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

Graduate School of Education & Information Studies
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THE INFLUENCE OF COGNITIVE AND NON-COGNITIVE FACTORS ON THE DEVELOPMENT OF RIFLE MARKSMANSHIP SKILLS[1]

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Abstract

In this report, researchers examined rifle marksmanship development within a skill development framework outlined by Chung, Delacruz, de Vries, Bewley, and Baker (2006). Thirty-three novice shooters used an M4 rifle training simulator system to learn to shoot an 8-inch target at a simulated distance of 200 yards. Cognitive, psychomotor, and affective measures were gathered in addition to measures of performance and component skills. Partial support was found for rifle marksmanship skill development following Ackerman's (1988) skill development theory. Support was found for the idea that known distance rifle marksmanship can transition rapidly from a learning phase to a practice phase, and that the cognitive and affective variables have a substantial influence on performance and skill development during the learning phase.

Introduction

Current demands of military operations in Afghanistan and Iraq are generating renewed interest in accelerating rifle marksmanship training. As reviewed by Chung, Delacruz, de Vries, Bewley, and Baker (2006), prior rifle marksmanship research has focused on a range of topics, including evaluating training programs (e.g., Evans, Dyer, & Hagman, 2000; Evans & Osborne, 1998; Evans & Schendel, 1984; Hagman, 1998, 2000; Hagman, Moore, Eisley, & Viner, 1987; Hagman & Smith, 1999; McGuigan, 1953), examining the relation between performance using a rifle simulator and performance on the firing range (e.g., Hagman, 1998; Marcus & Hughes, 1979; Schendel, Heller, Finley, & Hawley, 1985; Smith & Hagman, 2000 Torre, Maxey, & Piper, 1987; White, Carson, & Wilbourn, 1991), and the use of shooting as a testbed to study skilled behavior in relation to psychophysiological constructs and measurements (e.g., Bird, 1987; Hatfield, Landers, & Ray, 1987; Janelle et al., 2000; Kerick,

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Iso-Ahola, & Hatfield, 2000; Konttinen & Lyytinen, 1992, 1993; Konttinen, Lyytinen, & Konttinen, 1995).

What has been missing to date, however, is a theoretical framework to understand how rifle marksmanship skills develop and to more precisely account for the roles of cognitive, psychomotor, and affective dimensions. This report addresses this gap in the context of training novices to shoot using a rifle simulator to hit a circular target with an 8-inch diameter at a simulated distance of 200 yards in the kneeling position.

Rifle Marksmanship as a Complex Skill

One of the most remarkable achievements in modern marksmanship training and weaponry is in developing a novice's skill to routinely hit a 19-inch circular area at 500 yards in the prone position. What makes this achievement even more remarkable is that virtually any deviation of the rifle from the center line will result in a miss. A rifle muzzle deflection of 1/16 inch from the center line will result in the bullet strike being off by over 2 feet at 500 yards. Shooter-based factors—perhaps the most variable component—can severely affect where a round lands. Breathing, heartbeat, and muscle tremors due to fatigue all contribute to movement of the weapon. Misaligned sights can result in large deviations from the intended target, and flinching or bucking due to recoil or reaction to the report can result in large rifle movements, as does yanking the trigger. Exacerbating position instability is the emotional state of the shooter—anxiety can increase heart and breathing rates. Thus, accurately and consistently hitting a target is a complex interaction of physical and mental processes immediately before, during, and immediately after the weapon fires. Effective shooting is the simultaneous coordination among 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 rear sight. The coordination is intended to minimize muzzle movement by controlling body movement.

In their review of the rifle marksmanship research, Chung, Delacruz et al. (2006) conceptualized rifle marksmanship as a complex skill that was influenced by perceptual-motor, cognitive, and affective variables, while also acknowledging the importance (but uncontrollability) of equipment and environmental variables. In particular, successful shooters need to know what to do, how to do it, when to do it, and how to make use of perceptual cues and other feedback to adjust their technique and equipment—while minimizing movement of the weapon. Shooters also need to remain calm; anxious shooters may not only experience degraded performance, but also experience physiological manifestations such as increased heartbeat that directly affect the movement of the weapon.

Cognitive variables. Given the task demands underlying skilled shooting, we expect the main cognitive variables to be knowledge of concepts and procedures underlying the task and the capability of the shooter to reason using feedback, perceptual cues, and internal judgments about the quality of his or her position and techniques. In a related series of studies, Chung et al. (2004) found evidence that for members of the armed forces undergoing sustainment-level training, their record-fire scores were related to knowledge of (a) basic marksmanship facts (significant r ranging from .3 to .5) and (b) perceived level of importance of marksmanship knowledge to shooting performance (significant r ranging from .2 to .4). In general, high performers scored significantly higher than low performers on measures of basic marksmanship knowledge and conceptual knowledge, as did individuals who attended the coaches course. Similarly, in another sample from the armed forces, Chung, O'Neil, Delacruz, and Bewley (2005) found a significant and moderate correlation between qualification and aptitude scores $r = .34$, $p < .05$ among 2nd lieutenants undergoing basic marksmanship training. These findings are consistent with prior studies examining the relation between various knowledge and aptitude measures and shooting performance (e.g., Boyce, 1987; Carey, 1990; Cline, Beals, & Seidman, 1960; MacCaslin & McGuigan, 1956; Thompson, Smith, Morey, & Osborne, 1980; Wisher, Sabol, Sukenik, & Kern, 1991).

Psychomotor variables. The psychomotor component of rifle marksmanship encompasses the physical aspects of shooting such as assuming the different shooting positions, establishing proper sight alignment and sight picture, and maintaining rifle steadiness. A confirmation of the role of psychomotor processes is that skilled shooters have been found to be able to hold a rifle steadier than unskilled shooters and this steadiness relates positively to shooting performance (Humphreys, Buxton, & Taylor, 1936; McGuigan & MacCaslin, 1955a; Spaeth & Dunham, 1921). In general, being able to establish and maintain a steady position has consistently been found to be related to shooting performance. Compared to novices, expert shooters have been found to be much steadier (e.g., Era, Konttinen, Mehto, Saarela, & Lyytinen, 1996; Gates, 1918; Mononen, Konttinen, Viitasalo, & Era, 2007). To a large degree, a shooter's skill in consistently hitting the same spot on a target is determined by the extent to which he or she can maintain these factors before, during, and immediately after firing a round.

