**CRESST REPORT 754**

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# AN EXPLORATORY INVESTIGATION OF THE EFFECT OF INDIVIDUALIZED COMPUTER-BASED INSTRUCTION ON RIFLE MARKSMANSHIP PERFORMANCE AND SKILL

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**National Center for Research on Evaluation, Standards, and Student Testing**

Graduate School of Education & Information Studies
UCLA | University of California, Los Angeles

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# AN EXPLORATORY INVESTIGATION OF THE EFFECT OF INDIVIDUALIZED COMPUTER-BASED INSTRUCTION ON RIFLE MARKSMANSHIP PERFORMANCE AND SKILL [1]

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## Abstract

In this report, researchers examined whether individualized multimedia-based instruction would influence the development of rifle marksmanship skills in novice shooters with little or no prior rifle marksmanship experience. Forty-eight novice shooters used an M4 rifle training simulator system to shoot at an 8-inch target at a simulated distance of 200 yards. Participants received either (a) no instruction, (b) only an overview of rifle marksmanship, or (c) an overview and instruction targeted at particular skill gaps. Support was found for the idea that multimedia-based instruction can be highly effective for novices, with a large increase in shooting performance observed after 10 to 15 minutes of multimedia instruction. Subsequent individualized instruction using very short multimedia instruction appeared to be effective in shaping participants' skills toward an "ideal" state consistent with shooting doctrine.

## Introduction

In rifle marksmanship, accurately and consistently hitting an 8-inch circular area at 200 yards involves a complex interaction of physical and mental processes immediately before, during, and immediately after the weapon fires. Effective shooting is the simultaneous coordination between breathing; gross-motor control of positioning the hands, elbows, legs, feet, and cheek; fine-motor control of the trigger finger with respect to the trigger; and the processing of perceptual cues related to the target, the front sight, and the rear sight. The coordination is intended to minimize muzzle movement by controlling body movement.

Chung, Delacruz, de Vries, Bewley, and Baker (2006) reviewed the research on rifle marksmanship and called for more attention to the cognitive dimension underlying rifle

[1] We would like to thank Jesse Elmore of UCLA/CRESST for serving as our subject-matter expert and for providing the instruction shown in the videos. We also wish to thank Joanne Michiuye of UCLA/CRESST for her help with the preparation of this manuscript and with data collection.

marksmanship research. In their review, Chung et al. (2006) concluded that marksmanship research lacked a theoretical framework for understanding how marksmanship skill developed. Chung et al. proposed that rifle marksmanship comprised cognitive, psychomotor, affective, environment, and ballistics dimensions, of which the latter two were essentially uncontrollable. In a companion report, Chung, Nagashima, Espinosa, Berka, and Baker (2009, CRESST Tech. Rep. No. 753) found evidence that rifle marksmanship performance follows the skill development framework. In addition, the authors found differential influence of cognitive, psychomotor, and affective variables by different phases, as predicted by Ackerman's skill development theory (1988, 1992). The influence of the cognitive components of marksmanship—knowledge of shooting and scientific reasoning—was highly correlated to performance during the learning phase but not the practice phase for novices, and there was no correlation between knowledge of rifle marksmanship and performance for experts.

Curiously, Chung et al. (2009) did not find performance differences between instructional treatments, but did find evidence that instruction appeared to have a large impact on performance when performance was measured before and after a brief computer-based video introduction on rifle marksmanship. However, their design lacked a no-instruction and a minimal-instruction condition and thus the extent to which change in performance was due to instruction or practice effects could not be determined. In this study we gathered additional data (a no-instruction condition, a minimal instruction condition) and reanalyzed the data. We also elaborate on the instructional methods we used and focus specifically on the link between instruction and the development of novices' rifle marksmanship skills.

## Designing Instruction for Efficient Learning

The design of the multimedia instruction used in this study was based on the assumption that for instruction to be maximally effective, particularly when brief, the instructional design should incorporate the features known to promote learning. We drew extensively on the work related to multimedia learning and cognitive load and feedback (e.g., Black, Harrison, Lee, Marshall, & Wiliam, 2003; Chandler & Sweller, 1991; Kluger & DeNisi, 1996; Mayer, 2001, 2005b; Sweller, van Merriënboer, & Paas, 1998). Our goal was to implement in instruction the features with strong empirical evidence of effectiveness to deliver extremely efficient instruction targeted to low-knowledge learners.

**Conceptual instruction**. There were two broad instructional design objectives for the study. The first objective addressed the overall structure of the instruction—how should the to-be-learned information be structured to facilitate understanding of content that is unfamiliar to learners? We addressed this objective by providing instruction that conveyed both the concepts and procedures of the underlying skill. The desired learning outcome was for participants to understand the relation among the important concepts in rifle marksmanship—breath control, trigger control, aiming, and stability of position. Within each topic, instruction was chunked into three areas: what (i.e., the concept), how (i.e., the procedure), and why (i.e., an explanation of the importance of the particular concept or procedure).

**Multimedia-based instruction**. The second instructional design objective addressed the delivery of the instruction—what techniques could be used to facilitate the communication of the content? We focused on techniques that specifically addressed limitations of human cognition (e.g., limited working memory capacity), that exploited human sensory channels (visual, auditory), that would be appropriate for marksmanship, and that were within the capabilities of the available technology. We adopted many of the guidelines derived from research on multimedia instruction and cognitive load (e.g., Clark, Nguyen, & Sweller, 2006; Mayer, 2001, 2005a). In addition, we incorporated features found to promote motor learning (Ashford, Bennett, & Davids, 2006; Wulf & Shea, 2002). Figure 1 shows a screen shot of the user interface.

