# Realism and Effectiveness of Robotic Moving Targets

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## ABSTRACT

For the vast majority of U.S. Army Soldiers, the first opportunity to engage a realistic moving target with small arms is in combat. Even Infantry Soldiers and special-skill Soldiers (e.g., Snipers) have very limited opportunities to train realistic moving-target engagements. Current capabilities are limited to targets fixed to rail systems or silhouette targets mounted on pickets that can be walked by Soldiers in a firing-range target pit. Without the opportunity to practice engaging realistic moving targets, the Soldier is not able to develop the correct perceptual and motor tuning to adequately engage live moving targets. One solution for the lack of moving target training capabilities is the use of robotic human-type targets (RHTTs). RHTTs can present a realistic three-dimensional human-sized target that can freely move with semi-autonomous control. Furthermore, RHTTs can be programmed to react to events (e.g., flee after another RHTT is hit) and to move in groups in order to provide more complex training scenarios. Even though RHTTs provide a significant increase in training capability, the realism of the RHTTs will ultimately determine the training effectiveness of the capability. In a sense, the training effectiveness question is a matter of human-robot interaction. RHTTs are designed to emulate human beings moving over terrain, moving in a defined area, and reacting to scenario events. If the RHTTs are perceived as freely moving and acting humans, then training can be optimized. Perceptions of realism, shooting performance metrics, and training capabilities inventories were collected from Soldiers training with one type of RHTT to determine the level of target realism. Overall, the RHTT was determined to provide a realistic representation of human targets. However, several factors detracted from realism in certain scenarios. Both the factors that contributed to and the factors that detracted from realism provide insights for developing more effective RHTTs.

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## INTRODUCTION

For many U.S. Army Soldiers, the first opportunity to engage a realistic moving target with small arms is in combat. Even Infantry Soldiers and special-skill Soldiers (e.g., Snipers) have very limited opportunities to train realistic moving-target engagements. This training need reflects not just a limitation in training time, but also limitations in the training systems available. Without the opportunity to practice engaging realistic moving targets, the Soldier is not able to develop the correct perceptual and motor tuning to adequately engage live moving targets. The overall goal of the current research effort was to determine if new robotic target technologies could provide opportunities to increase moving-target skill.

### Moving Target Systems

Currently, there are three systems available to the Army that provide Soldiers the opportunity to engage moving targets during small arms live-fire training: small arms moving target ranges; moving individual targets and target sleds; and "Walking Targets." Small arms moving target ranges consist of E-type[1] targets fixed to automated target lifters. The lifters are mounted on a rail system that moves the targets bi-directionally at varying speeds. Target scenarios are programmed into a computer that controls exposure, movement, and automatically resets the targets after each engagement. A second system, moving individual targets and target sleds, consists of E-type targets attached to a wooden sled or large balloons hanging from a pulley on an angled cable. Target movement is provided by human or mechanical power, or, in the case of the balloon targets, gravity, and targets have to be manually reset after each engagement. Target speed varies based on human or mechanical strength, or angle of the cable. The last system, walking targets, consists of E-type targets attached to wooden pickets and walked back and forth in the target pits by Soldiers. Speed and distance vary based on movement by the Soldiers. When a walking target is hit, the location of the hit is marked so the Soldiers can see the location of their shots.

These current moving target systems are limited in terms of realism and effectiveness. For example, the current systems are limited in the speed and directionality of movement. Movement is limited to bi-directional, left to right movement and speed typically maxes out around 5 mph. Targets are also presented at a fixed distance from the firing position. Current targets present a 2-dimensional view (i.e., frontal or standard side view) and cannot be used to simulate a target that is oblique or that presents varied exposures.