Affective variables. The earliest investigation on how affect relates to shooting performance dates back to nearly a century. Gates (1918) found novice shooters' performance was affected negatively and severely by dwelling on steadiness factors (e.g., “I can’t seem to control myself” or “There, I moved again”; p. 3). More recent investigations that examined the anxiety-performance relation specifically have found significant and moderate negative correlations between qualification scores and self-reported state anxiety $r = -.51$, $p < .01$ and state worry $r = -.59$, $p < .01$ among 2nd lieutenant officers undergoing marksmanship training (Chung et al., 2005). Similarly, Chung et al. (2004) found significant negative correlations between sustainment-level qualification scores of enlisted members of the armed forces and their self-reports of state anxiety and state worry (*r*s in the range of -.4). A similar pattern of results were found by earlier researchers (e.g., Sade, Bar-Eli, Bresler, & Tenenbaum, 1990; Tierney, Cartner, & Thompson, 1979).

The Development of Rifle Marksmanship Skill

The skill development framework originally proposed by Fitts and Posner (1967) and extended by Ackerman (1988, 1992) provides a useful framework to understand the development of rifle marksmanship skills in novices. Fitts and Posner (1967) characterized skill learning in three phases: an initial cognitive or learning phase, an intermediate “associative” or practice phase, and a third “automaticity” phase. Ackerman’s extension specified the relative contribution of aptitude, perceptual, and psychomotor variables across the phases, showing the initial importance of aptitude during the learning phase when trainees are learning the task, with diminishing influence of aptitude during the latter phases. Conversely, perceptual-motor and psychomotor skills initially contribute less to overall performance during the learning phase and become increasingly important in the latter phases when trainees already understand the task demands. Note that these relations hold for tasks that are stable with respect to the task goals and features, as is the case with known-distance shooting.

Presumed Characteristics of Shooters in the Learning Phase

During the initial learning of a skill, trainees become familiar with the basic rules and procedures underlying the task. Trainees are focused on proper execution of the task procedures, relevant perceptual cues, proper shooting position, how to coordinate breathing and squeezing the trigger, how to hold the rifle, how to align the sights, and how to use results (i.e., where the round hit) as feedback. Learning is focused on the acquisition of basic knowledge and procedures and trainees often engage in verbal rehearsals (e.g., mentally or orally rehearsing facts or basic procedures, such as “squeeze—not pull—the trigger,” Anderson, 1982). A characteristic of the learning phase is that performance is fraught with error and a trainee’s cognitive load is high as the trainee attempts to coordinate verbal and motor dimensions of the task. Performance is low, error-prone, and inconsistent, and requires conscious thought. The high cognitive-processing demands imposed by the task also make performance sensitive to distractions and other ongoing activities. Novice shooters would be expected to have a poor grasp of the fundamentals, score low, exhibit poor coordination and integration of the different elements of the fundamentals, and not be able to recognize correct from incorrect positions. Novice shooters would also be expected to be more sensitive to changes in the environment (e.g., weather, equipment malfunction, anxiety) than more advanced shooters.

Although these characteristics presumably generalize across novices, individual differences in aptitude and motor control are expected to contribute to differential rates of skill acquisition. Ackerman's skill acquisition theory (1988) hypothesizes that when trainees are learning a complex task, high aptitude facilitates acquisition of the knowledge required of the task, whereas motor skills are less influential. For example, Ackerman found that correlations between measures of aptitude and performance on a simulated air-traffic controller task were highest during the early trials of the task and diminished over subsequent trials. Conversely, perceptual-motor measures showed the opposite pattern, with such measures showing the highest correlations in the latter trials.

Presumed Characteristics of Shooters in the Practice Phase

During the second phase, trainees have learned the basic rules and are now practicing implementing the skill. During the practice phase, gross errors common in the learning phase occur less frequently and trainees know what to expect of the task. For example, trainees would have a basic knowledge of weapons handling, terminology, and the fundamentals of rifle marksmanship. Attentional demands of the task are reduced and thus trainees can focus on refining gross- and fine-motor responses and develop and test techniques to improve performance. Practice on the task becomes more consistent and speed and accuracy improve over the learning period as coordination between cognitive and motor responses improves. Performance during the practice phase would continue to show improvement over the course of fire. During this phase and the more advanced automaticity phase, knowledge becomes increasingly compiled and broad ability measures and content-specific abilities become less influential on performance for closed-ended skills such as marksmanship (Ackerman, 1987, 1992).

Presumed Characteristics of Shooters in the Automaticity Phase

Trainees who have reached the last phase can execute the skill automatically. Performance is highest, and is often effortless and requires little overt attention (Ackerman, 1987, 1992; Fitts & Posner, 1967). Performance is consistent and seemingly effortless and knowledge about carrying out the task is "compiled" (Anderson, 1982). The cognitive load on performers with respect to executing the task is lowered (compared to other phases), thus freeing up mental resources. Shooters who have reached the autonomous phase could be expected to be true experts—snipers or members of the rifle team, for example. Performance is consistent and robust against distractions. There may be increases in performance but the rate of improvement slows over time. Few individuals are expected to reach this phase without deliberate, effortful, and consistent practice. Similar characterizations of the development of cognitive skill have been postulated by Anderson (1982). Whether the task is perceptual-motor or verbal, the general idea is that learning occurs in several phases, which may overlap but involve distinctly different learning (Shuell, 1990).