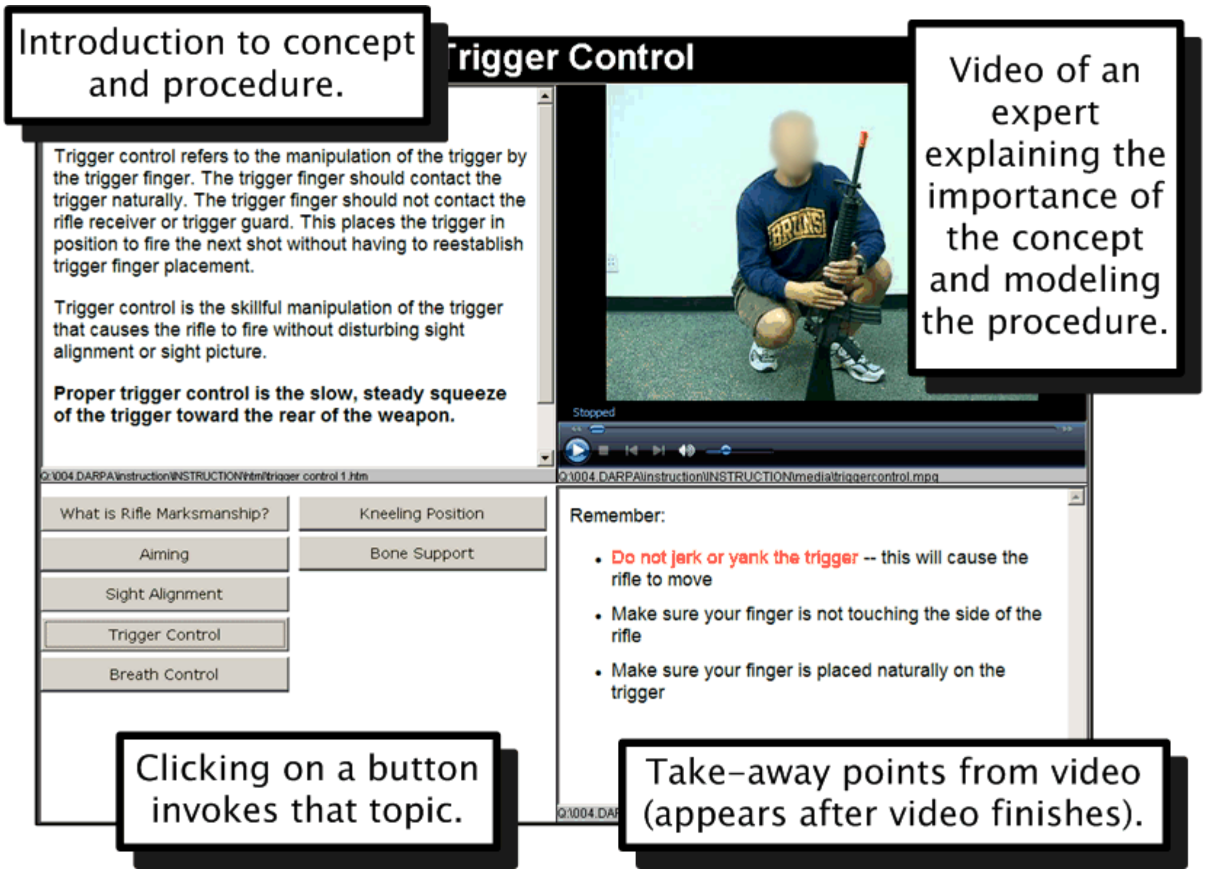


*Figure 1.* Initial instruction on marksmanship. Clicking on the button in the lower left panel invokes relevant text and video. The typical flow through the user interface was to first select the topic (lower left panel), read the introduction to the topic (upper left panel), view the video (upper right panel), and review the summary (lower right panel).

**Individualizing instruction.** Presumably, an effective way to train a novice to become a skilled shooter in as short a period as possible is one-on-one coaching. However, one-on-one training is time and labor intensive, expensive, and not feasible in environments where there are large numbers of people who need to be trained quickly. Recently, there has been renewed interest in the idea of individualized instruction, driven in part by advances in technology (e.g., Advanced Distributed Learning [ADL], 2006; IEEE Learning Technology Standards Committee [LTSC], 2006), advances in assessment (e.g., National Research Council [NRC], 2001; Williamson, Behar, & Mislevy, 2006), and a persistent desire to increase the access, efficiency, and cost effectiveness of training and education (e.g., Fletcher, Tobias, & Wisher, 2006). Our approach to individualized instruction in this report was to mimic what would be possible in an automated system. Our long-term goal is to develop an automated system that would support real-time feedback and instruction.

We operationalized individualized instruction as providing remedial instruction on topics that participants were diagnosed as having problems with. In addition, feedback was provided to participants and included (a) knowledge of results (whether the student got the problem correct or incorrect), and (b) explanatory feedback that provided guidance to learners on what they should focus on to fix the problem. These two techniques have been found to be effective feedback methods, particularly for learners with low knowledge of the domain (e.g., Azevedo & Bernard, 1995; Bangert-Drowns, Kulick, & Morgan, 1991; Black et al., 2003; Kluger & DeNisi, 1996). The general timing of the feedback was based on findings from Kester, Kirschner, and van Merriënboer (2005), who found that procedural information presented prior to the practice task and explanatory feedback provided during the practice task led to the most efficient learning. In our case, we interleaved the feedback between blocks of trials so that procedural and explanatory feedback was both before and during the shooting. Figure 2 shows a screen shot of the user interface.

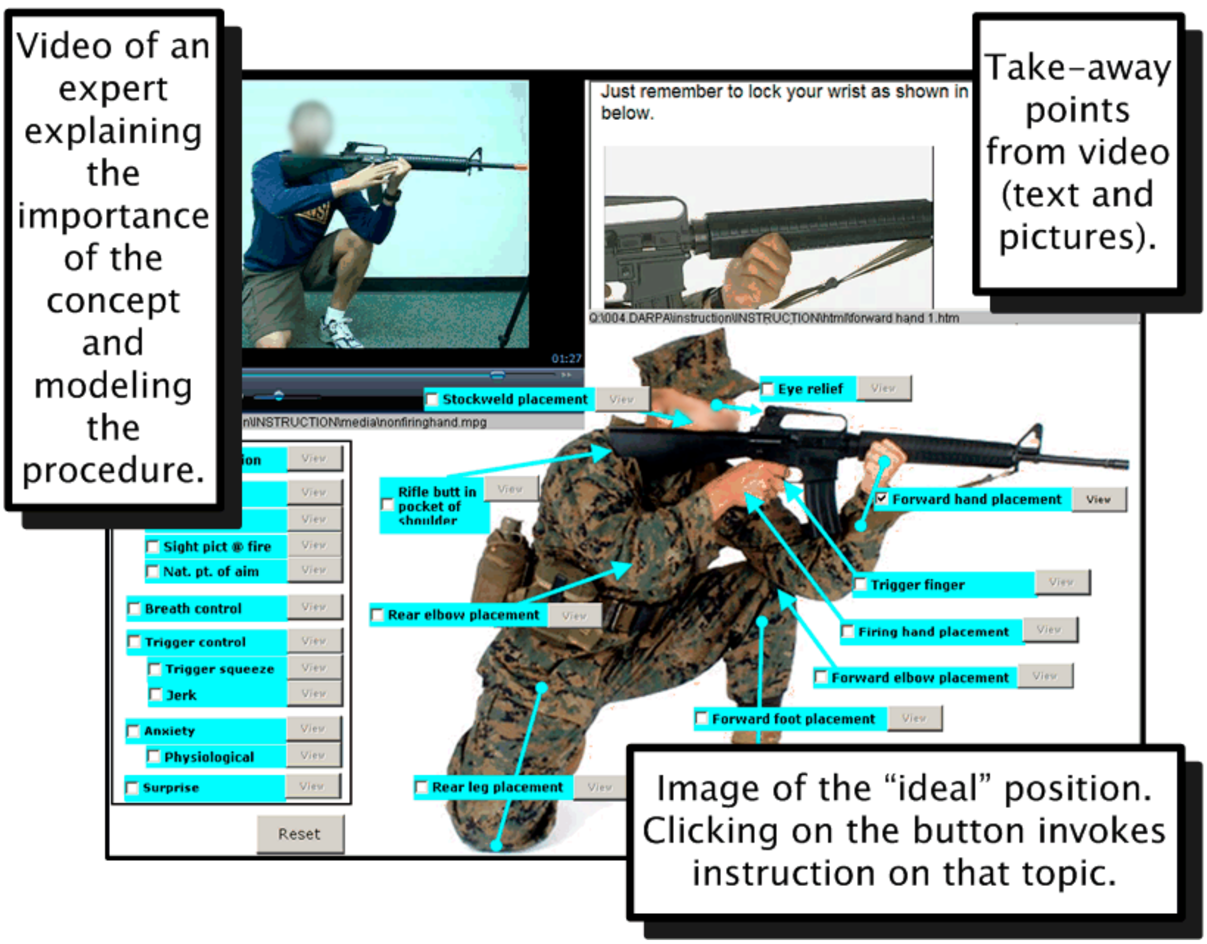


*Figure 2.* Position diagnostics and instruction. Clicking on an enabled button invokes related text and video. The researchers set the checkboxes to indicate what instruction was needed.