Robotic Human Type Targets (RHTTs) address many of the limitations of current moving target training systems. RHTTs are more similar in size, shape (3-dimensional), and height to the human body than E-type targets. Similarly, RHTT movement better replicates human movement than current Army systems in that changes in speed (i.e. walking speed to jogging or running speed) and changes of direction in response to obstacles or in reaction to events are possible. Feedback is immediate. If hit, the target stops moving and the torso falls backwards. The target can automatically reset or can be reset by the operator. Two hit sensors provide scalable accuracy training by discriminating between body shots and head/spine (i.e., vital) shots. Engagement scenarios are operator controlled or pre-programmed and can consist of single targets or groups of targets moving in specified directions or utilizing artificial intelligence and moving randomly. The RHTT system provides opportunities for basic to advanced skill acquisition. Table 1 summarizes the capabilities of each type of existing moving target system and the capabilities of RHTT.

[1] The E-type target is a green plastic standard U.S. Army personnel target that is 40 inches tall by 20 inches wide and used on the majority of live-fire small arms ranges.

**Table 1. Comparison of Moving Target Training System Capabilities**

| Current U.S. Army Systems | | | Demonstrated System |
|---|---|---|---|
| Small Arms Moving Target Ranges | Moving Individual Targets and Target Sleds | Walking Targets | Robotic Human Type Targets (RHTTs) |
| • Digital. | • Analog. | • Analog. | • Digital. |
| • Permanent infrastructure. | • Mobile, requires construction | • Infrastructure dependent, requires construction | • Mobile. |
| • Computer programmed | • Manually operated | • Manually operated | • Computer programmed |
| • Limited engagement scenarios. | • Restricted engagement scenarios. | • Restricted engagement scenarios. | • Unlimited engagement scenarios. |
| • Fixed target distance from firing position. | • Fixed target distance from firing position. | • Fixed target distance from firing positions. | • Variable target distance from firing position |
| • Bi-directional movement. | • Bi-directional movement. | • Bi-directional movement. | • Omni-directional movement |
| • Rail restricted movement. | • Terrain, Human, Mechanical restricted movement. | • Infrastructure restricted movement. | • Terrain restricted movement. |
| • Variable movement speeds. | • Limited movement speed. | • Limited movement speed. | • Variable movement speeds. |
| • 2-D targets. | • 2-D targets. | • 2-D targets. | • 3-D targets. |
| • Non-discriminatory hit sensors. | • No hit sensors. | • Human hit sensor. | • Discriminatory hit sensors. |
| • Immediate feedback if hit. | • Limited feedback if hit. | • Immediate feedback if hit. | • Immediate feedback if hit. |
| • Basic to Intermediate skills training. | • Basic skills training. | • Basic skills training. | • Basic to Advanced skills training. |

**Robotic Human Type Targets**

The RHTTs used for this research were Marathon® Smart Targets (www.marathon-targets.com). The targets present a three-dimensional human torso on an all-wheel drive steel-plated mobile base. The torso is made of self-healing plastic that can receive 1000+ rounds before being replaced. Hits are recorded by acoustic baffles in the torso, and there are separate baffles for "vital" areas (i.e., head, heart, and lungs) and peripheral areas. "Kills" can be pre-programed to require some combination of multiple hits or vital hits. The torso lowers after a "kill" to provide feedback. The torso can be dressed or equipped to represent enemy personnel or friendly personnel without impeding hit detection or feedback.


**Figure 1. Robotic Human Type Target**

The Smart Target mobile base is driven by four foam-filled tires, which can withstand multiple shots. The armor plates can withstand 5.56 mm, 7.62 mm, and .338 cal. ammunition. The mobile base uses a combination of laser sensing, global-positioning satellite, and wireless signal to navigate the terrain. The target can be preprogrammed to follow a given scenario or be manually controlled. The targets can communicate with others nearby, which means they can independently move, can move as a group, or can "react" to actions on other targets (e.g., seek cover once one target in a group is hit). The mobile base can also play sound to add realism to the training scenario, although sound was not used in the current research.

### Research Objectives

Even though RHTTs provide a significant increase in training capability, the realism of the RHTTs will ultimately determine the training effectiveness of the capability. In a sense, the training effectiveness question is a matter of human-robot interaction. RHTTs are designed to emulate human beings moving over terrain, moving in a defined area, and reacting to scenario events. If the RHTTs are perceived as freely moving and acting humans, then training can be optimized. Perceptions of realism, shooting performance metrics, and training capabilities inventories were collected from Soldiers training with one type of RHTT to determine the level of target realism.