Research Question

In this report our primary research question was adopted from Chung, Delacruz et al. (2006): To what extent does the development of rifle shooting performance and skill follow the phases-of-skill-development model? Implicit in this question is identifying the extent to which there is differential influence of psychomotor, cognitive, and affective variables on performance and skill during the different phases of skill development. We expect the development of rifle marksmanship skills to follow the model outlined by Ackerman (1988). Specifically, the psychomotor component will contribute increasingly more to the prediction of shooting performance as participants become more familiar with the shooting task, and the knowledge component to contribute less to the prediction of shooting performance. What is unclear from Ackerman's model is the role of affect and whether the influence of affect on performance differs by phase.

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 report, we focused on a subset of the sample that included an instructional intervention to teach novices how to shoot. Because there were no effects of the three instructional variations (interventions which were subtle) on shooting performance, we collapsed the data across the different conditions. The aggregation resulted in a single group within-subjects design and we focused our attention on the development of shooting performance and component skills. The various treatment conditions will not be described in detail.

Participants

Thirty-three participants remained in the sample from the original 37 recruited to participate in this study. Two participants were dropped for physical reasons (e.g., vision problems, severe problems with aiming, difficulty handling weight of weapon) and two were dropped because they reported recent and frequent shooting experience. The mean age of the sample was 22.7 years (*SD* = 4.4 years) and in terms of gender, there were 22 males and 11 females. In terms of their highest prior rifle shooting experience, participants reported a range of experience—shooting a real rifle (16), shooting an airsoft or paintball rifle (5), or shooting an arcade or arcade-like rifle (6). Six participants reported no experience at all with rifles. Overall, the participants in the sample have some experience with rifle shooting of some form.

Apparatus

An instrumented training rifle prototype was developed using off-the-shelf sensing components (Chung, Dionne, & Elmore, 2006) attached to a commercial rifle training system (LaserShot, 2008). The training rifle was of similar size and mass to an actual M4 rifle. The rifle trainer also had a CO_2 gas system that simulated the recoil and report of the real M4 rifle. The trainer weighed about 8 pounds and 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. In addition, participants wore a respiration band that was used to measure participants' breathing. 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).

Tasks

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

Surveys. Surveys were used to gather data on demographics, background and experience with marksmanship-related activities, affective states, ongoing task experience, scientific reasoning, and knowledge of rifle marksmanship.

Shooting. Each participant shot in the kneeling position. The basic task was for shooters 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 were shown their strikes after every two trials.

Participants received the following types of feedback: (a) knowledge of results—shots on target; (b) position quality—general and brief statements from the researcher about what was proper and improper. In addition, some participants viewed their breathing and trigger pressure plots, and a few participants received training in focusing techniques.

Computer-based instruction. All participants were given an overview of rifle marksmanship. Much of the content was video-based and generally showed a person describing and explaining the concept with the aid of a whiteboard and weapon, and also demonstrating the concept where appropriate with the aid of a weapon. The first instructional event, which all participants received, was an overview of rifle marksmanship. The topics covered were: *What is rifle marksmanship?*, *aiming*, *sight alignment*, *trigger control*, *breath control*, *kneeling position*, and *bone support*.

Some participants received additional instruction after each trial as needed. The instruction was tied to particular shooter errors committed during a 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*). Participants received instruction on the different topics only if they were diagnosed by the researcher as needing help on those topics. In general, participants received up to four topics at a time.

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).

Shooting Measures

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 1. 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.

Shot group precision was computed automatically from the laser-based rifle simulation system from shots taken by the participant. Espinosa, Nagashima, Chung, Parks, and Baker (2008) contains a detailed description of the method used to compute shot group precision.

Table 1

Shot Group Precision Measures (modified from Johnson, 2001)

Measure	Symbol	Formula	Interpretation
Center of shot group x	SG_x	$\frac{\sum_{i=1}^{N} x_i}{N}$	Center of *N* shots, *x* coordinate.
Center of shot group y	SG_y	$\frac{\sum_{i=1}^{N} y_i}{N}$	Center of *N* shots, *y* coordinate.
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}	$\frac{\sum_{i=1}^{N} d_{SG_i}}{N}$	This is the measure of precision and reflects the mean dispersion across all shots with respect to the center of the shot group.

Note. N = number of shots. x_i and y_i = location of ith shot.

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*. The measure was the sum of scores for all positions. The possible score range was 0 to 10, 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). The first author of this study acted as the coach and rated each participant's position. Cronbach alphas for this measure, by trial, were .54, .35, .72, .32, .16, .20, .07, and .00 (*n* = 33, 10 items).

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., 2008) to yield the location in the breathing cycle where the trigger broke.

Steadiness. Steadiness is the overall movement of the weapon immediately preceding the shot. Steadiness is achieved by establishing a stable platform from which to support the weapon. Various techniques have been developed to maximize bone support (vs. muscular support), with the objective to minimize the onset of fatigue. Steadiness was operationalized as the amount of total acceleration in the muzzle 2 seconds prior to the shot. The measure ranges from 0 to 1024 and is a unitless measure. For each participant, raw sensor data from the wobble sensor were processed using custom-developed software (Espinosa et al., 2008) to yield the total movement during the 2 seconds preceding the shot.

Psychomotor Measure

An arm steadiness test was used to measure involuntary movement with respect to steadiness of motor control (Spaeth & Duncan, 1921; Whipple, 1914). Participants were presented with a metal plate with five holes of increasingly smaller diameters. Participants were instructed to insert a metal probe into each target hole and to hold the probe without touching the metal plate for 10 seconds. The apparatus was connected to a computer, which counted the number of times the probe touched the metal plate. The hole diameters were

8/32, 7/32, 6/32, 5/32, and 4/32ths of an inch. The probe diameter was 3/64 in. The measure was the mean of the number of times the participant touched the plate for the 6/32 and 5/32 holes, measured after the shooting trials. Cronbach alpha for this measure was .88 (*n* = 31, 2 items).

Cognitive Measures

Scientific reasoning. Lawson's Classroom Test of Scientific Reasoning (revised 24-item multiple choice edition) was used to measure scientific reasoning (Lawson, 1987, 2000). Cronbach alpha for this measure was .85 (*n* = 26).