Thus, our overall instructional design strategy was pragmatic and focused on maximizing the chances of learning by incorporating instructional features that have been shown to be effective. Table 1 summarizes the design properties of the instruction and the research we based the property on.

Table 1

Summary of Instructional Design Features Adopted

| Instructional design property | Example implementation in instruction | Research base |
|---|---|---|
| Complementary sources of information—graphics and audio | We used an expert to explain the concept or procedure, while modeling the position, ensuring temporal integration. | Coherence principle: Learning is better when the same information is not presented in more than one format (Mayer, 2005c). Effect sizes in the range of 1.3.<br>Split attention principle: Materials should be physically and temporally integrated (Ayres & Sweller, 2005). |
| Learner-controlled pacing | We provided participant with the capability to self-pace through the instruction. | Segmenting principle: Learning is greater when a multimedia message is presented in user-paced segments rather than as a continuous unit (Mayer, 2005b). Effect sizes in the range of 1.0. |
| Visual annotations | Signaling was achieved in the video instruction through the subject matter expert's gesturing while explaining the concept or procedure. | Signaling principle: Learning is deeper from a multimedia message when cues are added that highlight the organization of the essential material (Mayer, 2005c). Effect sizes in the range of 0.6.<br>Temporal contiguity principle: Learning is deeper from a multimedia message when corresponding animation and narration are presented simultaneously rather than successively (Mayer, 2005c). Effect sizes in the range of 1.3. |
| Use of lay language, first and second person references, and use of domain-specific language | The subject matter expert was talking to the viewer using lay language. | Personalization principle: Learning is deeper when the words in a multimedia presentation are in conversational style rather than formal style (Mayer, 2005d). Effect sizes in the range of 1.3. |
| Target low-knowledge learners | We recruited novice shooters for the study. | Prior knowledge principle: Instructional strategies that help low-knowledge individuals may not help or may hinder high-knowledge learners (Mayer, 2001). Effect sizes in the range of 0.6. |
| Knowledge of results during practice<br>Explanatory feedback tailored to participants' shooting performance | We showed the participants their targets after every two shooting trials, and provided some participants feedback about their position, breath control, and trigger control. | Knowledge of results and explanatory feedback promote learning (Bangert-Drowns et al., 1991; Kluger & DeNisi, 1996). |

## Research Question

Our primary research question addressed Chung, Delacruz, et al.'s (2006) call to focus on the role of knowledge in rifle marksmanship research. In particular, we asked whether very brief multimedia-based instruction could remediate, via individualized computer-based instruction, shooter skill gaps on the fundamentals of rifle marksmanship: breath control, trigger control, and quality of position.

# Method

## Context of Current Report

This study was conducted as part of a larger study that focused on the development of neurophysiological measures to characterize expert and novice shooters and to be used in training and assessment tools. In this study, we focused on the subset of the sample that involved instructional interventions.

## Design

An interrupted time series design was used to test the effects of the instructional intervention. Four conditions were designed into the study to allow examination of the effect of two kinds of instructional treatment.

**No instruction.** Participants in this condition received no instruction. This condition represented the control condition against which the effects of instructional treatments could be compared to.

**Minimal instruction.** Participants in this condition received only minimal instruction—a brief 10- to 15-minute introduction to rifle marksmanship. This condition was used as a comparison group for the other individualized instruction conditions.

**Individualized instruction—without sensor.** Participants in this condition received the introduction to rifle marksmanship instruction as in the minimal instruction condition, and in addition, individualized instruction based solely on observation of what is currently available in training (i.e., the target and the shooter's position).

**Individualized instruction—with sensor.** Participants in this condition received the introduction to rifle marksmanship instruction as in the minimal instruction condition, and in addition, individualized instruction based on (a) observation of what is currently available in training (i.e., the target and the shooter's position), and in addition, (b) sensor plots of the shooter's breathing, trigger squeeze, muzzle wobble, and when the rifle fired.

The design contained two types of instructional treatments as summarized in Table 2. The first instructional treatment occurred after baseline Trial 2. Except for the no-instruction condition, all conditions were exposed to an introduction to rifle marksmanship. The second instructional treatment—individualized instruction—occurred between Trials 3–8 for both individualized instruction conditions. The treatment was providing a participant with multimedia instruction targeted to a specific skill gap identified during the preceding shooting trial. The difference between the two individualized instruction conditions was whether the sensor data were used—as feedback to the shooter and to help the coach diagnose breath and trigger control problems.

Table 2

Summary of Instructional Treatments and Feedback by Trial

| Condition | Baseline trials 1–2 | Between baseline and practice trials | Practice trials 3–8 |
|---|---|---|---|
| | | Instructional treatment 1 | Instructional treatment 2 |
| Instruction | None | Except for the no-instruction condition, all participants received a short multimedia introduction to rifle marksmanship. | Depending on the condition, participants were given individualized multimedia instruction targeted to specific skill gaps. |
| Feedback | None | None | Depending on the condition, participants received feedback about their shots and their position, and were shown sensor plots for their trigger and breath control. |

The design allowed us to examine whether the two types of instructional treatments had an effect on rifle marksmanship performance and skill. That is, we could test whether (a) the introductory instruction had an effect on performance and skill (no instruction vs. the other conditions at Trial 3); and (b) individualized instruction had an effect on performance and skill (no instruction and minimal instruction vs. instructional conditions 1 and 2 that had individualized instruction). The detailed design is shown in Table 3.

Table 3

Design

| | | Trial | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | $n$ | 1 | 2 | I | 3 | F | I | 4 | F | F | I | 5 | F | I | 6 | F | F | I | 7 | 8 |
| No instruction | 6 | o | o | – | o | – | – | o | – | $f_t$ | – | o | – | – | o | – | $f_t$ | – | o | o |
| Minimum instruction | 14 | o | o | $i_1$ | o | – | – | o | – | $f_t$ | – | o | – | – | o | – | $f_t$ | – | o | o |
| Individualized instruction 1 | 14 | o | o | $i_1$ | o | $f_p$ | $i_2$ | o | $f_p$ | $f_t$ | $i_2$ | o | $f_p$ | $i_2$ | o | $f_p$ | $f_t$ | $i_2$ | o | o |
| Individualized instruction 2 | 14 | o | o | $i_1$ | o | $f_{p,s}$ | $i_2$ | o | $f_{p,s}$ | $f_t$ | $i_2$ | o | $f_{p,s}$ | $i_2$ | o | $f_{p,s}$ | $f_t$ | $i_2$ | o | o |

*Note*. One trial comprises 5 shots. I = when an instructional intervention occurred. F = when feedback was given. o = observations taken during the shooting trial, including shot group precision, sensor-based measures, and ratings of position. $i_1$ = introduction to rifle marksmanship instruction. $i_2$= individualized instruction that was specific to each participant's problem areas. – = no instructional intervention. $f_t$ = feedback (target). $f_p$ = feedback to shooter about position elements. $f_{p,s}$ = feedback to shooter about position elements and breath and trigger control using the sensor data.