Data was collected during four live-fire exercises that differed in Soldiers' level of marksmanship experience and in the complexity of engagements trained. Soldiers' marksmanship varied from experienced Army Sniper Teams to Army Sniper School students to line Soldiers from an Operational Unit. The engagements varied on several dimensions, including the number of moving targets, the speed of moving targets, the presence or absence of "friendly" targets, direction of movement, and range. For each exercise, performance data was collected (i.e., number of hits and misses) as well as Soldiers' perceptions on several aspects of the RHTT technology. Performance data is presented here to highlight the difficulty of moving-target engagements and the impact of RHTT on improving moving-target engagement skill. The Soldiers' perceptions of the RHTT technology provided the assessment of training realism.

## METHOD

There were four research groups that provided data. Each group varied on the level of Soldiers' marksmanship experience and on the type of moving-target scenarios trained. The general procedure for each group was similar, however. Before beginning training, participants completed a brief background information questionnaire that addressed their deployment experience and recent marksmanship training (e.g., "When was the last time you engaged moving targets in training in the last 12 months?"). Soldiers were then trained in multiple engagement scenarios, which varied by group. Performance data was collected for each training scenario.

After completing the training scenarios, participants completed a user survey. The user survey asked about the realism and challenge of the RHTT technology and RHTT training (e.g., "Training with RHTTs provided sufficiently realistic conditions in which to train moving target") as well as the usefulness of RHTTs for various aspects of training (e.g., "RHTT allowed training that is not now or not easily conducted in marksmanship training"). Soldiers were also asked open-ended questions about the strengths and weaknesses of the RHTTs. The following describes each group and the important procedural details of each group's training and data collection.

### Experienced Sniper Teams

Participants were five sniper/spotter teams with an average of 9 years in service (range: 3-16 years). Three of these teams were instructors at the U.S. Army Sniper School, 1 team represented the Army Marksmanship Unit, and 1 team represented an operational unit. Seventy percent of the Experienced Snipers had deployment experience and these Soldiers had been deployed between 0 and 13 times. The background questionnaire revealed that 73% of the Sniper participants had engaged in long-range target shooting within the last month. Though almost half (46%) of participants had not engaged a moving target in training within the last 12 months, 55% indicated engaging moving targets in combat.

The training for Experienced Snipers consisted of a three-day course of fire. On the first day, all Soldiers shot a baseline scenario of 10 targets moving laterally right and left (i.e., 5 targets moving right and 5 targets moving left) at each distance of 200 m, 400 m, and 680 m. During the rest of the first day and all of the second day, Experienced Snipers engaged targets in complex scenarios that involved multiple targets, civilians on the battlefield, target identification, and alternate firing positions. At the beginning of the third day, Experienced Snipers again shot laterally moving targets at 200 m, 400 m, and 680 m (i.e., a record fire). These Soldiers also completed a Target Engagement Confidence questionnaire before training and again after training. Shooter confidence can be used as a metric of training effectiveness (U.S. Army Asymmetric Warfare Group, 2010).

**Operational Unit Soldiers**

One squad (i.e., 9 soldiers) from a Heavy Brigade Combat team along with two drill sergeants and two privates from Infantry one-station unit training with an average of 3.75 years in service (range: <1-13 years) participated in RHTTs training. Six participants had been previously deployed with a maximum of four deployments. Only two participants from the Operational Unit had taken an advanced marksmanship course. The majority (70%) of participants in this group had not trained on moving targets in the past six months. These Soldiers had less experience and training on average than any of the other groups.

As with the Experienced Snipers, the Operational Unit participated in three days of training and initially shot a baseline scenario of laterally moving targets. The Operational Unit shot laterally moving targets at only 200 m and 400 m. The Operational Unit received additional training on laterally moving targets on the first day and the second day and engaged in complex scenarios and alternate position firing on the third day. Like the Experienced Snipers, the Operational Unit again shot the laterally-moving scenario at the beginning of the third day and also completed the Engagement Confidence questionnaire before training and again after training.