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 .86 (*n* = 33) and .83 (*n* = 33) for the posttest.

Affective Measures

State anxiety. We adapted a measure from O'Neil and Abedi (1992) to measure participants' state anxiety across the shooting trials. In our prior work, moderate to high negative correlations were found between scores on this measure and qualification scores r_{sp} = -.4 to -.6, (Chung et al., 2004). The items in this scale were: (a) I felt calm while shooting; (b) I felt tense while shooting; (c) I felt at ease while shooting; (d) I felt jittery while shooting; (e) I felt relaxed while shooting. Participants indicated, on a 4-point Likert scale: 1 (*very much so*), 2 (*moderately so*), 3 (*somewhat*), and 4 (*not at all*), how they thought or felt during the shooting trials. The score range was 1.0 to 4.0 and *lower* values indicated higher anxiety. Cronbach alpha for this measure was .73 (*n* = 32).

State worry. We adapted a measure from O'Neil and Abedi (1992) to measure participants' state worry across the shooting trials. In our prior work, moderate to high negative correlations were found between scores on this measure and qualification scores r_{sp} = -.4 to -.6, (Chung et al., 2004). The items in this scale were: (a) I did not feel confident about my performance while shooting; (b) I thought my score would be so bad that everybody, including myself, would be disappointed; (c) I was afraid that I should have prepared more for shooting; (d) I was not happy with my performance while shooting; (e) I felt regretful about my performance while shooting; (f) I was concerned about what would happen if I did poorly while shooting. Participants were instructed to indicate, on a 4-point Likert scale: 1 (*very much so*), 2 (*moderately so*), 3 (*somewhat*), and 4 (*not at all*), how they thought or felt during the shooting trials. The score range was 1.0 to 4.0 and lower values indicated more worry. Cronbach alpha for this measure was .79 (*n* = 32).

Situational Measure

Firing line experience. This measure was adopted from prior work (Chung et al., 2004) and was used to gather information from participants on their perception of their shooting experience during each trial starting from Trial 2. In our prior work with 2nd lieutenants in the armed forces, high correlations were found between scores on this measure and qualification scores (r_{sp} = .6 to .8, Chung et al., 2004). The stem for the items was, "In general, when you were shooting, how often …" followed by six questions:

1. Did you hit the "zone" (smooth and calm performance, unaware of time pressure, effortless shooting)?;
2. Were you nervous about your shooting performance?;
3. Were you confident about your shooting performance?;
4. Did you know how the shot went (good or bad) as soon as you fired the rifle?;
5. Did you know how to adjust your position based on your prior shot(s)?;
6. Did you get distracted mentally (have negative thoughts—"I can't seem to control myself" or "There, I moved again," and so on)?

Participants were instructed to indicate for each item, on a 4-point Likert scale 1 (*almost never*), 2 (*sometimes*), 3 (*often*), and 4 (*almost always*), how often they encountered various shooting experiences. Cronbach alphas for this scale, by trial, were .70, .71, .74, .78, .80, .73, and .76 (*n* = 27 - 33).

Background Information

Information was gathered about participants' demographics, academic background (e.g., GPA and major), and experience related to shooting (e.g., prior shooting experience, sports).

Procedure

Pretests. A series of pretests were administered to gather information on participants' background, arm steadiness, shooting experience, knowledge of rifle marksmanship and scientific reasoning. This stage lasted about 45 minutes.

Shooting and remediation. Participants were given a 3-min. demonstration on the kneeling position and shown the basics of how to use the rifle. Participants then shot a practice trial and a baseline trial of 5 shots each. Following the second (baseline) trial, all participants received computer-based instruction on rifle marksmanship, which lasted about

15 minutes. Participants then returned to the firing line and fired six more trials of 5 shots. After each trial participants filled out a survey about their experience during the trial. Participants were shown their shots after every two trials (i.e., after Trials 4, 6, and 8). The researcher diagnosed shooting problems. Given the diagnosis, participants were given additional, targeted computer-based instruction videos (and text) that were less than 2 minutes each on the topic the participant was diagnosed as needing help on. This stage lasted about 65 minutes.

Posttest. Participants were administered the state worry and anxiety measures, and re-administered the basic knowledge of rifle marksmanship measure and the arm steadiness measure. Participants were paid and debriefed on the study, and thanked for their participation. This stage lasted about 15 minutes.

Results

The main research question of this report was to what extent does rifle marksmanship follow the phases-of-skill-development model? Specifically, we were interested in (a) whether there were differences in performance, skill, and knowledge across different phases of skill development, and (b) whether there were differential relations of cognitive, psychomotor, and affective variables to performance variables during different phases of skill development.

Analysis approach. To answer the question of whether there were changes in performance and skill across phases, we first identified learning and practice phases based on performance and errors. We then checked for within-subjects differences on performance and skill measures across the different phases. The existence of within-subjects differences would provide information on the development of rifle marksmanship skills. We also checked for knowledge differences to verify instructional effectiveness.

To address the second question, we examined correlations between cognitive, psychomotor, and affective variables and performance and skill measures for the learning phase and practice phase. As suggested by Ackerman's skill development theory, we expect differential influence of cognitive, psychomotor, and affective variables on performance and skill depending on the phase of skill development the participants are in.

Preliminary Analysis

Identifying the learning and practice phases. We inspected shot group precision, shooter position errors, and the administration of remediation (i.e., computer-based instruction) to determine whether there were distinct phases in performance as predicted by theory. The important indicators are more varied performance of shooters and the commission of gross errors in the learning phase, compared to when they are in the practice phase. As shown in Table 2, there appears to be gradual improvement in mean shot group precision. Variability of performance, as measured by the coefficient of variation, shows a drop between the baseline trial and Trial 3, and a step down from Trials 3–4 to Trials 5–8. In terms of gross errors, there were a large number of participants who committed position errors during Trials 3 and 4 and who received remediation. Position errors continued to decline across Trials 6–8, but they were not severe enough to require remediation. By Trial 6, there was only one person who had errors severe enough to receive remediation. Although Trials 5 and 6 had similar coefficient of variation values and a similar number of participants who still showed position errors, we used the administration of remedial instruction (an implicit measure of how severe the error was) as the determinant for delineating the learning from practice phase. Thus, we identified Trials 3–5 as the learning phase and Trials 7–8 as the practice phase. To simplify the analyses, we collapsed the data across these trials into the two phases for measures collected at the trial level.