## Participants

We recruited additional participants to complement the Chung et al. (2009) sample. Our objective was to form a no-instruction condition and a minimum-instruction condition, and to balance the other conditions. Unfortunately, the rifle simulator equipment failed during data collection resulting in incomplete data. The resulting sample size, combining the data from Chung et al. and the current data collection, was 48 participants assigned to one of four conditions shown in Table 3.

The mean age of the sample was 22.0 years (*SD* = 3.0 years, range = 18 to 32) and in terms of gender, there were 36 males and 12 females. In terms of their highest prior rifle shooting experience, participants reported a range of experience—competed or coached (5), shot a real rifle (19), shot an airsoft or paintball rifle (9), or shot an arcade or arcade-like rifle (10). Four participants reported no experience at all with rifles. For participants with experience with a real rifle, they were included only if they reported having shot once or twice ever, or occasionally (i.e., less than a few times a year). Overall, the participants in the sample had some experience with rifles.

## Apparatus

An instrumented training weapon prototype was developed using off-the-shelf sensing components (Chung, Dionne, & Elmore, 2006; Espinosa, Nagashima, Chung, Parks, & Baker, 2009) attached to a commercial rifle training system (LaserShot, 2008). The rifle was of similar size and mass to an actual M4 rifle. The trainer weighed about 8 pounds and had a $CO_2$ gas system that simulated the recoil and report of the real M4 rifle. A circular target was projected onto a screen via an LCD projector and was scaled to reflect 200 yards. The center ring of the target was filled black and was 8 inches in diameter (at 0 feet). When the rifle fired, a laser beam (non-visible) was emitted. The strike of the laser beam on the projected target simulated the hit. An infrared camera detected the laser hit and software converted the strike location to coordinates on the target (scaled to 200 yards).

**Sensing apparatus.** The trainer rifle was instrumented with a force pressure sensor on the trigger to measure trigger pressure and a 3-axis accelerometer on the muzzle to measure wobble, and participants wore a respiration band that was used to measure participants' breathing. Data acquisition hardware and software were custom-built to process the sensor data. Espinosa et al. (2009) contains a detailed description of the sensing system.

**Tasks**

Participants performed three types of tasks: (a) completing various surveys of their perceptions, experience, and knowledge related to shooting; (b) shooting in the kneeling position; and (c) viewing multimedia instruction on different rifle marksmanship topics.

**Surveys.** Surveys were used to gather data on demographics and experience with marksmanship-related activities, and knowledge of rifle marksmanship.

**Known distance shooting task.** Each participant shot in the kneeling position. The basic task was for participants to fire five shots, which represented one trial. During this period the shooter was not interrupted and had as much time as she or he needed to complete the trial. Participants did not receive any assistance from the researchers or receive feedback about their shooting. The pacing of shots was not regulated.

A job aid was placed in front of the firing line for participants to reference as needed. The job aid showed pictures of a shooter in the ideal kneeling position. The figure was adopted from earlier validated work in marksmanship (Baker et al., 2004).

**Multimedia instruction.** Participants were given multimedia-based instruction on rifle marksmanship. Much of the content was video-based and showed an expert describing and explaining the concept with the aid of a whiteboard and a training rifle, and demonstrating the concept where appropriate. Supplementary text and pictures were also provided. The text introduced the concept and procedure, or summarized the main points.

Two types of instruction were provided. The first was a conceptual introduction to rifle marksmanship. Participants were introduced to the topics *What is rifle marksmanship?*, *aiming*, *sight alignment*, *trigger control*, *breath control*, *kneeling position*, and *bone support*. Table 4 shows the topics, video running time, and amount of words for the text-based content. The instruction was designed to be very brief and the video times ranged from 27 seconds to slightly over 2 minutes. The total running time of the videos was 6.5 minutes.

Table 4

Introduction to Rifle Marksmanship Instructional Content

| Topic | Video-based content (mm:ss) | Text-based content (no. of words) |
|---|---|---|
| What is rifle marksmanship? | none | 58 |
| Aiming | 0:46 | 0 |
| Sight alignment | 0:27 | 105 |
| Trigger control | 1:10 | 140 |
| Breath control | 2:15 | 127 |
| Kneeling position | 1:08 | 302 |
| Bone support | 0:37 | 81 |

*Note*. Total video time: 6:23. Total number of words: 813.

The second type of instruction was tied to particular errors committed during the shooting trial. The available instruction covered position (*stockweld placement, eye relief, forward hand placement, trigger finger placement, firing hand placement, forward elbow placement, rear leg placement, rear elbow placement, rifle butt in pocket of shoulder*) and conceptual topics (*kneeling position, aiming, aim point, sight picture at trigger break, breath control, natural point of aim, trigger control, trigger squeeze, trigger jerk, anxiety, physiological effects of anxiety, surprise*). Table 5 shows the topics, video running time, and amount of words for the text-based content. The instruction was designed to be very brief and the video times ranged from 44 seconds to slightly over 2 minutes.

Table 5

Targeted Instructional Content

| Topic | Video-based content (mm:ss) | Text-based content (no. of words) | Topic | Video-based content (mm:ss) | Text-based content (no. of words) |
|---|---|---|---|---|---|
| Kneeling position | 1:08 | 302 | Position related | | |
| Aiming | 0:45 | none | Stockweld placement | 0:53 | 166 |
| Aim point | 1:42 | 35 | Rifle butt placement | 0:56 | 135 |
| Sight picture | 1:44 | 18 | Eye relief | 1:38 | 119 |
| Natural point of aim | 2:21 | 92 | Forward hand placement | 1:39 | 19 |
| Breath control | 2:15 | 127 | Trigger finger placement | 1:03 | 41 |
| Trigger control | 1:10 | 99 | Firing hand placement | 2:10 | 90 |
| Trigger squeeze | 1:41 | 59 | Forward elbow placement | 0:52 | 19 |
| Trigger jerk | 1:05 | 18 | Forward foot placement | 0:07 | 44 |
| Anxiety | 1:38 | 19 | Rear foot placement | none | 76 |
| Anxiety and physiology | 1:45 | 36 | Rear elbow placement | 0:07 | none |
| Surprise | 0:44 | 29 | | | |

*Note*. Total video time: 27:23. Total number of words: 1543.

**Feedback.** Depending on the condition they were in, participants received different feedback. Table 6 shows the type of instruction and feedback each condition received.