**Sniper School Students**

Data was collected from 26 students in the Army Sniper School who averaged 4.11 years of service (range: 1.5-12.42 years) and 1.03 deployments (range: 0 to 7, 46.43% had never been deployed, 17.86% had been deployed 2 or more times) with 28.57% of Soldiers deployed in 2013 or 2014. Over half of Soldiers (53.57%) had not engaged moving targets in training in the past 12 months, while 46.67% of Soldiers with past deployments reported engaging moving targets in combat.

Sniper School training provided an opportunity to compare RHTT training with walking target training. As part of the Army Sniper Course, there are moving-target record fires with two weapon systems. Students were split into two groups across the two moving-target record fires. One group used RHTTs for training and record fire while the other group used walking targets for one weapon system. The groups switched targets for training and record fire for the other weapon system. The record fire included laterally moving targets at 300 m, 400 m, 500 m, and 600 m. Shooting performance was compared between RHTT training and walking target training, though it should be noted that order of target type was confounded with weapon system.

**Individual Snipers**

Data was collected from 33 Snipers who averaged 4.67 years of service (range: 1-14 years) and 1.9 deployments (range: 0-6, 34.3% had never been deployed, 42.9% had been deployed two or more times). Almost half (42.9%) of Soldiers were last deployed in 2013 or 2014. More than half (51.4%) of the Soldiers indicated that they had not engaged moving targets in training in the last 12 months. Only 11.4% of Soldiers reported engaging moving targets during training more than once or twice in the last 12 months. Close to half (44.4%) of Soldiers who had been deployed reported engaging moving targets in combat. This group included Army Sniper School instructors and sniper-qualified Soldiers on assignment at Fort Benning, GA. Generally, individuals in this group shot as single shooters and not as a sniper team.

The Individual Snipers participated in various capabilities demonstration exercises. The course of fire varied within this group, but all Individual Snipers shot laterally-moving engagements and complex scenarios with multiple targets and civilians on the battlefield. There was no specific record fire for Individual Snipers as there was for the other research groups. However, detailed round counts were available for the Individual Snipers.

## RESULTS

### Shooting Performance

The proportion of target hits were compared across baseline and record fire for Experienced Snipers and the Operational Unit. The proportion of target hits increased ($t$[22] = 2.79, $SE_{diff}$ = .05, $p$ = .01) from baseline ($M$ = .36, $SE_m$ = .03) to record fire ($M$ = .49, $SE_m$ = .04), which suggested a benefit for training with RHTTs (see Figure 2). However, because there was no comparison condition for the Experienced Snipers and the Operational Unit, it was not possible to determine if the increase in shooting performance was due to the RHTTs or to a simple practice effect. The issue of a comparison condition was addressed with the Sniper School data.

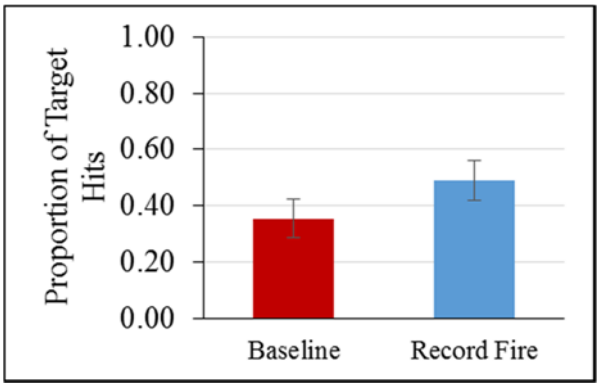


**Figure 2. Shooting Performance for Experienced Snipers and Operational Unit. Error Bars = 95% CI**

Experienced Snipers and Operational Unit Soldiers also rated their confidence in their ability to hit moving targets before RHTT training and after RHTT training. While the level of confidence could be informational, the more important metric was whether confidence levels changed after RHTT training. Confidence levels should change in response to perceived task difficulty, to changes in expectations of task performance, and to monitoring of task performance (Dunlosky & Rawson, 2012; Schraw, 1996). As a result, changes in confidence ratings reflect the level of perceived training challenge or effectiveness. The confidence ratings for all Experienced Snipers and Operational Unit Soldiers changed from before training to after training (45% increased confidence and 55% decreased confidence).