Table 2

Trial-by-Trial Performance, Number of Participants With Position Errors and Computer-based Instruction (*n* = 30–33)

	Trial						
	Baseline	Learning phase			Practice phase		
	2	3	4	5	6	7	8
Shot group precision mean (standard deviation)	19.98 (14.32)	16.19 (8.11)	15.44 (8.42)	14.86 (5.92)	13.73 (5.07)	12.81 (4.85)	11.92 (4.89)
Coefficient of variation[a]	0.72	0.5	0.55	0.4	0.37	0.38	0.41
No. of participants with at least one position element error	26	23	10	5	5	3	1
No. of participants given targeted computer-based instruction on at least one topic	–	21	6	2	1	0	0

Note. Trial 1, not shown, was a training trial intended to familiarize participants with the task.
[a] Computed as the standard deviation divided by the mean.

Check for normality and outliers. Visual inspection for outliers and non-normality for each variable showed the presence of one or two outliers for arm steadiness, knowledge of rifle marksmanship posttest, scientific reasoning, trigger control (learning and practice phases), breath control (practice phase), steadiness (learning and practice phases), and position quality (practice phase). Departures from normality were found on several important measures as well; thus, we used nonparametric procedures to examine correlations and parametric procedures for analyses that are robust to non-normality.

Main Analyses

Are there differences in the development of performance, skill, and knowledge across trials?

General rifle marksmanship performance and skill relations

Inspection of Table 3 means shows a general increase in performance and skill across the phases. Novices' shot groups had on average a 20-in. radius at baseline (no instruction), with a reduction of 4.5 in. over the learning phase, and a further reduction of 2.4 in. over the practice phase. Furthermore, variability on shot group precision suggests that participants' performance was becoming more similar, indicative of effective training. Overall, the training resulted in an increase of about 35% in shot group precision (d = 0.41) from no training to practice, and an increase in about 15% from the learning to practice phases (d = 0.47). These are large gains that suggest a rapid acquisition of task knowledge.

Participants also showed a general increase in performance on the skill measures of trigger control, breath control, and position quality. Curiously, breath control and trigger control showed an increase in variability across phases. There was no apparent change in participants' steadiness over phases. Participants' perception of their experience also showed increased improvement over phases.

The pattern of correlations shown in Table 3 is generally consistent with expectations as outlined by doctrine (e.g., U.S. Army, 2003; USMC, 2001). Shot group precision, our main outcome measure, was associated with breath control and trigger control (skills considered fundamental to marksmanship) as well as steadiness (MacCaslin & McGuigan, 1956; McGuigan & MacCaslin, 1955a). However, these relations were significant only during the learning phase and of moderate magnitude (*r*s around .4). Participants' self-reports of their experience was correlated moderately with outcome performance during the learning phase, similar to our prior work (Chung et al., 2004). Interestingly, breath control was related to steadiness during the baseline and learning phases, consistent with the idea that firing during the natural respiratory pause—the trough in the breath cycle—provides less movement than at other points in the breathing cycle.

Unexpectedly, position quality was not related to shot group precision, which is surprising given that proper position was assumed to be essential to establishing a stable platform (e.g., U.S. Army, 2003; USMC, 2001). One explanation may be that the composite position quality measure—intended to capture the overall quality of the position—was masking the contribution of specific position elements to shooting performance. There was scant evidence for this interpretation, with only the forward position elements (i.e., forward hand and forward leg positions) relating to shot group precision during the baseline $r_s(28) = .42$, $p < .01$ and practice phases r_s $(28) = .42$, $p = .06$.

Table 3

Descriptive Statistics and Intercorrelations (Spearman) for Performance and Skill Measures (*N* = 33)

						Shot group precision			Steadiness			Breath control			Trigger control			Position quality			Firing line experience[c]	
Measure	*M*	*SD*	Min.	Max.	COV	B	L	P	B	L	P	B	L	P	B	L	P	B	L	P	B	L
Shot group precision[b]																						
Baseline[d]	19.98	14.32	7.71	66.63	0.72	–																
Learning	15.46	6.10	8.25	34.26	0.39	.39*	–															
Practice	13.02	4.16	6.59	25.22	0.32	.00	.52**	–														
Steadiness[b]																						
Baseline[d]	1195	111	1040	1451	0.09	-.18	.14	.10	–													
Learning	1203	102	1060	1487	0.08	.04	.44**	.12	.68***	–												
Practice	1198	112	1039	1476	0.09	.13	.31§	.04	.53**	.68***	–											
Breath control[b]																						
Baseline[d]	0.40	0.17	0.02	0.71	0.43	.17	.19	.12	.52**	.35§	.05	–										
Learning	0.25	0.12	0.07	0.48	0.49	.23	.39*	.14	.35§	.40*	.34§	.42*	–									
Practice	0.22	0.13	0.04	0.57	0.61	.08	.23	-.03	.30	.14	.14	.29	.64***	–								
Trigger control[c]																						
Baseline[d]	7.17	9.89	1.15	52.19	1.38	.20	.43*	.11	.06	.12	.25	.07	.23	.14	–							
Learning	7.89	5.93	1.97	31.22	0.75	.28	.42*	.21	.18	.27	.27	-.10	-.09	.05	.52**	–						
Practice	10.83	13.39	1.78	68.93	1.24	.41*	.32§	.08	.00	.10	.14	-.13	-.11	.10	.54**	.87***	–					
Position quality[c]																						
Baseline	8.12	1.45	5	10	0.18	-.03	-.21	-.02	-.16	-.17	-.07	-.31§	-.26	-.36*	-.40*	-.20	-.25	–				
Learning	9.26	0.82	6	10	0.09	-.06	-.07	-.08	.07	-.04	-.01	.33§	.23	-.07	.06	-.39*	-.29	.28	–			
Practice	9.90	0.26	9	10	0.03	-.06	-.01	.24	.16	-.01	-.12	.36§	.23	.03	.13	-.07	-.25	.10	.22	–		
Firing line experience[c]																						
Baseline[e]	2.25	0.62	1.17	3.50	0.28	-.23	-.36*	-.19	.41*	-.04	-.15	.38*	.16	.26	-.03	-.16	-.21	-.03	.02	.26	–	
Learning	2.67	0.46	1.72	3.44	0.17	-.35§	-.38*	-.14	.41*	-.05	-.14	.32§	.11	.08	-.16	-.21	-.30§	.07	.12	.27	.76***	–
Practice	2.88	0.50	1.83	3.94	0.17	-.31§	-.45**	-.23	.40*	.07	-.07	.21	.06	-.07	-.29	-.30§	-.34§	.24	.13	.24	.59***	.88***