Table 6

Types of Instruction and Feedback Provided to Participants by Condition

| | Type of instruction | | Type of feedback | | |
|---|---|---|---|---|---|
| Condition | Introduction to rifle marksmanship | Individual-ized | Knowledge of results | Quality of position | Trigger and breath control sensor plots |
| No instruction | | | • | | |
| Minimum instruction | • | • | • | | |
| Individualized instruction 1 | • | • | • | • | |
| Individualized instruction 2 | • | • | • | • | • |

**Feedback: Knowledge of results.** Participants were shown their hits on the target after every two trials (see Table 3 for the schedule). The display was adjusted such that the target center was always located as the center of the shot group. Participants were informed that the goal was to get their shots as close to each other as possible. All conditions received knowledge of results feedback.

**Feedback: Quality of position.** Feedback to participants about their position was provided in the form of a description of what aspect of their position was proper or improper, but not an explanation of why the position was proper or improper. The reasoning for not providing an explanation was to minimize the amount of one-on-one coaching and to standardize coaching across as many participants as possible. The explanatory information was provided in the instructional videos. Only participants in the two individualized instruction conditions received this type of feedback.

In rare cases, if a participant's position was extremely improper, then the participant was provided with limited coaching. Coaching was in the form of modeling the correct position, or pointing out to the participant (when the participant was in position) what exactly was improper.

**Feedback: Trigger and breath control sensor plots.** Participants in the individualized instruction (using sensor feedback) condition were shown their breathing and trigger control plots. The plots were displays of the raw sensor data plotted over time. The breath and trigger control signals were superimposed on the same display so participants could view the relation among the respiratory cycle, the trigger squeeze, and when the trigger broke.

Feedback was provided to the shooter that explained (a) how to interpret the plots; (b) what the ideal pattern was: firing during the natural respiratory pause; (c) what the particular participant's pattern meant; and (d) what the participant should focus on improving. In addition, the physiological sensing data were used by the coach to diagnose whether participants needed instruction on breath or trigger control.

## Measures

A variety of measures were used to examine shooting performance. Measures were adopted from our prior work (Chung et al., 2004), and new sensor-based measurements developed to more directly measure marksmanship skills (Chung, Dionne, et al., 2006; Nagashima, Chung, Espinosa, Berka, & Baker, 2009; Espinosa et al., 2009).

**Shot group precision.** Shot group precision reflects how well a shooter can *consistently* apply the fundamentals of rifle marksmanship. Such measures have been found to correlate with shooting performance (Taylor, Dyer, & Osborne, 1986). Johnson (2001) defined precision as dispersion of shots within a shot group ($D_{SG}$) as shown in Table 7. The units are in inches and the magnitude reflects hits on target at 200 yards. Higher values of

$D_{SG}$ indicate greater dispersion of shots within a trial and poorer performance. Espinosa et al. (2009) contains a more detailed description of this measure.

Table 7

Shot Group Precision Measures (modified from Johnson, 2001)

| Measure | Formula |
|---|---|
| Center of shot group, *x* component, $SG_x$ | $\frac{\sum_{i=1}^{N} x_i}{N}$ |
| Center of shot group, *y* component, $SG_y$ | $\frac{\sum_{i=1}^{N} y_i}{N}$ |
| Distance of each shot to the center of the shot group, $d_{SG}$ | $\sqrt{(x_i - SG_x)^2 + (y_i - SG_y)^2}$ |
| Mean distance of *N* shots to the center of the shot group, $D_{SG}$ | $\frac{\sum_{i=1}^{N} d_{SG_i}}{N}$ |

*Note.* $N$ = number of shots. $x_i$ and $y_i$ = location of *i*th shot.

**Quality of shot.** In a companion report, Nagashima et al. (2009, CRESST Tech. Rep. No. 755) developed a logistic regression model to classify a participant's shot as expert-like or novice-like. Nagashima et al. used marksmanship experts and a sample of novices (drawn from a subsample of participants used in this study) to train the classification model. The model used the skill measures of breath control, trigger control, and muzzle wobble during the first two trials of shooting.

**Trigger control.** Proper trigger control during slow fire is important because yanking the trigger will cause the weapon to sway laterally. Trigger control was operationalized as the duration of the shooter's trigger squeeze, with duration a measure of whether the shooter was slowly squeezing the trigger or rapidly pulling it. For each participant, raw sensor data from the trigger sensor were processed using custom-developed software (Espinosa et al., 2008) to yield the duration of the shooter's trigger squeeze. The units are in seconds. The higher the value of the duration of the trigger squeeze, the better the trigger control.

**Breath control.** Firing while breathing can cause rounds to disperse vertically on the target due to the muzzle being displaced as the lungs expand and contract during the breathing cycle. Breath control was operationalized by measuring the point in the respiratory cycle that the trigger broke. Firing during the natural respiratory pause is the correct procedure (USMC, 2001). The measure ranges from 0 (at the bottom of the respiration cycle) to 1.0 (the peak of the respiration cycle), with higher values indicating poorer performance. For each participant, raw sensor data from the respiratory sensor were processed using custom-developed software (Espinosa et al., 2009) to yield the location in the breathing cycle where the trigger broke.

**Position quality.** Ratings of the participant's position on whether various position elements were proper or improper were used to evaluate the quality of the participant's position. Ten position elements were rated as proper (score of 1) or improper (score of 0). A proper position element was one that was appropriate for the particular shooter, taking into account the shooter's body type and size. A position element could deviate from doctrine if it was judged to be adequate for the long-term maintenance of position stability. An improper position element was one that deviated from doctrine. The set of position elements rated were: *placement of forward hand, placement of firing hand, placement of trigger finger, rear elbow placement, forward elbow placement, eye relief, rifle butt in pocket of shoulder, forward foot placement, rear leg placement,* and *stockweld placement*.

Although 10 position elements were rated, only the 3 most frequently identified errors were used to form the position quality scale (*eye relief, rifle butt in pocket of shoulder, stockweld placement*, see Table 8). The measure was the sum of scores and the possible score range was 0 to 3, with higher scores indicating higher quality of position. The rubric was based on marksmanship instructional materials (USMC, 2001) and our prior work (Baker et al., 2004; Chung et al., 2004; Chung, Dionne, et al., 2006). Cronbach alphas for this measure, by trial, were .71, .60, .33, .53, .46, .34, .50, and .71 ($n$ = 48, 3 items).

**Basic rifle marksmanship knowledge.** We adopted this measure from our prior work with the armed forces. Significant correlations were found between scores on this measure and qualification scores ($r_{sp}$ = .3 to .5, Chung et al., 2004). Items were selected from this measure to correspond to the content of the training participants received. The maximum possible score was 23. Cronbach alpha for the pretest was .84 ($n$ = 48) and .76 ($n$ = 48) for the posttest.

**Background information.** Information was gathered about participants' demographics and experience related to shooting (e.g., prior shooting experience).

## Procedure

**Pretests**. A series of pretests were administered to gather information on a variety of aspects related to participants' background, including demographic information, shooting experience, and knowledge of rifle marksmanship. The pretest stage lasted about 45 minutes.