Sniper School Students practiced and shot record fire on both RHTTs and walking targets. Thus, a comparison of the proportion of hits on record fires was made between students who trained on RHTTs first and then trained on walking targets and students who trained on walking targets first and then trained on RHTT. If RHTTs have a training advantage over other moving target systems (i.e., walking targets), then the initial RHTT training should generalize to walking-target performance and no such generalization should occur for initial walking-target training on RHTT performance. In fact, that was the case. Students who initially trained with RHTTs increased the proportion of hits on record fire when firing at walking targets, but students who initially trained on walking targets did not increase proportion of hits when firing at RHTTs ($F$[1, 24] = 37.01, $MSE$ = 6.83, $p$ < 1). Figure 3 shows the proportion of hits on each record fire grouped by each sub-group of Sniper School Students. The left-hand set of bars show the proportion of hits for students who initially trained and shot record fire using RHTT, and the right-hand set of bars show the proportion of hits for students who initially trained and shot record fire using walking targets.

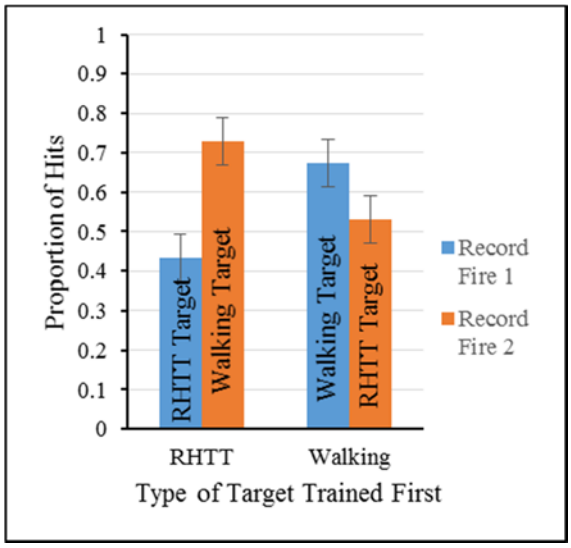


**Figure 3. Sniper School Students Moving-Target Record Fire. Error Bars = 95% CI.**

It can be noted that, overall, the proportion of hits on RHTTs (mean = .48, $SE_m$ = .02) was lower ($t$[25] = -3.94, $SE_{diff}$ = .04) than the proportion of hits on walking targets (mean = .64, $SE_m$ = .03). As argued, this difference may be primarily due to the difference in training effectiveness of the two target systems. That is, the increase in the proportion of hits on walking targets for Sniper Students who first trained on RHTT was due to the training value of RHTT. It may also be the case that the RHTT is simply more difficult to hit. While walking targets are always going to move in a straight line at a mostly constant speed, RHTT will slightly vary direction of travel and straight-line speed as they follow

terrain and avoid small obstacles. This variation may make the RHTT more difficult to hit, but it can also be argued that this variation (and difficulty) is also more realistic. Moving (actual) human targets will vary pace and direction over uneven terrain and around obstacles. Soldiers recently returning from deployment have reported difficulty in engaging moving targets (Dyer, 2015). The difficulty hitting RHTT was supported by the performance data from Individual Snipers.

Individual Snipers fired 1811 rounds at RHTTs across the various capabilities-demonstration events. Individual Snipers hit 72% of the targets presented, but only hit targets with 21% of rounds fired. In other words, of the 1811 rounds fired at RHTTs, only 388 hits on targets were recorded. This shooting efficiency (i.e, 21%) was not impressive given the level of experience of the shooters. The low shooting efficiency also mirrored the low shooting performance seen in Figures 2 & 3 (i.e., no proportion of hits on RHTT significantly above .50). So, if, in fact, engaging moving targets in combat is difficult, that difficulty (and realism) is reflected in overall performance on RHTT engagements.