Note. [a]COV = coefficient of variation, computed as the standard deviation divided by the mean. [b]Lower scores indicate higher performance. [c]Higher scores indicate higher performance. [d]$n = 30$. [e]$n = 31$. B = baseline phase, L = learning phase, P = practice phase.
***$p < .001$ (two-tailed). **$p < .01$ (two-tailed). *$p < .05$ (two-tailed). $^{\S}p < .10$ (two-tailed).

A second explanation may be that participants were able to achieve a stable position by "muscling" the weapon. In general, the position techniques described in the reference marksmanship instructional materials attempt to minimize the use of muscle to stabilize the weapon because fatigue can result in trembling and thus excessive movement of the weapon (USMC, 2001). In our report, the task may not have resulted in fatigue because of how short each trial was (generally less than a minute). Participants were also required to put down the weapon after each trial, and the total number of trials may not have been enough to cause the onset of severe fatigue.

Phase-specific differences

Performance. Shot group precision was analyzed with a repeated-measures ANOVA, with trial (baseline, learning phase, practice phase) as the within-subjects factor. A significant within-subjects effect was found for phase. Because the sphericity assumption was not met, the Greenhouse-Geisser correction was applied to the analysis, yielding $F(1.2, 37.7) = 5.78$, $p = .017$. Tests of within-subjects contrasts of each adjacent level detected a difference between the baseline ($M = 19.99$, $SD = 14.32$) and learning phases ($M = 15.49$, $SD = 6.02$), $p = .05$, $d = 0.41$, and between the learning phase and practice phase ($M = 12.84$, $SD = 3.54$), $p = .02$, $d = 0.54$. These results suggest that participants' shooting performance improved across phases, a finding consistent with the skill development framework.

Skill. Marksmanship skill measures (wobble, trigger control, breath control, position quality) were tested using separate repeated-measures ANOVAs, with trial (baseline, learning phase, practice phase) as the within-subjects factor. No significant effects of phase were found for wobble and trigger control.

However, significant effects of phase were found for breath control $F(1.5, 43.5) = 25.5$, $p < .001$, position quality $F(1.45, 46.53) = 33.05$, $p < .001$, and firing line experience $F(1.18, 35.48) = 41.63$, $p < .001$. Because the sphericity assumption was not met for each test, the Greenhouse-Geisser correction was applied to each analysis. For breath control, tests of within-subjects contrasts of each adjacent level detected a difference between the baseline ($M = .40$, $SD = .17$) and learning phases ($M = .25$, $SD = .13$), $p = .05$, $d = 0.99$, and a marginal difference between the learning phase and practice phase ($M = .21$, $SD = .14$), $p = .06$, $d = .30$. For position quality, differences were found between the baseline ($M = 8.12$, $SD = 1.45$) and learning phases ($M = 9.26$, $SD = 0.82$), $p < .001$, $d = 0.97$, and between the learning phase and practice phase ($M = 9.90$, $SD = 0.26$), $p < .001$ $d = 1.05$. Finally, for firing line experience, differences were found between the baseline ($M = 2.25$, $SD = 0.62$) and learning phases (*M* = 2.70, *SD* = 0.45), $p < .001$, $d = 0.83$, and between the learning phase and practice phase (*M* = 2.91, *SD* = 0.50), $p < .001$, $d = 0.44$.

Knowledge. Finally, a significant gain in knowledge was observed, $t(32) = 3.64$, $p < .001$, $d = 0.56$, with posttest knowledge scores (*M* = 13.85, *SD* = 4.83) higher than pretest knowledge scores (*M* = 11.03, *SD* = 5.32).

Summary. Overall, we found evidence that participants' performance in general showed moderate to large improvements from baseline to learning to practice phases. This result held for the outcome variable shot group precision, the skill measures of breath control and position quality, and participants' own perception of their firing line experience and their knowledge of marksmanship.

Are there differential relations of cognitive, psychomotor, and affective variables to performance variables at different phases of skill development?

Table 4 shows descriptive statistics and intercorrelations for the psychomotor, cognitive, and affective measures. In general, the pattern is consistent with our prior work (Chung et al., 2004, 2005). Interestingly, scientific reasoning and knowledge of rifle marksmanship were correlated, suggesting that the more participants were able to process cause-effect relations, the more knowledge they acquired from the instruction and task.

Table 4

Descriptive Statistics and Intercorrelations (Spearman) for Psychomotor, Cognitive, and Affective Measures

Measure	*n*	*M*	*SD*	Min.	Max.	1	2	3	4
1. Arm steadiness[a]	31	7.08	5.38	0.50	27.50	—			
2. Scientific reasoning[a]	33	16.39	5.89	3	23	-.04	—		
3. Knowledge of shooting [b]	33	13.85	4.83	0	20	.11	.65***	—	
4. State worry[c]	32	3.15	0.67	1.83	4	-.09	-.11	.02	—
5. State anxiety[c]	32	2.79	0.61	1.80	4	-.36*	.28	.21	.57***

Note. [a]Lower scores indicate higher performance. [b]Higher scores indicate higher performance. [c]Lower scores indicate higher worry or anxiety.
***$p < .001$ (two-tailed). **$p < .01$ (two-tailed). *$p < .05$ (two-tailed). $^{\S}p < .10$ (two-tailed).