**Shooting, feedback, and remediation**. Participants were given a 3-minute demonstration on the kneeling position and shown the basics of how to use the rifle. Participants then shot two baseline trials of 5 shots each. Following the second trial, all participants received computer-based instruction on rifle marksmanship, which lasted between 10 and 15 minutes. Participants then returned to the firing line and fired six more trials. Participants were then given feedback about their performance as shown in Table 6. After each trial, participants in the instructional conditions were given individualized instruction based on problems identified during the trial. The instruction comprised up to four topics that included video (less than 2 minutes each) and text. See Table 5 for the list of concepts. The shooting and remediation stage lasted about 65 minutes.

**Posttest**. Participants were re-administered the basic knowledge of rifle marksmanship measure. Participants were paid and debriefed on the study, and thanked for their participation. The posttest stage lasted about 15 minutes.

## Results

The main research question of this report focused on whether very brief multimedia-based instruction could remediate, via individualized computer-based instruction, shooter skill gaps on the fundamentals of rifle marksmanship: breath control, trigger control, and quality of position.

### Preliminary Analysis

**Overall learning.** The first analysis was to examine whether participants learned from the task. Because of the small sample size in the no-instruction condition, we examined that condition separately from the other conditions. A nonparametric paired sample test was conducted (Wilcoxon signed rank test) between the rifle marksmanship pretest and posttest. No significant differences were found between the pretest ($M$ = 11.83, $SD$ = 1.94) and posttest ($M$ = 13.12, $SD$ = 4.11) scores, $z = -.41$, $p = .68$. Of the six pairs of scores, three pairs decreased, two pairs increased, and one pair remained the same.

For the remaining conditions, a 3(Condition) × 2(Occasion) ANOVA was conducted, with repeated measures on the last factor. The between-subjects factor was condition (minimal instruction, individualized instruction, individualized instruction using sensors) and the within-subjects was occasion (pretest, posttest). Effect sizes were computed as partial Eta squared values.

There was no significant effect of condition and no significant Trial × Occasion interaction. However, there was a significant within-subjects effect of occasion, $F(1, 39)$ =

32.02, $p < .001$, $\eta^2 = .45$. Participants performed significantly higher on the posttest ($M$ = 10.29, $SD$ = 5.30) than the pretest ($M$ = 13.76, $SD$ = 4.12), suggesting that learning occurred over the task for all conditions.

Thus, there appears to be some support for the idea that participants who had instruction increased their knowledge of rifle marksmanship compared to participants who did not have instruction. However, this result is tentative because of the small sample size of the no-instruction condition. Furthermore, the absence of a Trial × Occasion interaction indicates that the overall gain in knowledge did not differ among participants who received additional individualized instruction compared to participants who received only the introductory instruction.

**Individualized instruction.** A second check on the data was to confirm that participants received individualized instruction. This check was conducted by inspection. As shown in Table 8, the majority of the individualized instruction was administered after Trials 3 and 4. By Trial 5, there were only a few topics administered. The most common set of topics participants received instruction on, covered breath control, trigger control (trigger squeeze, trigger jerk), and position quality related to the shoulder area (i.e., rifle butt placement, stockweld placement, and eye relief). Thus, we concluded that there was a sufficient number of participants who received instruction on topics that we also had direct measures for.

Table 8

Number of Participants Who Received Individualized Instruction by Trial

| Topic | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Topic | Trial 3 | Trial 4 | Trial 5 | Trial 6 |
|---|---|---|---|---|---|---|---|---|---|
| Aiming | 1 | 1 | 0 | 0 | Position related | | | | |
| Aim point | 3 | 3 | 0 | 0 | Stockweld placement | 6 | 1 | 0 | 0 |
| Sight picture | 2 | 4 | 0 | 0 | Rifle butt placement | 10 | 2 | 1 | 0 |
| Natural point of aim | 3 | 1 | 1 | 0 | Eye relief | 8 | 1 | 0 | 0 |
| Breath control | 14 | 4 | 2 | 0 | Forward hand placement | 6 | 0 | 0 | 0 |
| Trigger control | 5 | 1 | 0 | 0 | Trigger finger placement | 0 | 0 | 0 | 0 |
| Trigger squeeze | 11 | 3 | 1 | 0 | Firing hand placement | 1 | 1 | 0 | 0 |
| Trigger jerk | 8 | 1 | 0 | 0 | Forward elbow placement | 3 | 0 | 0 | 0 |
| Kneeling position | 0 | 0 | 0 | 0 | Forward foot placement | 3 | 0 | 0 | 1 |
| Anxiety | 3 | 2 | 0 | 0 | Rear foot placement | 1 | 0 | 0 | 1 |
| Anxiety and physiology | 3 | 2 | 0 | 0 | Rear elbow placement | 1 | 0 | 0 | 0 |
| Surprise | 5 | 2 | 0 | 0 | | | | | |

*Note*. Instruction was administered after completion of the trial. No instruction was given after Trials 7 and 8.

The next set of analyses examined the effect of the conceptual introductory instruction on rifle marksmanship instruction on performance and skill measures. Does such instruction improve participants' performance and skill over no instruction? The final set of analyses examined if there were differences between participants who received feedback and individualized instruction, compared to participants who did not receive such feedback and individualized instruction. Would the provision of instruction targeted to specific errors result in higher performance and higher skill for participants who received such instruction compared to those who did not?

## Effect of Conceptual Instruction on Initial Performance and Skills

To examine the effect of conceptual instruction on initial performance and skills, we examined whether the introductory multimedia instruction on rifle marksmanship, administered between Trials 2 and 3, had an immediate impact on performance and skills. For these analyses, we compared the mean value of Trials 1 and 2 to the value of Trial 3 on various measures. Because of the small sample size of the no-instruction condition, we conducted separate paired $t$ tests for each condition. A summary of the analyses is shown in Table 9.

In general, participants in the no instruction condition showed no significant differences across the pre- and post-instruction trials, whereas participants who received instruction did show improvement—on their shot group precision, quality of shots, and breath control. Moreover, the improvements were moderate to large, with the largest improvement occurring on shot group precision. However, caution is warranted when interpreting these results. First, the small sample size of the no instruction condition may be masking potential differences. For example, there is a large but non-significant difference on shot group precision. Also, inspection of pre-instruction means appears to indicate preexisting differences between conditions.

To the extent that these results are stable, the provision of 15 minutes of instruction resulted in a large improvement in participants' performance and skills. Participants' shot group size was reduced from a mean of 22 inches to 15 inches, an effect size of 1.80. An effect size of 1.80 indicates a 77% non-overlap between the pre-instruction and post-instruction distributions of shot group precision scores. Participants also improved substantially on the quality of their shots, increasing from 0.2 expert-like shots to 1.6 expert-like shots, an effect size of 1.3. Breath control also showed improvement, with participants firing nearer the trough of the breathing cycle after instruction compared to before instruction ($d$ = -.41).