**Soldier Perceptions of RHTT Realism and Effectiveness**

Overall, Soldiers tended to agree or strongly agree that the RHTTs could train a variety of skills (i.e., training utility), help improve skills, and provide realistic training (see Figure 4). Soldiers also considered RHTTs appropriate for most training environments, though feedback was mixed on the appropriateness of RHTTs for Initial Entry Training (BCT/OSUT, see Figure 5).

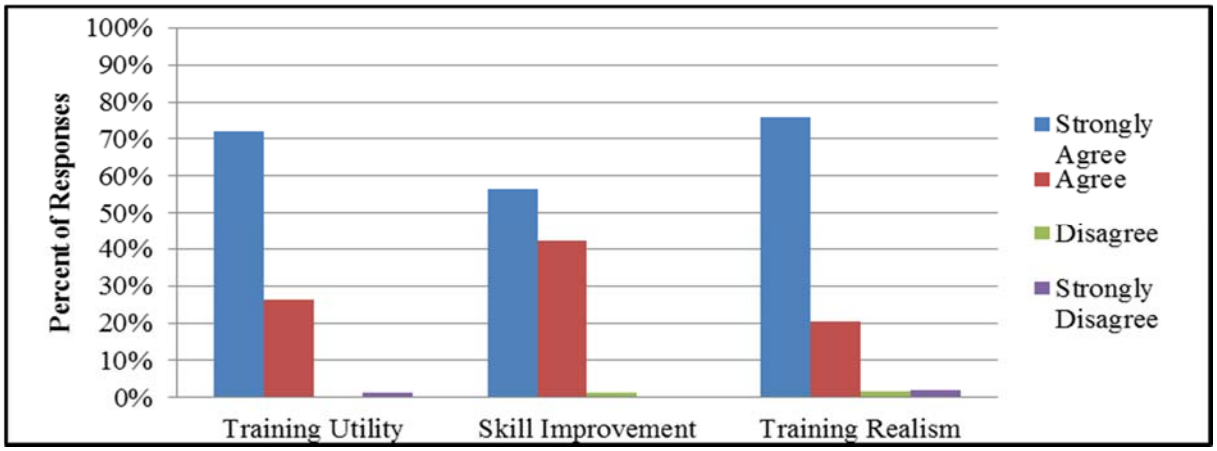


**Figure 4. Percent of Responses for Item Categories on User Survey Items**

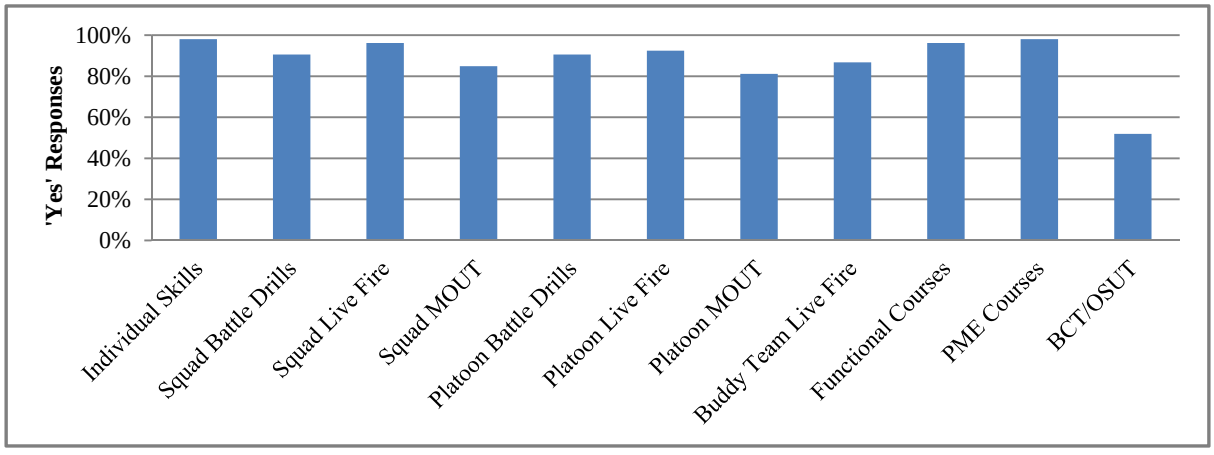


**Figure 5. RHTT Appropriateness for Training Environment**

In addition to questionnaire responses, Soldiers supported the realism and utility with free-response comments. When asked to identify the most useful part of RHTT training, most of the answers centered on the movement of the RHTTs. Movement variability, speed, direction, and realism were all praised. Soldiers also identified the realism and variety of scenarios, the realism of the targets, the usefulness of the feedback and the overall realism of the training. When asked what they like least about the RHTT training, Soldiers had fewer comments overall. The most common response was the need for more specific feedback about where the target was hit. This response was common particularly among Sniper School students who received more specific feedback when engaging walking targets or when using a Location of Misses and Hits range. Soldiers also noted that movement over rough terrain was not as good and that bad weather affected the Wi-Fi sensors. When asked what improvements they would like to see made to the RHTTs, the most common response was more precise feedback on where the target was hit. There were also some concerns about movement over rough terrains and use of RHTTs at night.

## DISCUSSION

The findings present a broad sample of information about RHTT training realism and training effectiveness. While no single finding was in itself compelling, the sum of the findings converge on the conclusion that RHTT provided challenging and realistic training that improved moving-target engagement skill. Experienced Snipers and Operational Unit Soldiers significantly increased their proportions of moving targets hits after training with RHTT. Likewise, Sniper School Students who initially trained moving-target engagements with RHTT significantly increased their proportions of moving targets hits. The fact that these groups with varying levels of shooting experience were able to improve their performance after practice engaging RHTTs suggests that even experienced shooters can benefit from the opportunity to engage realistic moving targets. Soldiers' perceptions of the RHTT training also indicated that RHTTs had training utility, helped improve performance, and provided training realism. RHTTs were also positively perceived for their ability to provide the Army with significant "bang for their buck." Generally, the movement of the RHTTs was praised along with the realism of the training, and several Soldiers mentioned that the RHTTs provided more realistic training. Soldiers did see ways to improve the RHTTs including specific feedback on hit location and smoother movement over rough terrain.