Correlational analyses were conducted to examine the relation between individual difference measures and outcome performance with respect to the different phases of skill development. Ackerman's (1988) theory of skill development predicts differential relations of cognitive and psychomotor to different phases of skill development. When participants are learning the task, cognitive variables should have a higher impact on performance than psychomotor variables, with the opposite relation when participants are in the practice phase. Our primary performance measure was shot group precision. Skill measures were breath control, trigger control, position quality, and steadiness.

Cognitive variables. Table 5 shows correlations between cognitive, psychomotor, and affective measures on the different performance measures. The pattern of correlations for cognitive variables is consistent with Ackerman's (1988) prediction that cognitive variables would have more influence during the learning phase than the practice phase. For example, scientific reasoning was correlated with shot group precision, steadiness, and breath control in the learning phase but not the practice phase. Similarly, knowledge of marksmanship was related to shot group precision, breath control, and marginally to trigger control ($p < .10$) during the learning phase but not the practice phase.

These results are consistent with our prior work and highlight calls for examining rifle marksmanship in the context of cognitive variables (Chung et al., 2004; Chung, Delacruz et al., 2006). Overall, these correlations are consistent with the general idea that cognitive variables have a dominant influence on task performance as participants are learning the task. These findings, particularly the influence of reasoning and knowledge on performance and skill during the learning phase, suggest that rifle marksmanship is primarily a cognitive task during the early stages of skill acquisition, consistent with skill development theory.

Psychomotor variable. The arm steadiness measure, presumably a psychomotor measure, was not found to be as influential as expected. For example, prior work suggested a high correlation between shooting scores and arm steadiness $r_s(73) = .61$, (Spaeth & Dunham, 1921). The magnitude of the correlation between arm steadiness and shot group precision increased over phases, but was marginally significant ($p < .10$) in the practice phase.

Because there was not strong evidence of a relation between arm steadiness and performance in the practice phase, as suggested by theory, we examined data from a sample of nine expert marksmanship coaches. We also compared scores on common measures between the coaches and our novice sample. Significant differences were found favoring the coaches over novices on arm steadiness, knowledge of shooting, shot group precision*,* muzzle wobble, and trigger control, and marginally significant ($p < .06$) on breath control. These results suggest the coaches were superior to the novice shooters on nearly every measure. We concluded that the coach sample was in the automaticity phase of skill development.

Table 5

Correlation (Spearman) Between Psychomotor, Cognitive, and Affective Measures and Shooting Measures (n = 27 – 32)

	Shot group precision^a		Steadiness^{a,b}	
	Skill development phase		Skill development phase	
Measure	Learning	Practice	Learning	Practice
Arm steadiness^a	.29	.34§	-.20	-.23
Scientific reasoning^a	-.44*	-.03	-.39*	-.21
Knowledge of shooting^b	-.38*	.07	-.19	.02
State worry^c	-.31§	-.25	.03	.06
State anxiety^c	-.52**	-.24	-.14	-.11
	Breath control^a		Trigger control^b	
	Skill development phase		Skill development phase	
	Learning	Practice	Learning	Practice
Arm steadiness^a	.03	.00	.06	.05
Scientific reasoning^a	-.44**	-.23	-.10	-.03
Knowledge of shooting^b	-.40*	-.33§	-.34§	-.30§
State worry^c	-.08	.06	-.12	-.16
State anxiety^c	-.39*	-.33§	-.20	-.29
	Position quality^b		Firing line experience^b	
	Skill development phase		Skill development phase	
	Learning	Practice	Learning	Practice
Arm steadiness^a	-.25	.08	-.32§	-.20
Scientific reasoning^a	.23	-.16	.11	.04
Knowledge of shooting^b	.26	-.02	-.09	.03
State worry^c	-.19	.18	.43*	.43*
State anxiety^c	-.09	-.10	.50**	.50**

Note. ^{a}Lower scores indicate higher performance. ^{b}Higher scores indicate higher performance. ^{c}Lower scores indicate higher worry or anxiety.
***p < .001 (two-tailed). **p < .01 (two-tailed). *p < .05 (two-tailed). $^{\S}p$ < .10 (two-tailed).

We then examined the correlations between arm steadiness and knowledge of marksmanship and shot group precision and the skill measures. There were no statistically significant relations owing to the small sample size; however, the general pattern of correlations was consistent with Ackerman's skill development theory. For example, shot group precision was correlated higher with arm steadiness, $r_s(7) = .48$, $p = .19$, compared to knowledge, $r_s(7) = .08$, $p = .84$. Interestingly, muzzle wobble was related to both arm steadiness, $r_s(7) = .54$, $p = .14$, and knowledge, $r_s(7) = .54$, $p = .14$. Similarly, breath control was correlated higher with arm steadiness, $r_s(7) = .37$, $p = .33$, compared to knowledge, $r_s(7) = -.15$, $p = .69$. Finally, there did not seem to be any relation between trigger control and arm steadiness, $r_s(7) = -.08$, $p = .83$, or knowledge, $r_s(7) = .27$, $p = .47$.

Affective variables. State anxiety related significantly and highly with shot group precision during the learning but not practice phase, and with breath control during the learning phase and marginally during the practice phase. In our prior work we found worry to be the stronger predictor of performance (Chung et al., 2004, 2005).

Summary. In general, we found strong support for the role of cognitive variables on marksmanship performance during the learning phase but not the practice phase. We found some support for the role of psychomotor variables having a larger influence during the practice phase than the learning phase, but this was found only for shot group precision. Coaches, presumably in the automaticity phase, show high correlations (although not significant) between arm steadiness and performance and none with knowledge, a pattern that is consistent with theory.