Table 9

Comparison of Performance and Skill Between the Pre- and Post-instruction Trials for Participants Who Did or Did Not Receive Instruction

| Measure | Pre-instruction | | Post-instruction | | *t* test (paired) | | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| No instruction | | | | | | | | |
| Shot group precision[a] | 12.51 | 3.09 | 15.61 | 18.78 | 0.42 | 5 | .690 | 1.02 |
| Quality of shots[a] | 0.67 | 0.98 | 0.33 | 0.82 | -2.00 | 5 | .102 | -0.38 |
| Breath control[a] | 0.41 | 0.21 | 0.40 | 0.20 | -0.37 | 5 | .726 | -0.03 |
| Trigger control[b] | 3.68 | 1.58 | 3.70 | 0.58 | 0.03 | 5 | .976 | 0.02 |
| Position quality[b] | 2.33 | 0.61 | 2.33 | 0.52 | 1.00 | 5 | 1.000 | 0.00 |
| Received introductory instruction | | | | | | | | |
| Shot group precision[a] | 21.66 | 22.08 | 14.84 | 7.49 | -2.11 | 39 | .041 | -1.80 |
| Quality of shots[a] | 0.20 | 0.53 | 1.60 | 1.73 | 5.76 | 41 | <.001 | 1.33 |
| Breath control[a] | 0.43 | 0.15 | 0.27 | 0.17 | -6.17 | 39 | <.001 | -0.41 |
| Trigger control[b] | 3.62 | 3.38 | 3.95 | 3.48 | 0.77 | 39 | .445 | 0.18 |
| Position quality[b] | 1.92 | 0.99 | 2.10 | 0.91 | 0.91 | 41 | .366 | 0.17 |

*Note*. [a]Lower values indicate higher performance. [b]Higher values indicate higher performance.

**Effect of Individualized Instruction on Rifle Marksmanship Performance**

The next set of analyses examined the effect of individualized instruction on performance. After Trial 3, participants received individualized instruction on topics particular to each person's errors. Most participants received instruction between Trials 3 and 4, and between Trials 4 and 5. We were interested in whether there were overall effects of such instruction on performance measures.

For these analyses, we computed a summary score for each measure averaged over Trials 4 to 8 and we used the Trial 3 value as a covariate to control for differences in participants' initial status. Also, we pooled the no instruction and minimal instruction conditions, given the small sample size of the no instruction condition and the identical procedure of the two conditions between Trials 3 to 8. We verified that there were no differences on the measures between both conditions.

The general approach of the analyses was to test for group differences among the no individualized instruction condition and the two individualized instruction conditions controlling for initial status using an ANCOVA procedure.

**Shot group precision.** There were no differences among the three conditions, $F(2, 44) = 0.97$, $p = .39$, $\eta^2 = .04$. This result indicates no effect of individualized instruction on shot group precision. As shown in Table 10, regardless of whether participants received individualized instruction over and above the initial introductory instruction, participants' shot group size averaged around 13 inches over Trials 4 to 8.

**Quality of shots.** Significant differences among the three conditions were found, $F(2, 44) = 3.69$, $p = .03$, $\eta^2 = .14$. Follow-up pairwise tests indicated significant differences between the individualized instruction condition that used sensor data, and (a) the no-individualized instruction condition, and (b) the individualized instruction condition that did not use sensor information. The latter two conditions were not significantly different from each other. As shown in Table 10, the mean number of shots classified as expert-like averaged about two shots per trial, almost twice as much as the other conditions.

Table 10

Adjusted Means, Standard Errors, and Analysis of Covariance (ANCOVA) of Performance Measures for Participants Who Did Not Receive or Did Receive Individualized Instruction on Rifle Marksmanship

| | | Did not receive individualized instruction | | Received individualized instruction | | Received individualized instruction using sensor information | |
|---|---|---|---|---|---|---|---|
| | | *n* = 20 | | *n* = 14 | | *n* = 14 | |
| Measure | Scale range | *Adj. M* | *SE* | *Adj. M* | *SE* | *Adj. M* | *SE* |
| Shot group precision | 0.0 – ∞ | 12.93 | .62 | 12.34 | .74 | 13.79 | .74 |
| Quality of shots | 0 – 5 | 1.19[a] | .24 | 0.95[b] | .29 | 2.00[a,b] | .29 |

[a]$p < .05$ (two-tailed). [b]$p < .05$ (two-tailed). [c]$p < .001$ (two-tailed).

## Effect of Individualized Instruction on the Development of Rifle Marksmanship Skills

The last set of analyses examined the effect of individualized instruction on particular skills. The rationale for these analyses was to examine precisely whether the administration of specific instruction related to specific skills would result in improvement of those skills. For all participants, we measured their breath control, trigger control, and position quality during each trial. We also tracked (a) the topic of instruction they received and (b) the trial after which the instruction was administered. Thus, we were able to identify precisely when an instructional treatment occurred.

Because of the low number of participants in each instructional condition receiving instruction on a particular topic, we collapsed across instructional conditions. The difference in treatment between the two conditions was in the use of sensor data (see Table 3). We verified that there were no differences on the measure between conditions.

To examine the impact of individualized instruction on a particular skill (i.e., breath control, trigger control, position quality), we tested for group differences between participants who received individualized instruction to participants who did not. Separate one-way ANCOVA procedures were used for each measure. For the instructional condition, the mean value of the measure from all the trials following instruction formed the dependent measure, and the value of the measure on the trial immediately preceding instruction formed the covariate.

For the minimal instruction condition, the mean value of the measure averaged over Trials 4 to 8 formed the dependent measure and the value of the measure at Trial 3 formed the covariate. We selected Trial 3 as the covariate because the majority of participants who received instruction on breath control, trigger control, or position quality received the instruction after Trial 3. Thus, we were able to roughly align the minimal instruction and individualized instruction conditions by trial.

Table 11

Adjusted Means, Standard Errors, and Analysis of Covariance (ANCOVA) of Skill Measures for Participants Who Did or Did Not Receive Individualized Instruction on the Skill

| | | Minimal instruction condition (no individualized instruction) | | | Received individualized instruction | | | ANCOVA[b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skill[a] | Scale range | *n* | *Adj. M* | *SE* | *n* | *Adj. M* | *SE* | Error *df* | *F* | *p* | Effect size[c] |
| Breath control | 0.0 – 1.0 | 14 | .31 | .02 | 15 | .25 | .02 | 26 | 3.11 | .09 | .11 |
| Trigger control | 0.0 – ∞ | 14 | 7.27 | 1.47 | 12 | 7.122 | 1.60 | 23 | .00 | .95 | .00 |
| Position quality | 0.0 – 3.0 | 14 | 2.05 | .17 | 14 | 3.04 | .17 | 25 | 14.47 | .001 | .37 |

[a]Higher values indicate higher performance. [b]Between-groups *df* = 1. [c]Hedge's *g*.

Table 11 displays the results of the ANCOVA analyses. There was a significant effect of individualized instruction on position quality, and a marginally significant effect on breath control. Participants who received individualized instruction on position had higher quality positions compared to participants who did not receive instruction. Similarly, participants who received individualized instruction on breath control fired the rifle nearer the trough of the breathing cycle compared to participants who did not, although this difference was marginally significant.

## Discussion

In this report we examined the effect of instruction on rifle marksmanship performance and skills. The instruction we designed was intended to be efficient and incorporated instructional design features that have been previously demonstrated to be effective. We examine whether very brief multimedia-based instruction could remediate, via individualized computer-based instruction, shooter skill gaps on the fundamentals of rifle marksmanship: breath control, trigger control, and quality of position.

