movement after the shot (M = 7.83) than inexperienced firers (M = 10.33), $t(22) = 3.24$, $p = .0038$. Finally, the experienced firers exhibited less accuracy error (M = 2.38) than those inexperienced (M = 3.45), $t(22) = 3.15$, $p = .004$

DISCUSSION

Four limitations of the present investigation have implications for future research. First, the performance sample was limited to 12 shots per firer. It is possible a larger performance sample might have yielded different results by allowing more opportunity for firers to exhibit conditioned anticipatory responses to the effects of recoil. Although a much larger performance sample was obtained in two other investigations (Torre et al., 1987; USAIB, 1986), their findings did not differ from those of the present investigation. Nevertheless, a larger performance sample would permit the conditioning and extinction of anticipatory responses to be measured over

time. Second, because only stationary targets with unlimited exposure times were used, future research should consider the use of moving targets and targets with limited exposure times to determine the extent to which the present findings can be generalized to other, more difficult, firing situations. Third, the present apparatus did not allow the effects of realistic firing noise on performance to be evaluated. Because it is possible that firing noise or noise in combination with recoil may be a more powerful UCS than recoil alone, it is suggested future research investigate the effects of noise and recoil, both singly and in combination. Finally, prior marksmanship experience was found to have a significant effect on each measure of marksmanship performance. To determine whether the present findings generalize to all experience levels, it is suggested future research investigate the potentially interactive effects of recoil and experience on marksmanship performance with a larger sample of firers in each experience condition.

Despite these limitations, the results of the present investigation are entirely consistent with previous research in the areas of classical conditioning and simulator fidelity (Osgood, 1949; Rescorla, 1988; Torre et al., 1987; USAIB, 1986). Marksmanship simulator performance, measured in terms of both movement before the shot and accuracy, did not differ significantly as a function of recoil. As expected, recoil was associated with significantly greater movement after the shot, due to the introduction of rifle movement by the recoil mechanism itself.

Results of the present investigation also offer additional evidence of the validity of MACS performance measures. These results are particularly consistent with the results of an earlier MACS investigation conducted by Schroeder and Thomas (cited in Evans, 1988). Both investigations found greater rifle movement in an unsupported firing position, relative to a supported position, and both found that experienced firers exhibited a lower amount of rifle movement than inexperienced firers. Further, the present investigation found a substantial relationship between measures of rifle movement and accuracy. Not surprisingly, more movement was associated with greater error in accuracy. Additional evidence of the validity of MACS performance measures comes from the finding that the measure of rifle movement after the shot was highly sensitive to the presence of recoil-induced motion after firing, as previously noted.

The present findings suggest it would not be worthwhile to add a recoil mechanism to the MACS system when it is used in conjunction with some live-fire training. Not only would the cost of the recoil mechanism increase the cost of the simulator substantially, but it is also doubtful that the addition of recoil would lead to greater training effectiveness for two reasons. First, MACS performance in the present investigation, in terms of both movement before the shot and accuracy, did not differ as a function of recoil. Thus, it is doubtful that simulation with recoil would have greater transfer to live firing than simulation without recoil. This notion is consistent with the findings of Torre et al. (1987) that marksmanship performance did not differ as a function of noise and recoil, either on a simulator or in subsequent live firing. Second, the results of research in classical conditioning suggest the presentation of simulated recoil after every shot actually could be less

effective in eliminating anticipatory errors than the total absence of simulated recoil, because it fails to decrease the overall probability of the UCS during the CS (Rescorla, 1988). If a recoil mechanism were added to the MACS system, however, then it is recommended the mechanism be capable of delivering recoil on a random or unpredictable schedule controlled either by the microcomputer or the instructor. Unfortunately, the recoil mechanism in the present investigation did not have this capability. Whether random recoil is more effective than no recoil at all in rifle marksmanship simulation is a matter for future research.

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