Discussion

In this report we examined the development of known-distance rifle marksmanship skill in the kneeling position at a simulated 200 yards. We adopted the phases-of-skill-development framework and Ackerman's theory of skill development (1988) to examine whether there were differences in performance, skill, and knowledge across different phases of skill development, and whether there were differential relations of cognitive, psychomotor, and affective variables to performance variables during different phases of skill development.

General Findings

We found evidence that the development of rifle marksmanship follows a skill development framework. We examined performance (shot group precision), variability of performance, the number of shooters who had position errors, and the number of shooters who received remediation. The patterns of performance, variation, and the errors and remediation were remarkably consistent with the skill development framework. Shooters demonstrated initially very poor and varied performance, with most shooters committing gross position errors and receiving remediation. This initial state was followed by a rapid rate of improvement over three trials (which included targeted instruction). Performance continued to improve over the remaining three trials, but at a slower rate than the previous trials. A few participants continued to have position errors but the errors were not severe enough to require remediation. Although such a finding is unsurprising, what is interesting is how fast the skill can be learned and how quickly participants move from the learning phase to the practice phase. For 80% of shooters, position errors were eliminated within three trials. On average, shooters went from a 20-inch shot group radius to a 13-inch shot group radius, a 35% improvement over seven trials (or 35 shots). Follow-up statistical tests confirmed developmental differences across the phases on shot group precision and most of the other measures.

Our second finding was that the cognitive variables we measured—scientific reasoning and knowledge of marksmanship—had a dominant influence on task performance during the learning phase and a diminishing one during the practice phase, as predicted by Ackerman's theory (1988). This finding suggests that rifle marksmanship is primarily a cognitive task during the early stages of skill acquisition, consistent with skill development theory. Yet knowledge appeared to play an important role on breath and trigger control—skills that required instruction and could not be reasoned through. In this case, the influence of knowledge persisted into the practice phase although marginally significant for breath control $r_s(31) = -.3433$ $p < .06$ and trigger control $r_s(29) = -.30$, $p < .09$.

Our third finding is suggestive and requires further study. We found some evidence to support the idea that arm steadiness, our measure of psychomotor skills, was more influential during phases after learning. In our sample of novices, arm steadiness was marginally $r_s(29) = -.34$, $p < .06$ related to shot group precision during the practice phase and not so during the learning phase. When we examined the same relation in a sample of nine expert marksmanship coaches, a moderate (but non-significant) correlation was observed. When we examined the influence of knowledge on shot group precision, the correlation was virtually 0.

Our last finding is related to the highly influential role of anxiety and worry on marksmanship performance. State anxiety was found to be the single best predictor of shot group precision during the learning phase, $r_s(30) = -.52$, $p = .002$, and state worry was the only predictor of participants' initial baseline performance $r_s(27) = -.38$, $p = .04$. The degree of influence anxiety has on shot group precision can be seen when the psychomotor, cognitive, and affective variables are regressed on shot group precision. Alone, anxiety accounts for 27% ($R = .52$) of the variance. The addition of the other variables to the multiple regression equation (arm steadiness, scientific reasoning, knowledge, worry) only explains an additional 13% of variance above and beyond anxiety, yielding $R = .64$. These findings are consistent with prior research that found a negative relation between state anxiety and shooting performance (Burton, 1971; Gould, Petlichkoff, Simons, & Vevera, 1987; Sade et al., 1990).

Implications for Training

One of the most surprising results was the variability of performance during the baseline phase, which continued throughout the learning and practice phases. 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. Given the presumably high cognitive load experienced by trainees in the cognitive phase, instructional techniques should be used to minimize extraneous load (e.g., Sweller, van Merriënboer, & Paas, 1998).

Furthermore, instruction should be delivered to maximize skill acquisition. In rifle marksmanship, for example, the task requires trainees to integrate gross-motor and fine-motor skills with perceptual cues while also minimizing the influence of any anxiety experienced. The inclusion of noncognitive measures to the assessment of human performance may provide additional information to develop a more complete picture of skilled performance. As found in this study, the addition of noncognitive assessments was an important replication and contributes to the phases-of-skill-development framework (Chung et al., 2005). For an integrated task like rifle marksmanship, whole-task instruction is preferable. For example, McGuigan and MacCaslin (1955b) found that delivering instruction that emphasized integration of the component skill during practice (whole-task), compared to instruction that emphasized each component skill in isolation (part-task), resulted in superior shooting performance. The superiority of whole-task methods over part-task methods has been found on tasks where the component skills are dependent each other (van Merriënboer, Kester, & Paas, 2006).

With respect to training during the practice phase, one implication for marksmanship training is that the trainees should be allowed to practice. During this phase, providing task feedback and how trainees make use of feedback for continued improvement may be two critical aspects of improvement. Feedback should be frequent enough to allow shooters to make adjustments to themselves, but not be so frequent as to interfere with the acquisition of the skill and carrying out the task itself.

A third implication, given the pervasive influence of affect on shooting performance, is to integrate training on rifle marksmanship with training on worry reduction strategies. Shooting has often been called a “mental” activity, which includes the skill to exclude unwanted thoughts, particularly under high-stakes situations (Coleman, 1980; Domey, 1989). It may be that for rifle marksmanship, success may lie with individuals who can successfully regulate the “match pressure.” That is, those who are able to remain calm and avoid getting flustered by poor performance may be less likely to engage in a debilitative mental spiral: high stakes and an unfamiliar task lead to worry and anxiety, anxiety leads to an unstable rifle, an unstable rifle leads to poor performance, and poor performance leads to more worry.

Finally, because we have evidence that is suggestive that rifle marksmanship follows the phases-of-skill-development model, a practical application would be to develop different models for shooters in different phases, or to develop models to predict what phase a shooter is in. Good prediction models could be used for screening purposes (e.g., to identify individuals who could profit from remedial training before reaching the firing line) or to address skill decay issues (e.g., to reduce or increase the training frequency depending on whether the shooter is in the practice or automaticity phase).

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