### Limitations

The main limitation of this study was the small sample size in the no-instruction condition. Equipment failures precluded us from gathering additional data. A second limitation was the large variability in performance as suggested by the pre-instruction measures in Table 9. This variability may be due to the complex nature of the task and the low experience of the sample, small sample size, or a skewed sample.

### General Findings

The first finding was that the initial conceptual instruction appears to have been effective in increasing participants' performance and skill. There were apparent differences between the pre-instruction and post-instruction shot group precision, quality of shots, and breath control. This is interesting given the brevity of the initial instruction. Participants generally took between 10 and 15 minutes to go through the instruction. The instructional materials themselves were very brief, with the total video running time about 6.5 minutes and the total amount of words around 800. Participants who received instruction apparently profited from the instruction, demonstrating significant improvement from the rifle marksmanship knowledge pretest to posttest. Participants who received no instruction at all did not appear to improve on the rifle marksmanship knowledge measure, nor did they appear to improve on performance or skill measures over the same trials that the participants who received instruction showed improvement on.

The second finding was that individualized instruction appeared to help overall shooting performance as well, but not as much compared to the initial instruction. There were no differences between participants who did and did not receive individualized instruction on shot group precision, whereas participants in the individualized instruction condition that used sensor data had nearly twice as many expert-like shots compared to participants that did not receive instruction. This latter finding is interesting as it suggests that sensing data may have played an important role, either as a diagnostic tool for the coach or as useful feedback to the shooter.

We also found evidence that those who received individualized instruction profited from it, particularly to improve their position. Participants who received instruction on position had higher quality positions than participants who did not receive individualized instruction. Breath control also appeared affected by instruction at $p$ = .09, with those who received instruction on breath control firing the weapon nearer the trough than participants who did not receive instruction.

These findings are consistent with a study with an identical approach to teach pre-algebra concepts (Chung, Delacruz, Dionne, Baker, Lee, & Osmundson, 2007). In their study, Chung et al. used multimedia-based instruction to provide short remedial instruction (between 6 and 17 minutes of instruction and practice) on various pre-algebra topics (e.g., multiplicative identify; multiplying fractions). Chung et al. found that students who received the instruction, compared to students who did not, performed higher on a posttest of the concept, with effect sizes between .7 and .9.

Finally, although we did find evidence that the individualized instruction was effective for some of the skill measures, we did not find an advantage of individualized instruction on our measure of overall performance—shot group precision. One explanation is that the constructs we chose to focus on—based on existing relevant marksmanship instructional materials—become more influential on shot group precision only after shooters reach some basic level of stability. That is, our sample were mostly novices that reported little or no experience handling rifles. It may be that breath control and trigger control may not have had as large an impact on shot group precision as other factors. Factors that have had large effects on motor performance include anxiety (e.g., Chung, O'Neil, Delacruz, & Bewley, 2005), focusing on one's own movement instead of the effect of the movement (e.g., Wulf & Prinz, 2001; Wulf & Su, 2007), "choking" (e.g., Markman, Maddox, & Worthy, 2006), type and frequency of feedback (e.g., Wulf & Shea, 2002). We also speculate that the nature of the feedback we provided may have led participants to focus on their own movements (e.g., various position elements or trigger or breathing) instead of focusing externally on the effect of movement (e.g., the up-and-down pattern of strikes on the target due to breathing). Future research should attempt to measure such constructs to clarify the conditions under which individualized instruction would be beneficial to skill improvement on a complex task.

## Implications for Training

One of the most surprising results was the variability of performance. One implication for marksmanship training is that instruction should be individualized to the extent possible and designed to address issues of cognitive load and skill acquisition. Presumably, the complexity of the task (one that involves cognitive, psychomotor, and affective variables) interacts with trainees' individual differences. Thus, certain individuals may need more, less, or no instruction at all on particular topics, depending on their prior experiences and comprehension of the marksmanship training instruction.

The approach we examined in this study—developing "instructional parcels" that were short, to the point, based on video with an expert explaining concepts and modeling procedures—may be a fruitful approach to address such variability. The advantage of the parcel approach is that instruction can be tailored to an individual's particular remedial needs. There is renewed interest in individualized instruction as a way to increase the access, efficiency, and cost effectiveness of training and education (e.g., Fletcher et al., 2006).

A second implication is related to the instructional techniques used in this study, particularly how the video instruction was designed. Our approach may serve as a model of how to implement efficient instruction. In general, we adopted instructional design practices that have been demonstrated to be effective, and attempted to integrate into the instruction findings from the motor learning literature to maximize learning. For example, the general form of each topic in the introductory videos was for the expert to first describe the concept, then the procedure, and explain why the topic is important. Throughout the instruction, the expert would use a variety of simple and presumably effective modeling techniques as he described the concept and procedure.

For example, one modeling technique we used in the video, known to promote motor learning, was the use of gesturing to convey relational information. To communicate sight alignment, the expert would position the rifle in his shoulder and then gesture a straight line from his eye, through the rear sight, and extend down to the front sight post. This modeling form was intended to capture the relation of the rifle butt to the shoulder, the rear sight to the eye, and the line of sight established from the eye *through* the rear sight *through* the front sight post—a non-obvious but central component of aiming. Such modeling techniques have been found to be effective for observational learning of motor and movement patterns (e.g., Al-Abood, Davids, & Bennett, 2001; Ashford et al., 2006; Weeks, Brubaker, Byrt, Davis, Hamann, & Reagan, 2002; Wulf & Shea, 2002). Also, our study design interleaved observational and physical practice, which has been found to be effective for learning complex motor tasks (e.g., Weeks & Anderson, 2000). We also limited the feedback throughout the task, also effective for learning complex motor tasks (e.g., Stefanidis, Korndorffer, Heniford, & Scott, 2007; Wulf, Shea, & Matschiner, 1998). One future area of improvement in our instructional design is to revise the feedback so that the participant's attention is focused on the effect of the movement and not the participant's movement itself (e.g., Wulf & Prinz, 2001).

**Next Steps**

Although the idea of individualized instruction has existed for some time (Courtis, 1938), what is remarkable are the striking similarities of desired goals and methods between current research in training and education and work beginning almost a century ago (e.g., teaching machines [Pressey, 1926, 1927; Skinner, 1958; Thorndike, 1912], programmed instruction [Lumsdaine & Glaser, 1960; McDonald, Yanchar, & Osguthorpe, 2005], mastery learning [Bloom, 1968/1981], domain-referenced [Baker, 1974; Hively, 1974; Hively, Patterson, & Page, 1968] and criterion-referenced testing [Glaser, 1963], CAI [Atkinson, 1968; Suppes & Morningstar, 1969], intrinsic programming [Crowder, 1960], hypertext [Engelbart, 1962]).

An immediate next step is to revise the feedback mechanisms and integrate more fully techniques known to improve motor learning. Real-time sensing and real-time classification of shots could be used to detect skill and performance improvements. We are exploring other instructional and feedback variables related to motor learning that could be tested and feasibly implemented in a trainer to accelerate the acquisition of rifle marksmanship skills.

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