Another salient finding was that overall ability to hit realistic moving targets was quite low. The proportion of hits on RHTTs for all Soldiers shooting scored events was only about 50%. In addition, Soldiers shooting complex scenarios (i.e., Individual Snipers) hit RHTTs with only 21% of the rounds fired. These metrics do not compare to the performance on traditional walking targets. The overall proportion of hits on walking targets by Sniper School Students was over 62%. The difficulty hitting RHTTs reflects the reported inability to accurately engage moving targets in combat (Dyer, 2015; Ehrhart, 2009). Obviously, moving-target engagements require more skill than static-target engagements. Part of the difficulty engaging moving targets is due to the unpredictability of target location due to natural movement of humans (Scholl & Tremoulet, 2000), and part of the difficulty is due to the fact that no engagement technique is effective at all target distances for all shooters (Schendel & Johnston, 1982). Because engaging moving targets represents a human-performance challenge, training must reflect the realities of the challenge, i.e., natural movement in multiple directions and the ability to "react" to the situation. The capability for RHTT to provide such training was evident in Soldiers' reports of their skill confidence. All Soldiers reported a change in confidence after engaging the RHTTs. This suggested that Soldiers were recalibrating their perceptions of their abilities in response to their performance with more realistic moving targets.

As with any training system, the goal of moving-target systems should be to provide trainees an immersive experience in which to practice and improve skills (Knerr, et al., 1998). In the case of RHTT, immersion will only be possible if shooters believe they are engaging human targets and not robots. While the findings reported here suggested that RHTT provided more realistic training than traditional moving-target systems (e.g., walking targets), there were no direct comparisons of RHTT to actual human targets. It can be inferred that Soldiers' perceptions of realism provided an indicator of immersion. It can also be postulated that perceptions of realism indicated how *life-like* the RHTTs were. This subtlety in inference reflects the extent to which Soldiers believed they were engaging human targets vice robot targets. As robotic technology becomes increasingly incorporated into training systems, additional consideration must be given to the level of human-robot interaction (Goodrich & Schultz, 2007) and to metrics of human-robot interaction (Steinfield, et al., 2006).

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